Textbook of

Neonatal Resuscitation®

9th Edition

American Heart Association.

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN®

Textbook of Neonatal Resuscitation®

9th Edition

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For nearly 40 years, the Neonatal Resuscitation Program® (NRP®) has been the trusted standard in neonatal resuscitation education, equipping health care professionals with the essential knowledge and skills to save newborn lives.

Developed by a diverse group of neonatal experts, NRP combines the latest science with real-world experience to ensure providers are prepared with the most current, evidence-based practices. With its blend of online adaptive learning, simulation-based scenarios, and hands-on skills practice, NRP delivers a flexible and practical educational experience. Its vision is simple yet powerful: to improve neonatal health by having an expert provider at every birth and an expert team at every resuscitation.

The ninth edition continues this commitment, integrating cutting-edge research, innovative learning approaches, and the collective expertise of the neonatal community to set the worldwide standard for excellence in resuscitation training.

New in the 9th Edition

- **Aligned with the 2025 American Heart Association (AHA)/American Academy of Pediatrics (AAP) Guidelines** for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care
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Contents

Preface

Each day in the United States and Canada, nearly 1,000 newborn infants require immediate assistance to take their first breath. As a health care professional enrolled in the Neonatal Resuscitation Program® (NRP®), you are demonstrating your commitment to ensuring that every infant in your care has the best possible start. Since 1987, NRP has been the training standard for health care professionals entrusted to provide lifesaving care for newborn infants in North America and 130 countries around the world. As a participant in this gold standard program, you are joining 5 million health care professionals who have been trained or retrained to acquire the knowledge and skills necessary to save newborn infants' lives. The *Textbook of Neonatal Resuscitation*, 9th edition, has been fully updated and includes new material; however, it continues to emphasize the same basic principles that have been the foundation of NRP since its inception.

The recommendations in this textbook are developed following a rigorous and structured review process. Members of the American Academy of Pediatrics, Canadian Paediatric Society, American Heart Association, and Heart and Stroke Foundation of Canada work with resuscitation councils from around the world as partners on the International Liaison Committee on Resuscitation (ILCOR) Neonatal Life Support Task Force. This group of experts continuously reviews the most up-to-date neonatal resuscitation science and formulates international consensus statements with treatment recommendations. Based on these consensus statements, member councils develop resuscitation guidelines reflecting their regional needs. The current North American guidelines are published in the journals *Circulation* and *Pediatrics*. Finally, the NRP Steering Committee develops educational materials to help learners acquire the knowledge and skills necessary to implement the North American guidelines.

Like all previous editions, the current textbook and its associated course materials emphasize the importance of adequate preparation, effective ventilation, and quality teamwork. Reflecting the complexity of evolving resuscitation science, readers will recognize that some recommendations are not as specific as they might like. Neonatal resuscitation is an expanding field of study, and ongoing research will inform future recommendations. Based on the most current available science, practice changes incorporated in this edition include updated recommendations for umbilical cord management, changes in the rate and peak pressure used during assisted ventilation, and interim recommendations for the oxygen concentration used during ventilation of preterm newborn infants. New skills incorporated into the 9th edition include paracentesis for abdominal ascites and pericardiocentesis for cardiac tamponade. This edition includes updated versions of the previous 14 lessons and 2 new supplemental lessons. The new supplemental lessons focus on initial stabilization and resuscitation of newborn infants with congenital heart disease (Lesson 15) and bridging the gap between neonatal and pediatric resuscitation guidelines for infants in the neonatal intensive care unit (Lesson 16). These 2 supplemental lessons are supported by 2 new courses: *NRP Cardiac* and *Resuscitation in the NICU*.

This textbook and the educational program it supports could not be completed without a highly talented and dedicated team. I want to acknowledge the tremendous effort made by the entire NRP Steering Committee and its liaison and consulting members, the primary authors of the new supplemental lessons (Anne Ades, Noorjahan Ali, Taylor Sawyer), our 9th edition photographer (Ty Gomez), the content director of the skills videos (Nathan Sundgren) and video producer (Jeremy Bloom), our copy editor (Janice Snider), the AAP staff who guided the entire process (Jessica Weglarz and Kaitlin Butterfield), and the inspiration provided by the giants in neonatal resuscitation (John Kattwinkel and Jeffrey Perlman). Most importantly, I want to acknowledge the contributions made to the entire NRP educational program by my editorial partners Christine Cooper and Henry Lee.

On behalf of everyone involved in preparing the 9th edition course materials, we hope they support your personal journey to master the skills of neonatal resuscitation and our shared mission to improve the health of newborn infants and their families.

Gary M. Weiner, MD, FAAP

Neonatal Resuscitation Program® Provider Course Overview

Neonatal Resuscitation Scientific Guidelines

The Neonatal Resuscitation Program® (NRP®) materials are based on the Part 5: Neonatal Resuscitation: 2025 American Heart Association (AHA) and American Academy of Pediatrics (AAP) Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care (*Pediatrics*. 2025; doi: 10.1542/peds.2025-074352). A link to the Guidelines appears in the Appendix. Please refer to the Guidelines if you have any questions about the rationale for the current program recommendations. The Guidelines, originally published in October 2025, are based on the International Liaison Committee on Resuscitation (ILCOR) Consensus on Cardiopulmonary Resuscitation Science with Treatment Recommendations. The evidence-based reviews prepared by members of ILCOR, which serve as the basis for both documents, can be viewed at https://ilcor.org/publications.

Level of Responsibility

The NRP 9th edition curriculum offers 2 NRP provider categories:

- **NRP Essentials:** Anyone involved in the care of a newborn infant should take NRP Essentials, which consists of materials in Lessons 1 through 4.
- **NRP Advanced:** This provider option may be appropriate for those who attend births and are responsible for anticipated resuscitation of the infant with known risk factors and for those who participate in neonatal resuscitation beyond ventilation. The NRP Advanced participant is responsible for material in Lessons 1 through 11.

Any learner may study supplemental lessons 12 through 16 but will not be tested on that material.

Each facility determines its own policy for who should attain NRP Essentials or Advanced provider status. If most staff participate in births with risk factors and are called to assist with complex resuscitation, then only a small number of select staff with limited responsibilities may be suited to NRP Essentials.

Special Note: Neonatal resuscitation is most effective when performed by a designated and coordinated team. It is important for you to know the neonatal resuscitation responsibilities of team members who are working with you. Periodic practice among team members will facilitate coordinated and effective care of the newborn infant.

Course Completion

The NRP 9th edition curriculum offers 2 learning methodologies for attaining NRP provider status: instructor-led courses and RQI® for NRP®.

Instructor-Led Courses

In hospitals that use the instructor-led course format, learners must complete the Online Learning Assessment and, within 90 days, attend the in-person skills/simulation portion of the course. During the in-person course, learners demonstrate mastery of resuscitation skills (Lessons 2 through 4 for Essentials and Lessons 2 through 7 for Advanced) and participate in simulated resuscitation scenarios, as determined by the course instructor(s).

Upon successful completion of these requirements, participants are eligible to receive an NRP Course Completion eCard (Essentials or Advanced). Once the online course evaluation is completed, an electronic Course Completion Card will be available in the learner's profile of the NRP Learning Platform™. Learners who attain provider status through an instructor-led course must renew their provider status every 2 years.

RQI® for NRP®

As a result of findings showing that episodic learning can improve neonatal resuscitation outcomes, the AAP has formed a collaboration with RQI Partners (a partnership between the American Heart Association and Laerdal Medical) to develop RQI for NRP, an optional learning methodology for NRP Essentials provider training.

RQI for NRP is a quality improvement program offering an alternative educational and administrative method that verifies competence in ventilation skills on a neonatal simulator. This program offers self-directed learning that uses low-dose, quarterly cognitive review and skills sessions to cover the content of NRP Essentials (Lessons 1 through 4).

Initial entry into the RQI for NRP format requires that learners complete the Online Learning Assessment and complete the skills required at the simulator. At that point, the learner attains an Essentials eCredential. An RQI for NRP learner is required to engage in quarterly cognitive and skills activities at their hospital simulation station (Figure) to maintain a current Essentials eCredential. With each quarterly activity, learner skills are reinforced and the expiration of the learner's eCredential is extended by 3 months.

If an RQI learner changes their NRP training location to a hospital that uses instructor-led courses and 2-year provider renewal, the learner requests an eCard that is valid for 2 years from the last completed quarterly engagement activity.

The NRP Advanced provider in a hospital that uses RQI for NRP maintains their Essentials provider status by completing the quarterly cognitive and skills-based practice sessions at the simulation station and renews their Advanced provider status at an instructor-led course every 2 years.

Figure. An NRP learner practices ventilation skills at the RQI simulation station.

Completion Does Not Imply Competence

The NRP is an educational program that introduces the concepts and basic skills of neonatal resuscitation. Attaining and maintaining NRP provider status does not imply that an individual has the competence to perform neonatal resuscitation in the clinical setting. Each hospital is responsible for determining the level of competence and qualifications required for someone to assume clinical responsibility for neonatal resuscitation.

Standard Precautions

The United States Centers for Disease Control and Prevention has recommended that standard precautions be taken whenever the risk of exposure to blood or bodily fluids is high and the potential infection status of the patient is unknown, as is certainly the case in neonatal resuscitation.

All fluid products from patients (eg, blood, urine, stool, saliva, vomitus) should be treated as potentially infectious. Gloves should be worn when resuscitating a newborn infant, and the rescuer should not use their mouth to apply suction via a suction device. Mouth-to-mouth resuscitation should be avoided by having a resuscitation bag and mask or T-piece resuscitator always available for use during resuscitation.

Masks and protective eyewear or face shields should be worn during procedures that are likely to generate droplets of blood or other bodily fluids. Gowns or aprons should be worn during procedures that probably will generate splashes of blood or other bodily fluids. Birth settings must be equipped with resuscitation bags, masks, laryngoscopes, endotracheal tubes, mechanical suction devices, and the necessary protective shields.

Lesson 1

Foundations of Neonatal Resuscitation

What you will learn

- Why neonatal resuscitation skills are important
- Physiologic changes that occur during and after birth
- The format of the Neonatal Resuscitation Program® Algorithm
- Communication and teamwork skills used by effective resuscitation teams
- How implementing quality improvement methods can improve outcomes

Key Points

1. Most newborn infants make the transition to extrauterine life without intervention.
2. Before birth, pulmonary blood vessels in the fetal lungs are tightly constricted, and the alveoli are filled with fluid, not air.
3. Respiratory failure is the most common reason that neonatal resuscitation is needed.
4. The most important and effective step in neonatal resuscitation is to ventilate the newborn infant's lungs.
5. Very few newborn infants will require chest compressions or medication.
6. Teamwork, leadership, and communication are critical to successful resuscitation of the newborn infant.

Neonatal resuscitation skills are important

The Neonatal Resuscitation Program (NRP®) will help you learn the cognitive, technical, and teamwork skills needed to resuscitate and stabilize newborn infants. Most newborn infants make the transition to extrauterine life without intervention. Within 30 seconds after birth, approximately 85% of term newborn infants will begin breathing. An additional 10% will begin breathing in response to drying and stimulation. To successfully transition, approximately

- Five percent of term newborn infants will receive assisted ventilation.
- Less than 1% of term newborn infants will be intubated.
- One to 3 per 1,000 newborn infants will receive chest compressions or emergency medications.

The likelihood of requiring these lifesaving interventions is higher for infants with certain identified risk factors and those born before full term. Even though most newborn infants do not require intervention, the large number of births each year means that timely intervention can save many newborn infants' lives. Because the need for assistance cannot always be predicted, health care professionals need to be prepared to respond quickly and efficiently at every birth.

During your NRP course, you will learn how to evaluate a newborn infant, make decisions about what actions to take, and practice the steps involved in neonatal resuscitation. As you practice together in simulated cases, your team will gradually build proficiency and speed. The most gratifying aspect of providing skillful assistance to a compromised newborn infant is that your efforts are likely to be successful. The time you devote to learning how to resuscitate newborn infants is time well spent.

Newborn infants require a different approach to resuscitation

Most often, adult cardiac arrest is a complication of coronary artery disease.

- It is caused by a **sudden arrhythmia** that prevents the heart from effectively circulating blood.
- Without effective circulation, the individual loses consciousness and stops breathing. At the time of cardiac arrest, the blood oxygen and carbon dioxide (CO_2) content is usually normal, and the lungs remain filled with air.
- During adult resuscitation, chest compressions maintain circulation until the heart's function is restored.

In contrast, most newborn infants requiring resuscitation have a healthy heart. When a newborn infant requires resuscitation, it is usually because **respiratory failure** interferes with oxygen and CO_2 exchange.

- Before birth, fetal respiratory function is performed by the placenta instead of the fetal lungs. When the placenta is functioning normally, it transfers oxygen from the pregnant person to the fetus and carries CO_2 away from the fetus to the pregnant person.
- When placental respiration fails, CO_2 accumulates and **acid increases in the fetal blood** as cells attempt to function without oxygen.
- Fetal monitoring may show a decrease in activity, loss of heart rate variability, and heart rate decelerations. If placental respiratory failure persists, the fetus will make a series of reflexive gasps followed by apnea and bradycardia.
- If the fetus is born in an early phase of respiratory failure, tactile stimulation may be sufficient to initiate spontaneous breathing and recovery. If the fetus is born in a later phase of respiratory failure, stimulation alone is not sufficient. The newborn infant will require assisted ventilation to recover. The most severely affected newborn infants may require chest compressions and epinephrine. **At the time of birth, you will not know if the newborn infant is in an early or a late phase of respiratory failure.**
- After birth, respiratory failure occurs if the newborn infant does not initiate or cannot maintain effective breathing effort.
- When respiratory failure occurs, the primary problem is a lack of gas exchange. Therefore, **the focus of neonatal resuscitation is effective ventilation of the newborn infant's lungs**.

Many concepts and skills are taught in this program. Establishing effective ventilation of the newborn infant's lungs during neonatal resuscitation is the single most important concept emphasized throughout the program.

Ventilation of the newborn infant's lungs is the single most important and effective step in neonatal resuscitation.

Physiologic changes that occur after birth

Understanding the basic physiology of the cardiorespiratory transition from intrauterine to extrauterine life will help you understand the steps of neonatal resuscitation.

- **Before birth, the fetal lungs are filled with fluid,** not air, and they do not participate in gas exchange. All of the oxygen used by the fetus is supplied by the pregnant person's blood via diffusion across the placenta. The oxygenated fetal blood leaves the placenta through the umbilical vein and flows to the fetal heart (Figure 1.1A).
- Blood vessels in the fetal lungs (pulmonary vessels) are **tightly constricted** and very little blood flows through them. Instead, most of the oxygenated blood returning from the placenta via the umbilical vein bypasses the lungs and flows directly to the left side of the fetal

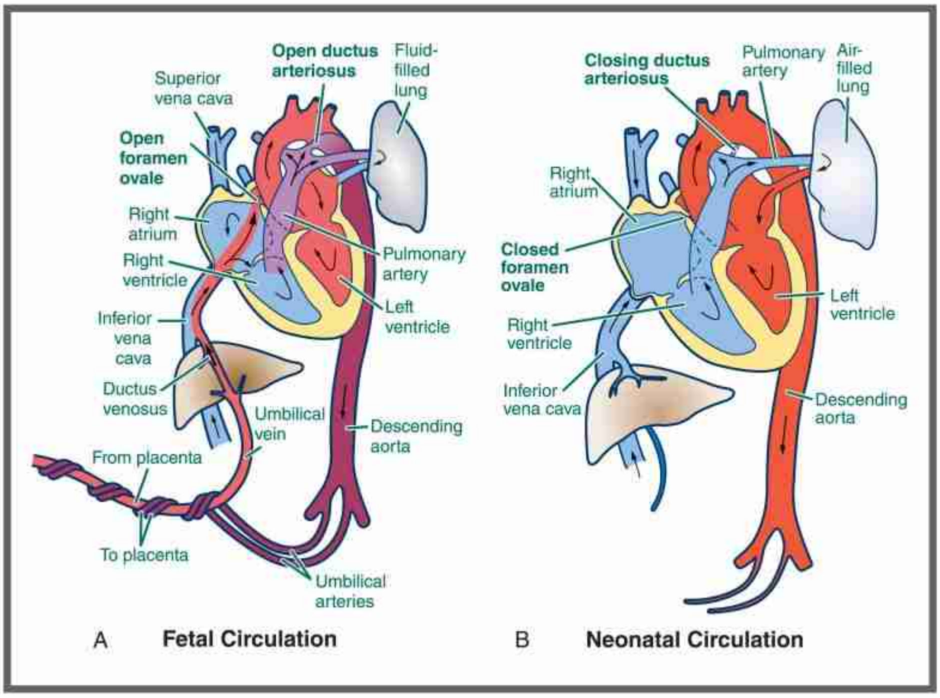


Figure 1.1. (A) Fetal Circulation Path: Oxygenated blood (red) enters the right atrium from the umbilical vein and crosses to the left side through the open foramen ovale and ductus arteriosus. Only a small amount of blood flows to the lungs. There is no gas exchange in the fluid-filled lungs. (B) Neonatal Circulation Path: The newborn infant breathes, pulmonary vessels relax, and blood flows to the air-filled lungs. Blood returning to the left side of the heart from the lungs has the highest oxygen saturation.

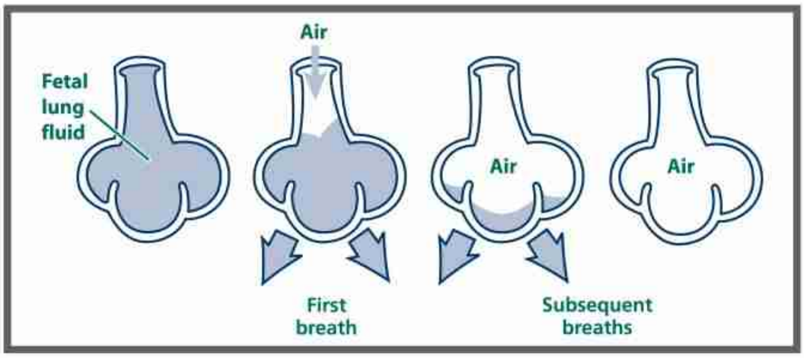


Figure 1.2. Air replaces fluid in the alveoli.

heart. This allows the most highly oxygenated blood to flow directly to the fetal brain and heart.

- After birth, a series of events culminates in a successful transition from fetal to neonatal circulation (Figure 1.1B).
  - As the infant takes deep breaths and cries, the **lungs fill with air** and fluid is pushed out of the air sacs (alveoli) (Figure 1.2).
  - **Air in the lungs causes the previously constricted pulmonary vessels to relax** so that blood can flow to the lungs and reach the alveoli where oxygen will be absorbed, and CO_2 will be removed.
  - **Oxygenated blood returning from the infant's lungs helps to fill the infant's heart** and ensure that the heart and brain will receive adequate blood flow once the umbilical cord is clamped.
  - Clamping the umbilical cord increases the infant's systemic blood pressure, decreasing the tendency for blood to bypass the infant's lungs.

Although these changes begin within a few minutes of birth, the entire process may not be completed for hours or days. For example, it may take up to 10 minutes for a healthy term newborn infant to achieve an oxygen saturation greater than 90%. It may take several hours for fluid in the lungs to be completely absorbed, and complete relaxation of the pulmonary blood vessels occurs gradually over several months.

When normal transition does not occur

If normal transition does not occur, the newborn infant's organs will not receive enough oxygen, acid will accumulate in tissues, and blood vessels in the infant's intestines, kidneys, muscles, and skin may constrict.

Temporarily, a survival reflex maintains blood flow to the newborn infant's heart and brain to preserve function of these vital organs. If inadequate gas exchange continues, the heart begins to fail and blood flow to all organs decreases. The lack of adequate blood flow and oxygen may lead to organ damage. Table 1-1 summarizes some of the clinical findings associated with an interruption in normal transition.

Table 1-1. Clinical Findings of Abnormal Transition

• Irregular breathing, absent breathing (apnea), or rapid breathing (tachypnea)
• Slow heart rate (bradycardia) or rapid heart rate (tachycardia)
• Decreased muscle tone or decreased activity
• Decreased alertness
• Persistent blue skin around mouth and face (central cyanosis)
• Persistent pale skin (pallor)
• Low oxygen saturation

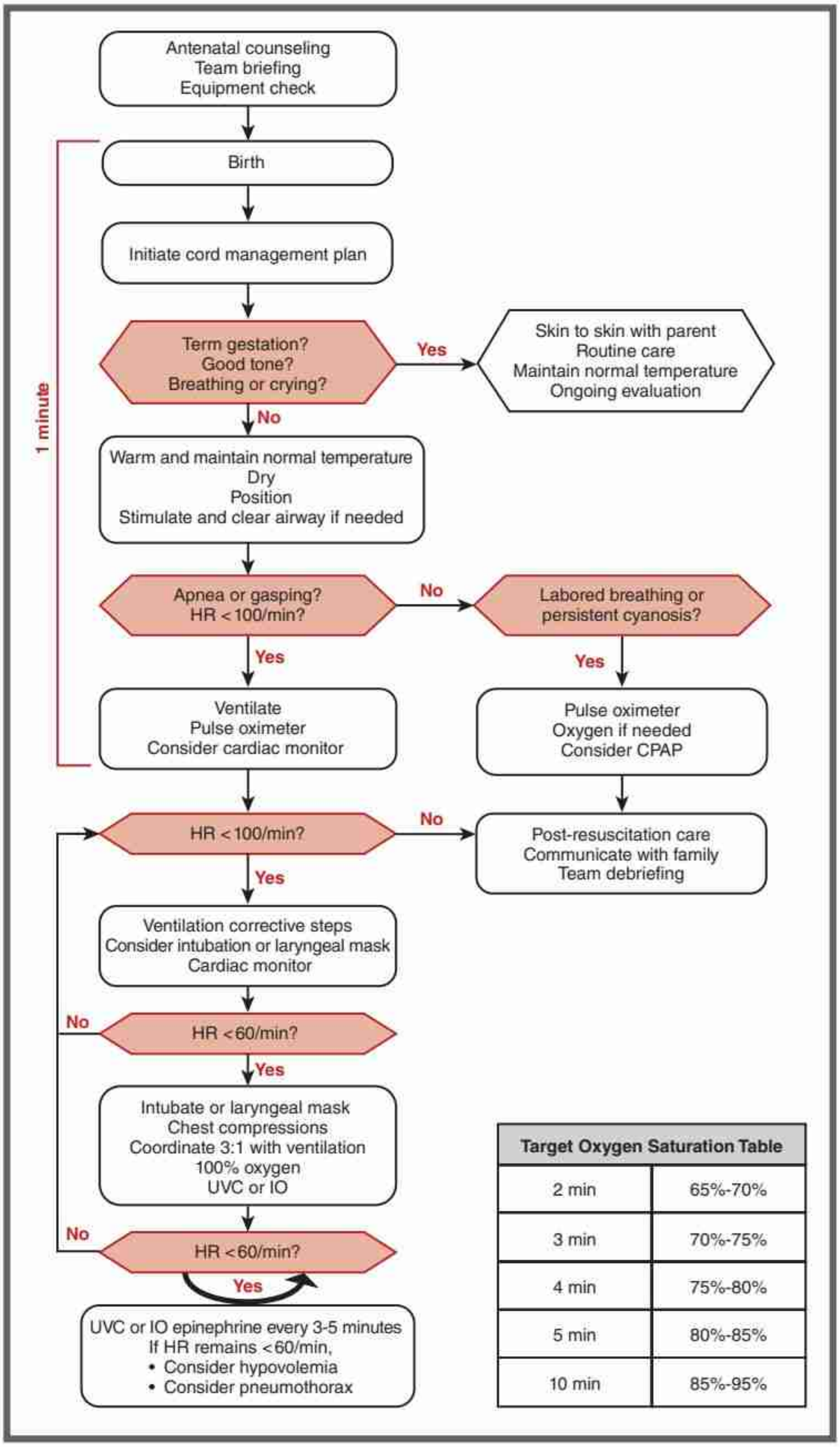
The Neonatal Resuscitation Program Algorithm

The NRP Algorithm (Figure 1.3) describes the steps that you will follow to evaluate and resuscitate a newborn infant. It is divided into 6 blocks beginning with your team's preparation for the birth and continues through the series of interventions you may perform (**ABCD**). Throughout the Algorithm, hexagons indicate assessments and rectangles show actions that may be required. Although it is important to work quickly and efficiently, **you must ensure that you have adequately performed the steps of each block before moving on to the next block**. Assessments are repeated at the end of each block and will determine if you need to proceed. The details of each block are described in subsequent lessons.

- *Preparation:* Identify risk factors, discuss with obstetric care provider, counsel parents, assemble the team, perform a team briefing, and check supplies and equipment.
- *Initial Evaluation:* During the interval between birth and umbilical cord clamping, perform an initial evaluation to determine if the newborn infant can remain with the parent or should be moved to a radiant warmer for further assessment and intervention.
- *(A) Airway:* Perform the initial steps to establish an open Airway and support spontaneous respiration.
- *(B) Breathing:* Ventilation is provided to assist Breathing for infants with apnea or bradycardia. Other interventions (continuous positive airway pressure [CPAP] or supplemental oxygen) may be appropriate if the infant has labored breathing or low oxygen saturation.
- *(C) Circulation:* If severe bradycardia persists despite assisted ventilation, Circulation is supported by performing chest compressions coordinated with ventilation.
- *(D) Drug:* If severe bradycardia persists despite assisted ventilation and coordinated chest compressions, the Drug epinephrine is administered as coordinated ventilation and chest compressions continue.

Take a moment to familiarize yourself with the layout of the NRP Algorithm (Figure 1.3).

- Neonatal Resuscitation Program Essentials learners will focus on anticipating and preparing for resuscitation, the rapid evaluation, airway, and breathing steps of the Algorithm.



Target Oxygen Saturation Table	
2 min	65%-70%
3 min	70%-75%
4 min	75%-80%
5 min	80%-85%
10 min	85%-95%

Figure 1.3. Neonatal Resuscitation Program Algorithm.

- Neonatal Resuscitation Program Advanced learners will study the entire Algorithm.

Teamwork

Effective teamwork is essential during neonatal resuscitation. Joint Commission investigations continue to find that **failures in teamwork, communication, and leadership are among the most common root causes of potentially preventable infant deaths in the delivery room**.

- During a complex resuscitation, providers need to perform multiple procedures without delay. Confusion and inefficiency may occur because several teams of caregivers are working in a confined space at the same time.
- Even though each individual may have the knowledge and skills needed to perform a successful resuscitation, each person's skills will not be used optimally without effective coordination.

Key Behavioral Skills

The 10 NRP Key Behavioral Skills, described in Table 1-2, are adapted from previously described models of effective teamwork (Center for Advanced Pediatric & Perinatal Education [CAPE], Lucile Packard Children's Hospital at Stanford University). In each of the lessons that follow, we will highlight how effective teams use these behavioral skills.

Improving your teamwork, communication, and leadership requires deliberate practice under conditions that are as realistic as possible. As you review each lesson and participate in simulation, think about how these behavioral skills can be used to improve your own team's performance. **Remember that every member of the team has a responsibility to tell the leader and other team members of observations or information that will improve the resuscitation in progress.**

Quality improvement methods improve outcomes

The NRP course helps you acquire the knowledge and skills that you need to save newborn infants' lives, but knowledge alone does not guarantee improved outcomes. Completing an NRP course is only the first step in improving the quality of care you provide.

- Making a difference in clinical outcomes requires a commitment to quality improvement (QI). Providers who are committed to quality improvement set goals, measure outcomes, identify areas for improvement, and make changes that improve care.
- Carefully look at the systems and processes used in your own setting to determine how best to put your knowledge and skills into practice.

Table 1-2. Neonatal Resuscitation Program Key Behavioral Skills

Behavior	Example
Know your environment.	• Know the location of resuscitation equipment and how to access it. • Know how to call for help and who is available.
Use available information.	• Know the prenatal and intrapartum history, including pregnancy complications, medications received, and other risk factors.
Anticipate and plan.	• Perform a pre-resuscitation team briefing to ensure all team members know the clinical situation. • Assign roles and responsibilities. • Discuss an action plan in the event of complications.
Clearly identify a team leader.	• Identify the team leader before the birth. • Effective leaders – Clearly articulate goals. – Delegate tasks as appropriate while monitoring the distribution of workload. – Include other team members in assessment and planning. – Think out loud. – Maintain situation awareness. – Hand over leadership to another team member if they must become involved in a procedure.
Communicate effectively.	• Call team members by name. • Share information actively. • Inform your team if you identify a problem, an error, or a patient safety concern. • Order medications by name, dose, and route. • Use concise, clear language. • Use closed-loop communication. • Verify information. • Ensure that changes in information or assessments are shared with all team members. • Include family members in communication as appropriate.
Delegate workload optimally.	• Do not duplicate work or use more resources than necessary. • Change task assignments depending on skill sets and what is required at the moment. • Do not allow one person to become overloaded with tasks. • Do not allow the team to become fixated on a single task.
Allocate attention wisely.	• Maintain situation awareness by scanning and reassessing the clinical situation frequently. • Monitor each other's skill performance to ensure patient safety.
Use available resources.	• Know what personnel are available. • Know what additional or special supplies are available and how to access them.
Call for additional help when needed.	• Anticipate the need for additional team members based on risk factors and the progress of the resuscitation. • Call for additional help in a timely manner. • Know how you will call for additional help and the process for getting the right kind of assistance.
Maintain professional behavior.	• Use respectful verbal and nonverbal communication. • Actively seek and offer assistance. • Support and promote teamwork. • Respect and value your team.

- As you read the lessons in the textbook, think about opportunities to improve care in your own setting. In the lessons that follow, note the measurable processes and outcomes that may identify opportunities for improvement. Additional QI resources are included in Supplemental Lesson 14.

LESSON 1 REVIEW

1. Before birth, the alveoli in the fetal lungs are filled with (fluid)/(air).
2. Before birth, oxygen is supplied to the fetus by (the placenta)/(the fetal lungs).
3. Before birth, most fetal blood (enters the fetal lungs)/(bypasses the fetal lungs).
4. After birth, air in the alveoli causes vessels in the newborn infant's lungs to (constrict)/(relax).
5. When resuscitating newborn infants, chest compressions and medication are (rarely)/(frequently) needed.
6. Members of an effective resuscitation team (share information)/(work quietly and independently).

Answers

1. Before birth, the alveoli in the fetal lungs are filled with fluid.
2. Before birth, oxygen is supplied to the fetus by the placenta.
3. Before birth, most fetal blood bypasses the fetal lungs.
4. After birth, air in the alveoli causes vessels in the newborn infant's lungs to relax.
5. When resuscitating newborn infants, chest compressions and medication are rarely needed.
6. Members of an effective resuscitation team share information.

Lesson 2

Anticipating and Preparing for Resuscitation

What you will learn

- Risk factors that can help predict which newborn infants will require resuscitation
- Four key questions to ask the obstetric provider before birth
- How to determine what personnel should attend a birth
- How to perform a pre-resuscitation team briefing
- How to assemble and check resuscitation supplies and equipment
- Why accurate documentation is important

Key Points

1. Identify risk factors and prepare for the birth by asking the obstetric provider these 4 questions: (1) What is the expected gestational age? (2) Is the amniotic fluid clear? (3) Are there any additional risk factors? (4) What is the umbilical cord management plan?

2. Some newborn infants without any apparent risk factors will require resuscitation.

3. Every birth should be attended by at least 1 qualified individual who can initiate resuscitation and whose only responsibility is managing the newborn infant.

4. If risk factors are present, at least 2 qualified individuals should be present solely to manage the newborn infant. The number and qualifications of these individuals will be determined by the risk factors.

5. A qualified team with full resuscitation skills should be identified and immediately available for every resuscitation. The fully qualified resuscitation team should be present at the time of birth if the need for advanced resuscitation measures is anticipated. All supplies and equipment necessary for a complete resuscitation must be readily available and functional for every birth.

Case: Preparing for a birth with perinatal risk factors

A pregnant person arrives in labor at 36 weeks' gestation. The pregnancy has been complicated by insulin-requiring gestational diabetes and hypertension. The obstetric provider reports ruptured membranes with clear amniotic fluid. Fetal heart rate monitoring shows a Category II pattern (indeterminate pattern requiring evaluation, surveillance, and possibly other tests to ensure fetal well-being). Labor progresses rapidly and a vaginal birth is imminent. The obstetric provider calls your resuscitation team to attend the birth.

You ask the obstetric provider 4 brief questions and determine that there are several perinatal risk factors. You assemble a team composed of enough people with qualified skills to manage the interventions that may be needed. The team identifies the team leader, performs a pre-resuscitation team briefing, discusses roles and responsibilities, and performs a complete equipment check. As your team enters the room, you introduce yourselves to the parents and the obstetric team and take your positions near the preheated radiant warmer.

Anticipate the need for resuscitation

At every birth, you should be prepared to resuscitate the newborn infant. Table 2-1 describes risk factors that increase the likelihood that the newborn will require support. Thoughtful consideration of these risk factors will help you identify the correct personnel to attend the birth. Although attention to these risk factors is helpful and will identify most newborn infants who require resuscitation after birth, **some newborn infants without any apparent risk factors will require resuscitation**.

Table 2-1. Perinatal Risk Factors Increasing the Likelihood of Neonatal Resuscitation

Antepartum Risk Factors	Intrapartum Risk Factors
Gestational age less than 36 0/7 weeks	Emergency cesarean delivery
Gestational age greater than or equal to 41 0/7 weeks	Forceps or vacuum-assisted delivery
Preeclampsia or eclampsia	Breech or other abnormal presentation
Maternal† hypertension	Category II or III fetal heart rate pattern*
Multiple gestation	General anesthesia
Fetal anemia	Maternal† magnesium therapy
Polyhydramnios	Placental abruption
Oligohydramnios	Intrapartum bleeding
Fetal hydrops	Chorioamnionitis
Fetal macrosomia	Opioids administered within 4 hours of delivery
Fetal growth restriction	Shoulder dystocia
Significant fetal malformations or anomalies	Meconium-stained amniotic fluid
No prenatal care	Prolapsed umbilical cord

***See Appendix 3 in this lesson for a description of fetal heart rate categories.**
†We use the term *maternal* to respectfully refer to persons of any gender who are pregnant and giving birth.

Ask 4 key questions

Obstetric and newborn health care providers can coordinate care by establishing effective communication. Before every birth, review the antepartum and intrapartum risk factors described in Table 2-1 and ask the following 4 pre-birth questions:

1. What is the expected gestational age?
2. Is the amniotic fluid clear?
3. Are there any additional risk factors?
4. What is the umbilical cord management plan?

Based on the responses to these questions, assemble the necessary personnel and equipment. You will learn more about the timing of umbilical cord clamping and establishing a plan for umbilical cord management in Lesson 3.

Assemble the correct team

The number and qualifications of personnel will depend on your risk assessment. Consider creating a written policy for how many people should attend a birth, what qualifications they should have based on assessment of perinatal risk, and how to call for additional help if needed.

- **Every birth should be attended by at least 1 qualified individual**, skilled in the initial steps of newborn care and ventilation, whose only responsibility is managing the newborn infant. When a birth is attended by only 1 qualified individual, the likelihood of resuscitation should be low. In the event of unanticipated resuscitation, this team member will initiate resuscitation and call for additional help.
- **If risk factors are present** (Table 2-1)**, at least 2 qualified individuals should be present solely to manage the newborn infant.** The number and qualifications of personnel will vary depending on the anticipated risk, the number of infants, and the birth setting.
- **A qualified team with full resuscitation skills**, including endotracheal intubation, chest compressions, emergency vascular access, and medication administration, **should be identified and immediately available for every resuscitation**.
  - The fully qualified resuscitation team should be present at the time of birth if the need for advanced resuscitation measures is anticipated.
  - It is not sufficient for the team with these advanced skills to be on call at home or in a remote area of the hospital. When resuscitation is needed, it must begin without delay.

Each hospital must develop and practice a system for assembling its resuscitation team. Identify how the team will be alerted if risk factors are present, who will be called, and how additional help will be contacted if necessary. Practice various scenarios to ensure you have sufficient personnel immediately available to perform all necessary tasks.

Perform a pre-resuscitation team briefing

Once your team is assembled, perform a pre-resuscitation team briefing to review the clinical situation and any management plans developed during antenatal counseling. Identify a team leader, delegate tasks, identify who will document events as they occur, determine what supplies and equipment will be needed, and identify how to call for additional help. Use all of the available perinatal information to anticipate potential complications and plan your response (Table 2-2).

The pre-resuscitation team briefing (Figure 2.1) is important even for well-established teams. A common analogy is to compare the medical team's pre-resuscitation briefing to an airline pilot's preflight check. Even pilots who have flown the same route many times perform their preflight check to ensure their passengers' safety.

Table 2-2. **Pre-resuscitation Team Briefing**

• Assess risk factors. • Identify the team leader. • Review the resuscitation plan. • Anticipate potential complications and plan a team response. • Delegate tasks. • Identify who will document events as they occur. • Determine what supplies and equipment will be needed. • Identify how to call for additional help. • Address any concerns raised by team members.

Figure 2.1. Neonatal pre-resuscitation team briefing.

Prepare supplies and equipment

All supplies and equipment necessary for a complete resuscitation must be readily available and functional for every birth. **When a high-risk newborn is expected, all appropriate supplies and equipment should be ready for immediate use.** It is not sufficient to simply look at what is on the radiant warmer. It is much more effective to establish an organized routine using a standardized checklist before every birth. In this way, you will confirm what is ready for immediate use and identify which pieces of equipment are missing.

The appendices of this lesson include 2 lists:

- The Neonatal Resuscitation Program® (NRP®) Quick Supplies and Equipment Checklist is a tool that you can use during your briefing to check the most essential supplies and equipment. It follows the steps of the NRP Algorithm. Consider keeping this checklist near the radiant warmer so it is accessible before every birth.

- The Neonatal Resuscitation Supplies and Equipment List is a comprehensive inventory of the supplies and equipment that should be available within the resuscitation area.

Identify an effective team leader

Every resuscitation team needs to have a team leader. Any team member who has mastery of the NRP Algorithm, effective leadership skills, and a willingness to assume the leadership role can be the team leader. The leader does not have to be the most senior member of the team or the individual with the most advanced degree. That person may have technical skills that will be required during the resuscitation and, thus, may not be able to maintain their full attention on the infant's condition. If you are the person with sole responsibility for managing the newborn infant at birth and the infant unexpectedly requires resuscitation, you become the team leader and direct your assistants to help you until the full resuscitation team arrives.

- Effective team leaders exemplify **good communication skills** by giving clear directions to specific individuals, sharing information, delegating responsibilities to ensure coordinated care, and maintaining a professional environment.
- A skilled leader effectively uses resources by **allowing all team members to contribute** their unique talents to the resuscitation process.
- It is important for the team leader to remain aware of the entire clinical situation, maintain a view of the "big picture," and not become distracted by a single activity. This is called **situation awareness**.
- If the leader is involved in a procedure that diverts their attention, the leader may need to appoint **another qualified person to assume the leadership role**. If the person in the leadership role changes during the resuscitation, a clear verbal statement should be made so that all team members know who is leading the team.

Use closed-loop communication

Although the team has a leader, each team member shares responsibility for ongoing assessment and ensuring that interventions are performed in the correct sequence with the correct technique. Successful coordination requires team members to share information and communicate with each other. Closed-loop communication is a technique that ensures instructions are heard and understood.

When you give an instruction,

- Direct the request to a specific individual.
- Call your team member by name.
- Make eye contact.
- Speak clearly.

- After giving an instruction, ask the receiver to report back as soon as the task is completed.
- After receiving an instruction, repeat the instruction back to the sender.

The following example demonstrates instructions directed to a specific individual, clear and concise language, and closed-loop communication.

Nicole: *"Lou, I need a size 3.5 endotracheal tube, with a stylet, and a laryngoscope with a size-1 blade now. Let me know when ready."*
Lou: *"You need a size 3.5 endotracheal tube, stylet, and laryngoscope with a size-1 blade now."*
Nicole: *"Correct."*
Once the equipment is ready, Lou says, *"Nicole, a size 3.5 tube, stylet, and size-1 laryngoscope are ready."*

Document events accurately

During an emergency, highly effective teams accurately document the series of events as they occur. Complete and accurate documentation is important for clinical decision-making and as a source for quality improvement data.

The sense of urgency surrounding resuscitation can make accurate documentation challenging, but preparation can make this essential task easier. If your hospital uses paper documentation, consider keeping a hard copy of your hospital's neonatal code documentation sheet on a clipboard at every radiant warmer. If your hospital uses electronic documentation, consider keeping a device that can be used to rapidly enter your electronic medical record system near every radiant warmer. During mock codes and simulation, practice documentation skills as you would any other resuscitation skill.

- During your team briefing, **assign someone to be the scribe who will document events**. Ideally, this should be an experienced team member who knows what is important to record, is comfortable communicating with team members, and can provide decision support to the team leader. For example, the scribe may remind the team leader how much time has passed since chest compressions were started or epinephrine was administered. Without experience, the scribe may have difficulty deciding what is important to record and providing decision support to the team leader.
- **Use a single time reference to document when events occur.** If team members use different watches or clocks during a resuscitation, it may cause confusion or documentation errors.
- Because multitasking can disrupt observation and communication, and increase medication errors, **the scribe should not be responsible for performing other critical tasks**.
- To assist the scribe, **team members need to clearly announce their assessments** and when interventions are performed.

- Consider using a paper form or an electronic template designed specifically for neonatal resuscitation. Well-designed forms that follow the NRP Algorithm enable rapid data entry, allowing the scribe to assist the team leader by providing prompts for the next intervention and identifying delayed assessments.
- After the event, consider supplementing the resuscitation record with a narrative summary that clarifies decision-making.

Perform a post-resuscitation debriefing

A post-resuscitation team debriefing is a constructive review of actions and thought processes that promotes reflective learning. Performing a debriefing after the resuscitation reinforces good teamwork habits and helps your team identify areas for improvement.

- **A quick debriefing can be performed immediately after the event**, while a more comprehensive debriefing may be scheduled a short time afterward.
- Ask your team:
  - What did we do well?
  - What can we do better?
  - Did we have all the information we needed?
  - Did we have the right people and equipment?
  - Are there any things that need follow-up?

Your debriefings do not have to find major problems to be effective. You may identify a series of small changes that can result in significant improvement in your team's performance and clinical outcomes.

Focus on Teamwork

The preparation phase of neonatal resuscitation highlights several opportunities for effective teams to use the NRP Key Behavioral Skills.

Behavior	Example
Know your environment.	Know how the resuscitation team is contacted and how additional personnel and resources can be summoned. Know how to access additional supplies and equipment for a complex resuscitation.
Use available information.	Ask the obstetric provider the 4 pre-birth questions to identify risk factors and prepare for the birth.
Anticipate and plan.	Know which providers are qualified to attend the birth based on the identified risk factors. Perform a standardized supplies and equipment check before every birth. Assign roles and responsibilities.
Clearly identify a team leader.	If risk factors are present, identify a team leader before the birth and perform a pre-resuscitation team briefing to ensure that everyone is prepared, and responsibilities are defined.
Use available resources.	Prepare additional supplies and equipment, as necessary, based on identified risk factors.

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own hospital setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. Who is responsible for ensuring that supplies and equipment are ready before every birth?
2. Is the table of risk factors (Table 2-1) accessible in your delivery setting?
3. Is a supplies and equipment checklist available at every warmer?
4. Do you have a designated paper form or an electronic template designed specifically for neonatal resuscitation readily available at every birth?
5. How is the resuscitation team mobilized when a newborn infant without risk factors needs resuscitation?

Process and outcome measures

1. What percentage of health care providers involved in the care of newborn infants have completed the NRP course?
2. What percentage of births have a qualified provider present who is only responsible for the newborn infant?
3. What percentage of births have a standardized supplies and equipment checklist completed?
4. What percentage of births attended by 1 NRP provider require additional team members for an unanticipated resuscitation?

Frequently Asked Questions

What is the ideal number of people to have on the resuscitation team?

There is no single correct answer to this question. You must have sufficient personnel immediately available to perform all of the necessary tasks without delay. The personnel required at any particular birth will depend on the identified risk factors, the qualifications of the individuals on the team, and the setting. Simulate different scenarios to ensure that you have sufficient personnel on your team to perform all necessary procedures quickly and efficiently. A complex resuscitation will likely require 4 or more people.

What if I am concerned that we do not have the correct team configuration (number of people or qualifications) to attend a birth?

This problem usually can be avoided by having a clearly written hospital protocol to determine the number and qualifications of people who should attend a birth based on a standardized assessment of risk factors and effective team communication. Remember that safety is the top priority in decision-making. Following the concepts outlined in the NRP Key Behavioral Skills, use the available information to identify the safety concern, use effective communication and professional behavior to express your concern, and use your knowledge of the available resources to suggest an alternative. Start by saying, "I believe this delivery has risk factors that require . . ." If your concern is not addressed, continue with "I am concerned because . . ." and suggest an alternative course of action.

LESSON 2 REVIEW

1. What are the 4 pre-birth questions to ask the obstetric provider before every birth?
2. Every birth should be attended by at least 1 qualified individual (whose only responsibility is managing the newborn infant)/(who is responsible for managing both the pregnant person's care and the newborn infant's care).
3. If a complex resuscitation is anticipated, (1 qualified individual)/(a qualified team) should be present at the birth.
4. During the pre-resuscitation team briefing, (prepare for a routine delivery because you do not know what will be needed)/(anticipate potential complications and discuss how responsibilities will be delegated).
5. A qualified nurse or respiratory therapist who has mastery of the NRP Algorithm, effective leadership skills, and a willingness to assume the leadership role (can)/(cannot) be the team leader.
6. The supplies and equipment check includes (checking that all supplies and equipment for a complete resuscitation are readily available and functional only when anticipating a high-risk birth)/(checking that all supplies and equipment for a complete resuscitation are readily available and functional for every birth).

Answers

1. The 4 pre-birth questions are: (1) What is the expected gestational age? (2) Is the amniotic fluid clear? (3) Are there any additional risk factors? (4) What is the umbilical cord management plan?
2. Every delivery should be attended by at least 1 qualified individual whose only responsibility is managing the newborn infant.
3. If a complex resuscitation is anticipated, a qualified team should be present at the birth.
4. During the pre-resuscitation team briefing, anticipate potential complications and discuss how responsibilities will be delegated.
5. A qualified nurse or respiratory therapist who has mastery of the NRP Algorithm, effective leadership skills, and a willingness to assume the leadership role can be the team leader.
6. The supplies and equipment check includes checking that all supplies and equipment for a complete resuscitation are readily available and functional for every birth.

Appendix 1. NRP Quick Supplies and Equipment Checklist

This checklist includes only the most essential supplies and equipment needed at the radiant warmer for most neonatal resuscitations. Tailor this list to meet your unit-specific needs. Ensure that a supplies and equipment check has been done prior to *every* birth.

Warm	• Preheated warmer • Warm towels or blankets • Hat • *Plastic bag or plastic wrap (< 32 weeks' gestation)* • *Thermal mattress (< 32 weeks' gestation)*
Clear airway	• Bulb syringe • 10F or 12F suction catheter attached to wall suction, set at 80 to 100 mm Hg • Tracheal aspirator
Auscultate	• Stethoscope
Ventilate	• Flowmeter set to 10 L/min • Ventilation device • Term- and preterm-sized resuscitation masks • Orogastric tube (5/6F or 8F) and 20-mL syringe • Laryngeal mask (neonatal size) and 5-mL syringe (if needed for mask inflation)
Oxygenate	• Oxygen blender set to desired initial oxygen concentration • Pulse oximeter with sensor and cover • Target Oxygen Saturation Table • Equipment to give free-flow supplemental oxygen
Intubate	• Laryngoscope with size 0 and size 1 straight blades (size 00, optional) • Endotracheal tubes (sizes 2.5, 3.0, 3.5) • Stylet (optional) • Carbon dioxide (CO_2) detector • Cardiac monitor and leads • Measuring tape and/or endotracheal tube insertion depth table • Waterproof tape or tube-securing device • Scissors
Medicate	Access to • Epinephrine (0.1 mg/mL = 1 mg/10 mL) • Normal saline (100-mL or 250-mL bag, or prefilled syringes) • Supplies for placing emergency umbilical venous catheter and administering medications • Table of precalculated emergency medication dosages for infants weighing 0.5 to 4 kg

Appendix 2. Neonatal Resuscitation Supplies and Equipment List

Suction equipment

Bulb syringe

Mechanical suction and tubing

Suction catheters, 5F or 6F, 10F, 12F or 14F

Tracheal aspirator

Ventilation equipment

Ventilation device

Face masks, term and preterm sizes

Oxygen source

Compressed air source

Oxygen blender to mix oxygen and compressed air with flowmeter (flow rate set to 10 L/min) and tubing

Pulse oximeter with sensor and cover

Target Oxygen Saturation Table

Stethoscope (with neonatal head)

Laryngeal mask (neonatal size) or similar supraglottic airway device, and 5-mL syringe (if needed for inflation)

5/6F or 8F orogastric tube and 20-mL syringe

Intubation equipment

Laryngoscope with straight blades, No. 0 (preterm) and No. 1 (term)

Extra bulbs and batteries for laryngoscope, if required

Endotracheal tubes, 2.5-, 3.0-, 3.5-mm internal diameter (ID)

Stylet (optional)

Carbon dioxide detector or capnograph

Cardiac monitor and leads

Measuring tape

Endotracheal tube insertion depth table

Scissors

Waterproof tape or tube-securing device

Alcohol pads

Medications

Epinephrine (0.1 mg/mL = 1 mg/10 mL)

Normal saline for volume expansion—100-mL or 250-mL bag, or prefilled syringes

Dextrose 10%, 250 mL (optional)

Normal saline for flushes

Syringes (1 mL, 3 mL or 5 mL, 20-60 mL)

Three-way stopcocks or fluid-dispensing connectors

Table of precalculated emergency medication dosages for infants weighing 0.5 to 4 kg

Umbilical vessel catheterization supplies

Sterile gloves

Antiseptic prep solution

Umbilical tape

Small clamp (hemostat)

Forceps (optional)

Scalpel

Umbilical catheter (single lumen), 3.5F or 5F

Three-way stopcock

Syringes (3-5 mL)

Needle or puncture device for needleless system

Normal saline for flushes

Clear adhesive dressing to temporarily secure umbilical venous catheter to abdomen (optional)

Miscellaneous

Timer/clock with second hand

Gloves and appropriate personal protection equipment

Radiant warmer or other heat source

Warmed linens

Hat

Tape, ½ or ¾ inch

Intraosseous needle (optional)

For very preterm infants

Food-grade plastic bag (1-gallon size) or plastic wrap

Thermal mattress

Size 00 laryngoscope blade (optional)

Size 2.0-mm endotracheal tube (optional)

Transport incubator to maintain infant's temperature during move to the nursery

Appendix 3. Fetal Heart Rate Categories

Category I: This tracing is predictive of normal fetal acid-base status at the time of the observation, and routine management is indicated.

Category II: This is considered an *indeterminate* tracing. This tracing is not predictive of abnormal fetal acid-base status at the time of the observation, yet presently there is inadequate evidence to classify these tracings as either Category I or Category III. Further evaluation and surveillance are indicated. Interventions may be required.

Category III: Abnormal fetal acid-base status at the time of the observation cannot be ruled out for infants with this tracing. A Category III tracing requires prompt evaluation and intervention.

References

ACOG Practice Bulletin, No. 106: intrapartum fetal heart rate monitoring: nomenclature, interpretation, and general management principles. *Obstet Gynecol*. 2009;114(1):192–202

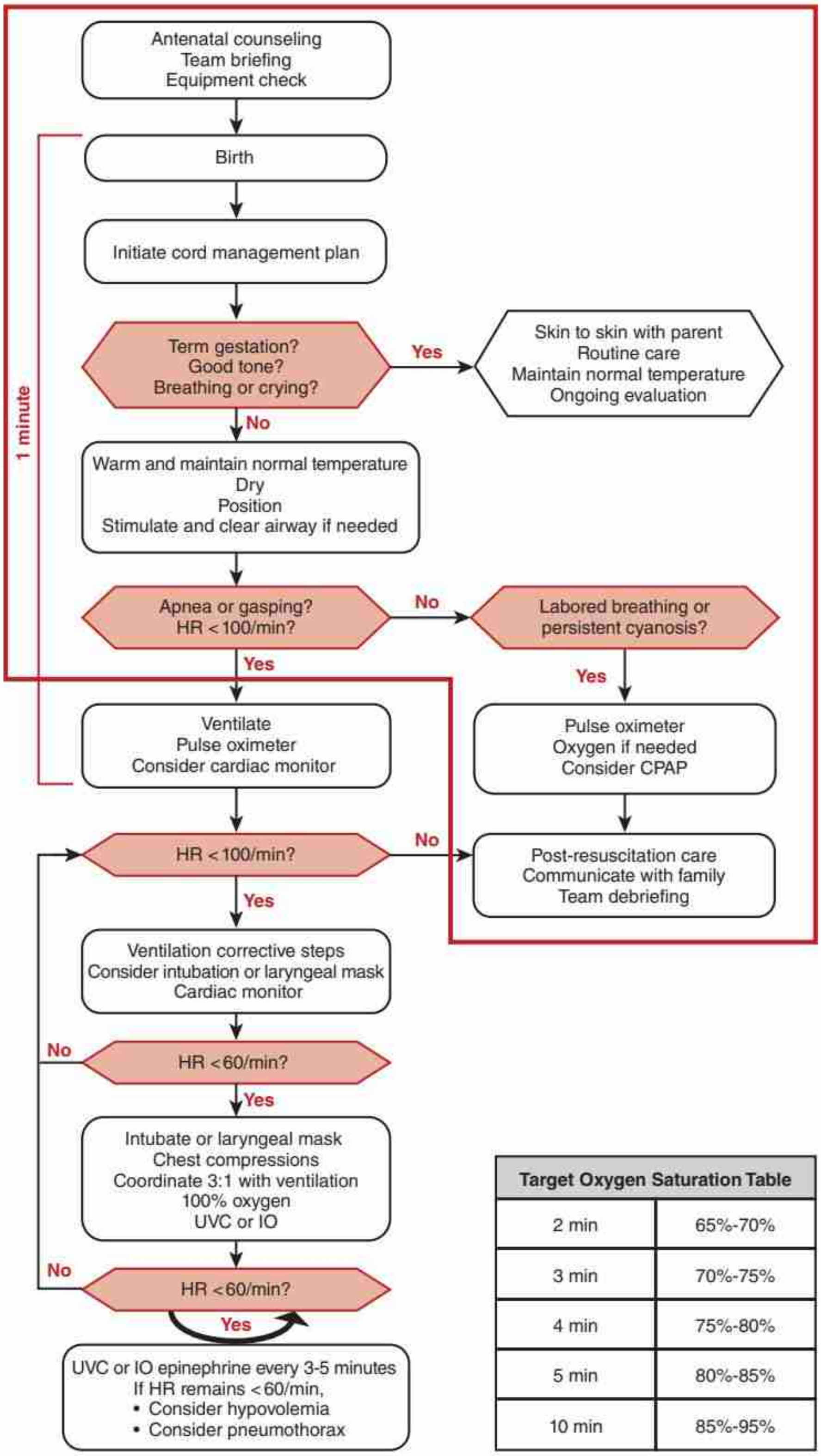
ACOG Practice Bulletin, No. 229: antepartum fetal surveillance. *Obstet Gynecol*. 2021;137(6):e116–e127

Lesson 3

Initial Steps of Newborn Care

What you will learn

- How to perform the initial evaluation of a newborn infant
- The initial steps of newborn care
- How to determine if additional steps are required
- What to do if a newborn infant has persistent cyanosis or labored breathing
- How to use a pulse oximeter and interpret the results
- How to give supplemental oxygen
- When to consider using continuous positive airway pressure
- What to do when meconium-stained amniotic fluid is present



Target Oxygen Saturation Table	
2 min	65%-70%
3 min	70%-75%
4 min	75%-80%
5 min	80%-85%
10 min	85%-95%

Key Points

1. For most newborn infants who do not require immediate resuscitation, clamping the umbilical cord should be deferred for at least 60 seconds.
   a. For newborn infants who are not vigorous at the time of birth, there is not enough evidence to make a definitive recommendation regarding umbilical cord management. If the placental circulation is intact, it may be reasonable to briefly defer cord clamping while the obstetric provider begins the initial steps of newborn care.
   b. Umbilical cord management should not delay appropriate initiation of assisted ventilation for newborn infants who remain apneic or have a heart rate less than 100 beats per minute (bpm) by 60 seconds after birth.

2. All newborn infants require an initial evaluation to determine if they can remain skin-to-skin with their parent to continue transition or if they should be moved to a radiant warmer for further assessment and intervention.
   a. This initial evaluation may occur during the interval between birth and umbilical cord clamping.
   b. Ask if the infant is term, has good muscle tone, and is breathing or crying. At the time of umbilical cord clamping, if the answer is *no* to any of these, the infant should be brought to a radiant warmer.

3. The routine initial steps of newborn care include the following: providing warmth, drying, and positioning the infant to ensure the airway is open.
   a. If there is ineffective breathing effort or apnea after birth, gentle tactile stimulation may stimulate breathing.
   b. Routine oral, nasal, oropharyngeal, or endotracheal suctioning is not recommended. If necessary, secretions in the upper airway can be cleared by wiping the infant's mouth and nose with a cloth. If there is concern for airway obstruction, the mouth and nose may be gently suctioned.

4. Within 1 minute after birth, assess the newborn infant's response to the initial steps. If the infant is not breathing, is gasping, or the heart rate is less than 100 bpm by 1 minute after birth, assisted ventilation is indicated.

5. Use pulse oximetry and the Target Oxygen Saturation Table to guide oxygen therapy (a) when resuscitation is anticipated, (b) to confirm your perception of persistent central cyanosis, (c) if you give supplemental oxygen, or (d) if ventilation is required. Visual assessment of cyanosis is not a reliable indicator of oxygen saturation.

6. For infants born through meconium-stained amniotic fluid, routine laryngoscopy with or without intubation for tracheal suction is not suggested. Intubation and tracheal suction are recommended if the infant requires assisted ventilation and there is concern for airway obstruction.

Case 1: An uncomplicated birth

A healthy pregnant person arrives in active labor at 39 weeks' gestation. You review the 4 pre-birth questions with the obstetric provider to identify risk factors and plan for the birth. You confirm that only 1 qualified person is needed to manage the care of the newborn infant. You anticipate a term birth, the amniotic fluid is clear, the pregnancy has been uncomplicated, and there are no additional risk factors. You confirm with the obstetric provider that, if immediate resuscitation is not required after birth, cord clamping will be deferred for at least 60 seconds. You complete a standardized checklist to ensure that neonatal resuscitation supplies and equipment are ready for use if needed, and you introduce yourself to the parents.

At the time of birth, the newborn infant appears to be full term, has good muscle tone, and cries vigorously. The infant is placed skin-to-skin on the parent's chest and is covered with a warm blanket. You gently dry the infant and position the head to ensure that the airway is open. One minute after birth, the cord is clamped and cut. The infant's color becomes increasingly pink during the transition to newborn circulation. You continue to evaluate breathing, tone, color, and temperature to determine if additional interventions are required. Shortly after birth, the infant is positioned on the birthing parent's chest to initiate breastfeeding.

Case 2: Delayed transition

A pregnant person arrives in labor at 39 weeks' gestation. Labor progresses rapidly and the obstetric provider calls your resuscitation team to attend the vaginal birth. You ask the obstetric provider the 4 pre-birth questions to assess perinatal risk factors and plan for the birth. A full-term birth is anticipated. Membranes are ruptured and the fluid is clear. Additional risk factors include intrapartum fever and fetal tachycardia. The laboring patient has received intrapartum antibiotics for suspected chorioamnionitis. Fetal heart rate monitoring shows a Category II (indeterminate) pattern. Because perinatal risk factors are present, you call additional staff to assist you. You discuss the umbilical cord management plan with the obstetric providers.

On entering the room, you introduce the team to the parents. Your team completes a pre-resuscitation briefing and standardized equipment check.

Immediately after birth, the newborn infant has poor tone and does not cry. The obstetric provider holds the infant in a warm blanket, dries the infant and stimulates the infant to breathe by gently rubbing the back; however, the infant continues to have poor tone, is not crying, and has inconsistent respiratory effort. After approximately 30 seconds, the obstetric provider clamps and cuts the cord and brings the infant to the radiant warmer for further evaluation. You position the infant's head and neck to open the airway while an assistant continues to provide gentle stimulation. A scribe documents the events as they occur.

During the next 20 seconds, the infant's tone and respiratory effort improve. Listening with a stethoscope at 1 minute, your assistant reports that the infant's heart rate is 120 bpm. You observe the infant's tone improving and the infant starting to cry. However, between 5 and 10 minutes after birth, central cyanosis persists and a pulse oximeter sensor is secured on the infant's right hand. The pre-ductal oxygen saturation (SpO_2) is below the target described in the Target Oxygen Saturation Table, so free-flow supplemental oxygen is administered. Documentation continues while the oxygen concentration (FiO_2) is adjusted so that the SpO_2 remains within the target range. By 15 minutes after birth, supplemental oxygen has been gradually discontinued. The SpO_2 remains normal and the infant is placed skin-to-skin on the parent's chest to continue transition while vital signs and activity are closely monitored for possible deterioration. Soon afterward, the team members conduct a short debriefing to evaluate their preparation, teamwork, and communication.

Umbilical cord management

At the time of birth, a large volume of the newborn infant's blood remains in the placenta. If blood is still flowing to the placenta through the uterine arteries and the umbilical cord has not been clamped, placental gas exchange will continue and additional oxygenated blood will be returned to the newborn infant through the umbilical vein. This blood may play an important role in the transition from fetal to neonatal circulation.

Mark the time of birth by starting a timer when the last fetal part emerges from the pregnant person's body. The ideal time for clamping the umbilical cord is the subject of ongoing research.

- In preterm infants, the beneficial effects of deferred cord clamping compared with immediate cord clamping include increased survival, decreased use of medications to support blood pressure after birth, and fewer blood transfusions during the initial hospitalization. However, there is an increased risk of hypothermia shortly after birth.

- In term infants, deferred cord clamping increases hematocrit and iron levels during infancy, which, although uncertain, may improve neurodevelopmental outcomes. However, there may also be an increased chance of needing phototherapy for hyperbilirubinemia.

Enhanced Learning

https://bcove.video/3HR8Fnj

QR 3.1 Scan here to see a video about deferred cord clamping.

Vigorous newborn infants

Before birth, establish with the obstetric provider the plan for the timing of umbilical cord clamping.

- **For most newborn infants who do not require immediate resuscitation, clamping the umbilical cord should be deferred for at least 60 seconds.**
- During this time, the infant may be placed skin-to-skin on the parent's chest or abdomen, or held securely in a warm, dry towel or blanket (Figure 3.1). Very preterm infants, born at less than 32 weeks' gestation, may be wrapped in polyethylene plastic to help maintain their temperature. During the interval between birth and umbilical cord clamping, the obstetric care provider and neonatal team should evaluate the infant's tone and breathing effort and continue the initial steps of newborn care described in the remainder of this lesson.

Figure 3.1. Place the newborn infant on the parent's chest or abdomen. Evaluate the infant's tone and breathing effort.

- **Early (immediate) cord clamping is indicated when the placental circulation is not intact, such as after a placental abruption, bleeding placenta previa, or cord avulsion.**

Early cord clamping may also be considered in the following situations:

- Many of the clinical trials that evaluated deferred cord clamping excluded multiple gestations. There are theoretical risks for unfavorable hemodynamic changes during deferred cord clamping, especially in monochorionic multiple gestations. There is currently not enough evidence to recommend for or against deferred cord clamping in the setting of a multiple gestation birth. Shared decision-making with the obstetric care provider and parents is encouraged.
- Other scenarios, in which safety data on deferred cord clamping are limited, will require a decision based on unit-specific policies. These scenarios may include fetal growth restriction, abnormal umbilical artery Doppler measurements, abnormal placentation, and other situations where utero-placental perfusion or umbilical cord blood flow is affected.

Non-vigorous newborn infants

For newborn infants who are not vigorous at the time of birth, there is not enough evidence to make a definitive recommendation regarding umbilical cord management. If the placental circulation is intact, it may be reasonable to briefly defer cord clamping while the obstetric provider begins the initial steps of newborn care and gently stimulates the infant to breathe. If the infant does not begin to breathe during this time, additional interventions may be required. Clamp the umbilical cord and bring the infant to the radiant warmer. Umbilical cord management should not delay appropriate initiation of assisted ventilation for newborn infants who remain apneic or have a heart rate of less than 100 bpm by 60 seconds after birth.

- For term and late preterm infants (35-42 weeks' gestation) who remain non-vigorous despite stimulation, milking the intact umbilical cord from the placenta toward the infant may be a reasonable alternative to early cord clamping.
- For non-vigorous preterm infants born at 28 to 34 weeks' gestation, there is not enough evidence to recommend routinely milking the intact umbilical cord.
- **Intact umbilical cord milking is not recommended for preterm infants born at less than 28 weeks' gestation because it has been associated with an increased risk of severe intraventricular hemorrhage.**

Enhanced Learning

https://bcove.video/4fRojMh

QR 3.2 Scan here to see a video about immediate cord clamping for term infant.

Enhanced Learning

https://bcove.video/4lIFuRe

QR 3.3 Scan here to see a video about cord milking for non-vigorous term infant.

Enhanced Learning

https://bcove.video/47RwhCO

QR 3.4 Scan here to see a video about immediate cord clamping for non-vigorous preterm infant.

The initial evaluation

After birth, all newborn infants require an initial evaluation to determine if they can remain skin-to-skin with their parent to continue transition or if they should be moved to a radiant warmer for further assessment and possible treatment. This initial evaluation may occur during the interval between birth and umbilical cord clamping. **You will rapidly ask 3 questions:** (1) Does the newborn infant appear to be term? (2) Does the newborn infant have good muscle tone? and (3) Is the newborn infant breathing or crying?

1. Does the newborn infant appear to be term?

Determine if the infant's appearance is consistent with the expected gestational age. In some situations, the infant's gestational age is unknown before birth. If the infant appears to be term, proceed to the next assessment question. If the infant appears to be preterm (less than 37 weeks' gestation), bring the infant to the radiant warmer after umbilical cord clamping for further assessment.

Preterm newborns are more likely to require interventions during the transition to extrauterine life. For example, they have more difficulty aerating their lungs, establishing good respiratory effort, and maintaining their body temperature. Because of these risks, once the cord has been clamped, preterm infants should be brought to the radiant warmer. If the infant is born at a late-preterm gestational age (34 to 36 weeks) and remains vigorous with good respiratory effort, the infant can be brought to the parent within several minutes to continue transition.

2. Does the newborn infant have good muscle tone?

Observe the infant's muscle tone. Healthy term infants should be active with flexed extremities (Figure 3.2). Newborn infants requiring intervention may have flaccid extremities (Figure 3.3).

Figure 3.2. Low-risk newborn infant: full-term, good tone, crying.

Figure 3.3. High-risk newborn infant: preterm, poor tone, not crying.

3. Is the newborn infant breathing or crying?

A vigorous cry is a clear indicator of strong respiratory effort (Figure 3.2). If the infant is not crying, observe the chest for breathing effort. Be careful not to be misled by an infant who is gasping. Gasping is a series of deep, single or stacked inspirations that occurs in the setting of severely impaired gas exchange. After umbilical cord clamping, a gasping newborn infant requires intervention and must be brought to the radiant warmer.

The initial steps of newborn care

As you complete your evaluation, perform the initial steps of newborn care, which include providing warmth, drying, and positioning the infant so the airway is open. In addition, some infants may require gentle tactile stimulation to stimulate breathing, and some may require gentle wiping or suctioning of the mouth and nose to clear the upper airway of secretions. For most newborn infants, these initial steps may be initiated between birth and umbilical cord clamping. In many cases, the initial steps are performed by more than 1 person and some steps may be performed simultaneously.

Enhanced Learning

https://bcove.video/3HskLDh

QR 3.5 Scan here to see a 30-second video of the initial steps of newborn infant care.

The routine initial steps for vigorous, term newborn infants

If the infant is full term, has good tone, and is breathing well or crying, the routine initial steps can be performed with the umbilical cord intact while the infant is skin-to-skin on the parent's chest or abdomen.

1. Provide warmth using direct skin-to-skin contact and by covering the infant with a warm towel or blanket (Figure 3.4).
2. Dry the infant with the towel or blanket.
3. Position the infant on the parent's chest or abdomen to ensure the airway is open.
4. If necessary, secretions in the upper airway can be cleared by wiping the infant's mouth and nose with a cloth.

After the initial steps are completed, continue monitoring the newborn infant's breathing, tone, activity, color, and temperature to determine if additional interventions are required.

Figure 3.4. Vigorous, term newborn infant. Initial steps are performed skin-to-skin with parent.

Figure 3.5. Radiant warmer used for the initial steps in high-risk newborn infants.

The initial steps for non-vigorous and preterm newborn infants

Non-vigorous newborn infants who require immediate resuscitation should be brought directly to a radiant warmer to receive the initial steps of newborn care. Initially non-vigorous infants who qualify for a trial of deferred umbilical cord clamping may receive the initial steps of newborn care, as described earlier, during the interval between birth and cord clamping. Infants who remain non-vigorous, and those born preterm, should be brought to a radiant warmer after the cord is clamped for completion of the initial steps, to undergo further assessment, and to receive additional intervention as needed. The initial steps for these infants may need to be modified as follows:

1. Provide warmth.

Place the infant under a radiant warmer so that the resuscitation team has easy access to the infant without causing excessive heat loss (Figure 3.5). Leave the infant uncovered to allow full visualization (preterm infants born at less than 32 weeks' gestation will remain covered in clear polyethylene plastic as described in Lesson 8).

- Monitor the infant's body temperature to **avoid both hypothermia and overheating**.
- During resuscitation and stabilization, **the infant's body temperature should be maintained between 36.5°C and 37.5°C (97.7°F to 99.5°F)**.
- After resuscitation, stabilization, and a standardized evaluation, therapeutic hypothermia is indicated for certain high-risk newborn infants and is described in Lesson 9.

2. Dry.

Wet skin increases evaporative heat loss (Figure 3.6). Place the infant on a warm towel or blanket and gently dry off any fluid. If the first towel or blanket becomes wet, discard it and use fresh, warm towels or blankets for continued drying (Figure 3.7).

- Drying is not necessary for very preterm infants born at less than 32 weeks' gestation because they should be covered immediately in polyethylene plastic, which reduces evaporative heat loss. The interventions used to reduce heat loss in very preterm infants are described in Lesson 8.

Figure 3.6. Uncovered, wet skin promotes rapid body cooling.

Figure 3.7. Dry the newborn infant and remove wet linen to prevent heat loss and stimulate breathing.

3. Position the head and neck to open the airway.

Position the infant on the back (supine) with the head and neck neutral or slightly extended and the eyes directed straight upward toward the ceiling in the "sniffing the morning air" position (Figure 3.8). This position opens the airway and allows unrestricted air entry.

- Avoid hyperextension or flexion of the neck because these positions may interfere with air entry.
- To help maintain the correct position, you may place a small, rolled towel under the infant's shoulders (Figure 3.9). A shoulder roll is particularly useful if the infant has a large occiput (back of head) from molding, edema, or prematurity.

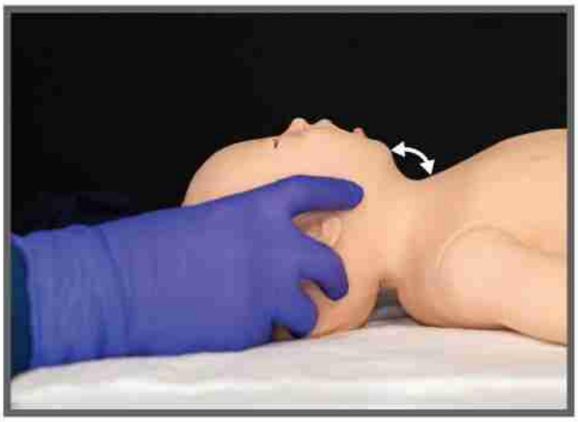


Figure 3.8. The sniffing position. The newborn infant's eyes are directed straight upward.

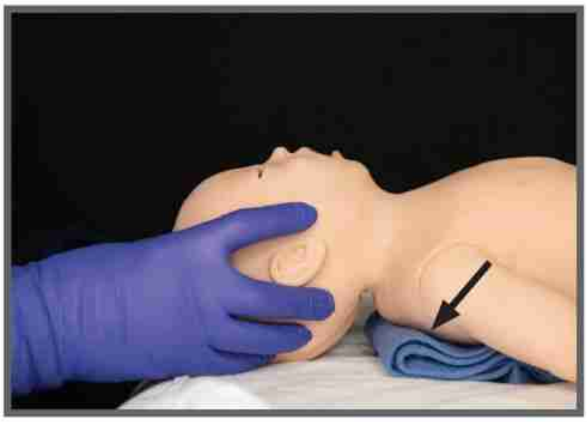


Figure 3.9. Optional shoulder roll for maintaining the sniffing position.

4. Stimulate if needed.

Drying the infant will frequently provide enough stimulation to initiate breathing. If the infant does not have adequate respiratory effort, brief additional tactile stimulation may initiate breathing.

- Gently rub the infant's back, trunk, or extremities. Overly vigorous stimulation is not helpful and can cause injury.
- **Never shake an infant.**

5. Clear secretions from the airway if needed.

Routine oral, nasal, oropharyngeal, or endotracheal suctioning is not recommended. If there is concern for airway obstruction, the mouth and nose may be gently suctioned with a bulb syringe (Figure 3.10). If copious secretions are coming from the newborn infant's mouth, turn the head to the side. This will allow secretions to collect in the cheek where they can be removed.

- **Be careful not to suction vigorously or deeply.** Vigorous suction may injure tissues. Stimulation of the posterior pharynx during the first minutes after birth can produce a vagal response leading to bradycardia or apnea. Moreover, there is no evidence to support either routine esophageal or gastric suction.
- If using a neonatal suction tip or catheter, the suction control should be set so that the negative pressure reads approximately **80 to 100 mm Hg** when the tubing is occluded.

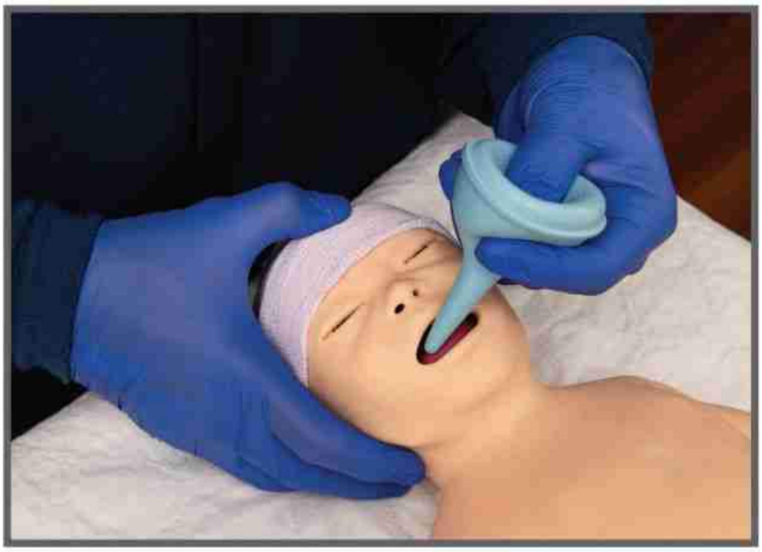


Figure 3.10. If there is concern for airway obstruction, gently suction the mouth and nose with a bulb syringe. Use your thumb to depress the bulb syringe before placing it in the newborn infant's mouth or nose.

Evaluate the newborn infant's response to the initial steps

Within 1 minute after birth, assess the newborn infant's response to the initial steps.

1. Determine if the infant is apneic or gasping.

After completing the initial steps, determine if the infant is crying or breathing. **If the infant is apneic or has gasping respirations, you will start assisted ventilation by 1 minute after birth.** If you are the only provider at the warmer, call for additional help.

If the infant has not responded to the initial steps by 1 minute after birth, it is not appropriate to continue to provide only tactile stimulation. For infants who remain apneic or bradycardic, delaying the start of ventilation beyond the first minute worsens outcomes.

Remember: Ventilation of the newborn infant's lungs is the most important and effective step during neonatal resuscitation.

The details of providing assisted ventilation are described in Lesson 4.

2. If the infant is breathing, assess the heart rate.

If the infant is breathing effectively, the heart rate should be at least 100 bpm by 1 minute after birth. **Start assisted ventilation if the heart rate is less than 100 bpm 1 minute after birth.**

Your initial assessment of the heart rate will be made using a stethoscope. Auscultation along the left side of the chest is the most accurate physical examination method of determining a newborn infant's heart rate (Figure 3.11). Although pulsations may be felt at the umbilical cord base, palpation is less accurate and may underestimate the true

Figure 3.11. Assess the heart rate by listening with a stethoscope.

heart rate. While listening, you may tap out the heartbeat on the bed so that your team will also know the heart rate.

- **Estimate the heart rate by counting the number of beats in 6 seconds and multiplying by 10.** For example, if you listen for 6 seconds and hear 12 beats, the heart rate is 120 bpm.
- Clearly report the heart rate to your team members ("The heart rate is 120 beats per minute").

If you cannot determine the heart rate by physical examination and the infant is not vigorous, ask another team member to quickly connect a pulse oximeter or cardiac monitor. Other options include the use of a handheld Doppler ultrasound or digital stethoscope.

Cautions

- A pulse oximeter may not display a reliable signal if the newborn infant's heart rate is low or if the infant has poor perfusion. In this case, determining the heart rate with a cardiac monitor is the preferred method.
- In unusual circumstances, a cardiac monitor may show an electrical signal, but the heart is not actually pumping blood. This is called pulseless electrical activity (PEA). In the newborn infant, PEA should be treated the same as an absent heart rate (asystole).

Persistent cyanosis

Figure 3.12. This newborn infant has cyanosis of the hands and feet (acrocyanosis), but the trunk and mucous membranes are pink. Acrocyanosis is normal. Supplemental oxygen is only needed if the infant's oxygen saturation is below the target range.

The term *cyanosis* describes skin or mucous membranes with a blue hue caused by poorly oxygenated blood. Cyanosis limited to the hands and feet (acrocyanosis) is a normal finding in the newborn infant and does not indicate poor oxygenation (Figure 3.12). Low oxygen saturation causing the infant's lips, tongue, and torso to appear blue is called central cyanosis.

- Healthy infants may have central cyanosis for several minutes after birth.
- **Studies have shown that visual assessment of cyanosis is not a reliable indicator of the infant's oxygen saturation and should not be used to guide oxygen therapy.**
- If persistent central cyanosis is suspected, a pulse oximeter placed on the right hand or wrist should be used to assess the infant's oxygenation and guide therapy.

Pulse oximetry

Oxygen is carried by the hemoglobin inside red blood cells. Hemoglobin that is carrying oxygen absorbs red light differently from hemoglobin that is not carrying oxygen. A pulse oximeter uses a light source and sensor to measure the absorption of red light passing through capillaries in the skin and estimates the percentage of hemoglobin that is carrying oxygen (Figure 3.13). The monitor displays the oxygen saturation, which ranges from 0% to 100%. This number is not the same as the partial pressure of oxygen (PO_2) measured with a blood gas machine. The pulse oximeter also displays the newborn infant's heart rate by sensing pulsatile blood flow in the capillaries. Indications for using a pulse oximeter in the birth setting are described in Table 3-1.

Figure 3.13. Pulse oximeter with sensor attached to a newborn infant's right hand on the hypothenar eminence.

Table 3-1. Indications for Pulse Oximetry in the Birth Setting

- When resuscitation is anticipated
- To confirm your perception of persistent cyanosis
- If supplemental oxygen is given
- When assisted ventilation is required

Placing a pulse oximeter

In most newborn infants, the artery supplying the right arm branches from the aorta before the patent ductus arteriosus enters the aorta. Blood in the right arm is often called *pre-ductal* and has a similar oxygen saturation as the blood perfusing the infant's heart and brain. The origin of blood flow to the left arm is less predictable. The arteries supplying both legs branch from the aorta after the patent ductus arteriosus and are called *post-ductal*.

- To measure the oxygen saturation of the pre-ductal blood that is perfusing the heart and brain, **place the pulse oximeter sensor on the infant's right hand or wrist**.
- The left arm and both legs may have lower oxygen saturation. They may receive blood from the aorta that has been mixed with poorly oxygenated venous blood that bypassed the lungs through the patent ductus arteriosus (post-ductal).

Proper placement of the sensor is important. **Once the sensor is attached to the infant, watch the monitor to ensure that it is detecting a pulse with each heartbeat.** Most instruments will not display a saturation reading until a consistent pulse is detected. If you are monitoring the heart rate with a cardiac monitor, the heart rate displayed on the pulse oximeter should be the same as the heart rate on the cardiac monitor.

- The sensor must be oriented correctly so that it can detect the transmitted red light. After placement, **it may be helpful to cover the sensor to shield it from light in the room.** If the pulse oximeter is not detecting a consistent pulse, you may need to adjust the sensor to be sure that it is positioned opposite the light source.

- With good technique, a pulse oximeter will accurately display the heart rate and oxygen saturation within approximately 1 to 2 minutes of application.
- **If the infant has a very low heart rate or poor perfusion, the pulse oximeter may not be able to detect the pulse or oxygen saturation.**

The target oxygen saturation

Healthy newborn infants undergoing normal transition usually take several minutes to increase their blood oxygen saturation from approximately 60%, which is the normal intrauterine state, to more than 90%, which is the eventual state of air-breathing healthy newborn infants. Oxygen saturation values following cesarean birth are slightly lower than those following vaginal birth. Oxygen saturation values after deferred cord clamping are slightly higher than those following immediate cord clamping.

When the pulse oximeter has a reliable signal, compare the infant's pre-ductal oxygen saturation with the range of target values in Table 3-2. These values are based on oxygen saturations obtained from healthy, term infants breathing room air during the first 10 minutes after birth. The ideal oxygen saturation during the first minutes after birth has not been established and there is ongoing controversy about which targets should be used. These targets have been selected to represent a consensus of acceptable values that can be easily remembered.

Table 3-2. **Target Pre-Ductal Oxygen Saturation**

Target Oxygen Saturation Table	
2 minutes	65%-70%
3 minutes	70%-75%
4 minutes	75%-80%
5 minutes	80%-85%
10 minutes	85%-95%

Enhanced Learning

https://bcove.video/45sqMYG

QR 3.6 Scan here to see a 45-second video about administering supplemental free-flow oxygen.

Administering supplemental oxygen

Use supplemental free-flow oxygen when the pulse oximeter reading remains below the target range for the infant's age. Free-flow oxygen can be given to a spontaneously breathing infant by holding oxygen tubing close to the infant's mouth and nose or using one of the ventilation devices described in Lesson 4 (Figure 3.14). Free-flow oxygen is not effective if the infant is not breathing.

- Free-flow oxygen may be administered through the open reservoir (tail) on some self-inflating bags (Figure 3.14). If your hospital has self-inflating bags with closed reservoirs, you will need separate oxygen tubing to administer free-flow oxygen.
- **If you are using a flow-inflating bag or T-piece resuscitator, hold the mask close to the face but not so tight that you make a seal and pressure builds up within the mask.**
- If a flow-inflating bag is used, the bag should not inflate when used to provide free-flow oxygen. An inflated bag indicates that the mask is tight against the face and unintended positive pressure is being delivered.
- If a T-piece resuscitator is being used, do not occlude the opening on the T-piece cap. During free-flow oxygen administration, the T-piece pressure manometer should read "zero."

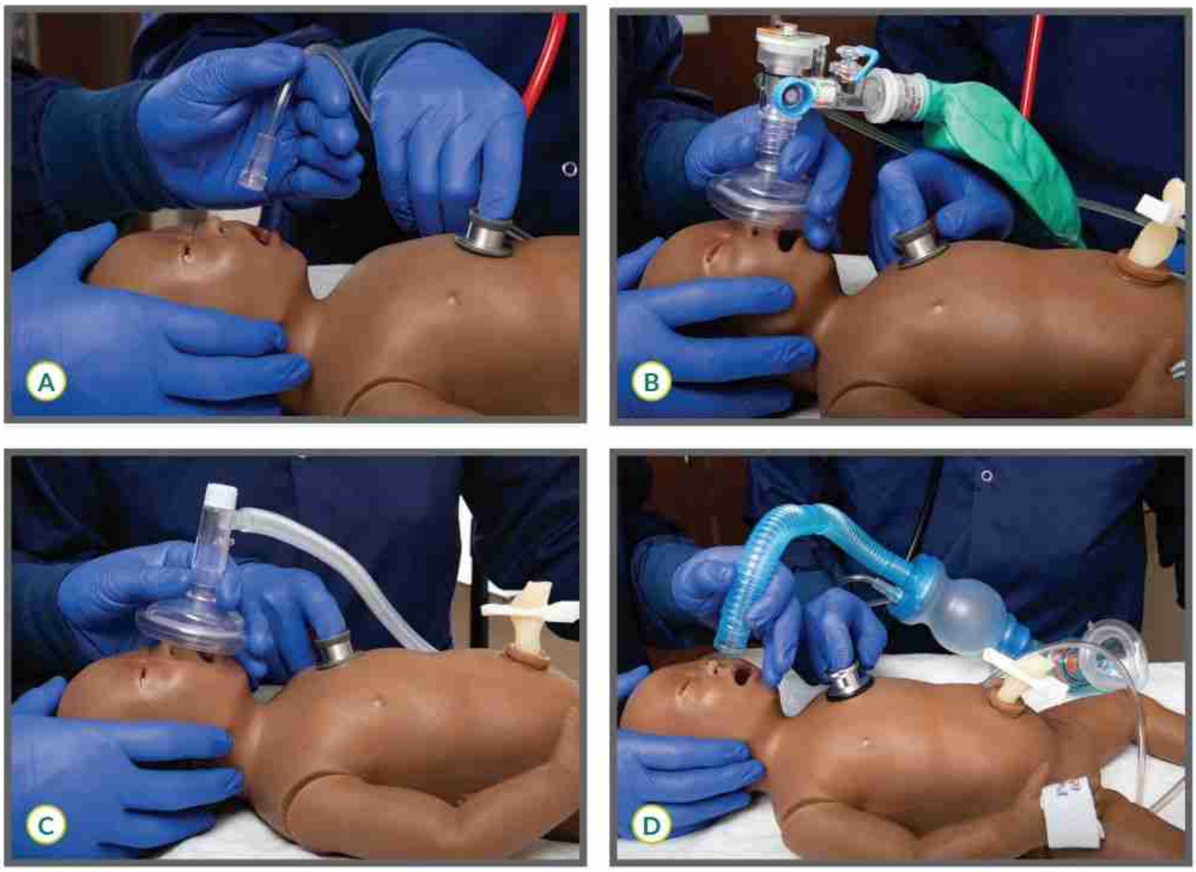


Figure 3.14. Free-flow supplemental oxygen given to a spontaneously breathing newborn infant by (A) oxygen tubing, (B) a flow-inflating bag, (C) a T-piece resuscitator, (D) the tail of a self-inflating bag with an open reservoir. The oxygen source is held close to the infant's mouth and nose. Note: For free-flow supplemental oxygen, the mask of a flow-inflating bag and T-piece resuscitator is *not* held tightly against the infant's face.

Figure 3.15. Do not attempt to give free-flow oxygen using the mask of a self-inflating bag.

Figure 3.16. Adjust the concentration and flow of oxygen with compressed air (inflow from yellow hose), compressed oxygen (inflow from green hose), an oxygen blender (a), and a flowmeter (b). The blender adjusts the concentration of oxygen, and the flowmeter adjusts the flow of gas. This image shows 2 flowmeters attached to the oxygen blender. Your system may only have a single flowmeter.

Do not attempt to administer free-flow oxygen through the mask of a self-inflating bag (Figure 3.15) because gas does not reliably flow through the mask unless the bag is being squeezed.

Adjusting the concentration of supplemental oxygen

If free-flow oxygen is necessary, it is reasonable to start with approximately 30%. Then, guided by pulse oximetry, adjust the FiO_2 to maintain the newborn infant's oxygen saturation within the target range shown in Table 3-2. The goal is to prevent low oxygen saturation without exposing the newborn to the potential risk of additional, unnecessary oxygen. Adjust the concentration and flow of supplemental oxygen using compressed air and oxygen, a blender, and a flowmeter (Figure 3.16).

Compressed air and oxygen

Compressed gases may be built into the wall or obtained from portable tanks. Medical air (21% oxygen) is supplied from high-pressure hoses that are color coded yellow, and 100% oxygen is supplied from high-pressure hoses that are color coded green.

Oxygen blender and flowmeter

The compressed gases are connected to a blender, which has a dial that adjusts the gas mixture (21%-100%). The blended gas travels to an adjustable flowmeter. The flowmeter commonly has a floating ball within a glass tube that indicates the rate of gas flow leaving the device. Depending on the size of the flowmeter, you can adjust the dial to achieve gas flows between 0 L/min and 20 L/min. The blended gas, adjusted to the desired concentration and flow rate, is directed through tubing to the oxygen delivery device.

- For free-flow supplemental oxygen, **adjust the flowmeter to 10 L/min**.
- Begin free-flow oxygen supplementation with the **blender set to 30% oxygen**. Using the blender, adjust the FiO_2 as needed to achieve the oxygen saturation target.

Attempt to gradually decrease the FIO_2 until the newborn infant can maintain saturation within the target range without supplemental oxygen. If respirations and heart rate are stable but the newborn continues to require supplemental oxygen, use pulse oximetry to guide the appropriate FIO_2.

- Oxygen administered directly from a compressed source is cold and dry. To prevent heat loss, oxygen given to newborns for a prolonged period should be heated and humidified.

If an oxygen blender is not available

If supplemental free-flow oxygen is necessary and an oxygen blender is not available, such as when resuscitation occurs outside the delivery room, free-flow oxygen may be delivered by using 100% oxygen from the wall or a portable oxygen source. As described previously, direct the flow of oxygen toward the infant's mouth and nose using oxygen tubing, a mask, or an appropriate ventilation device. As oxygen flows out of the tubing or mask, it mixes with air. The concentration of oxygen that reaches the infant's nose is determined by the amount of 100% oxygen coming from the tubing or mask and the amount of air it must pass through to reach the infant. Guided by pulse oximetry, adjust the oxygen concentration by moving the tubing or mask closer to or farther from the infant's face.

Using CPAP for labored breathing or persistently low oxygen saturation

If the newborn infant has spontaneous but labored breathing, or the oxygen saturation cannot be maintained within the target range despite administering 100% free-flow oxygen, you may consider a trial of continuous positive airway pressure (CPAP).

CPAP is a method of respiratory support that uses a continuous low gas pressure to keep a spontaneously breathing infant's lungs open. CPAP may be helpful if the airway is open but the infant has signs of labored breathing or persistently low oxygen saturations. CPAP should only be considered if the infant is breathing and the heart rate is at least 100 bpm.

- **Administering CPAP may increase the chance of developing a pneumothorax** (air leak).
- Providers should be aware of this potential complication and be prepared to address it.

If desired, a trial of CPAP can be given by using a flow-inflating bag or a T-piece resuscitator attached to a mask that is held tightly to the infant's face (Figure 3.17). **CPAP cannot be given using a self-inflating bag.** The equipment and method for administering CPAP are described in more detail in Lesson 4.

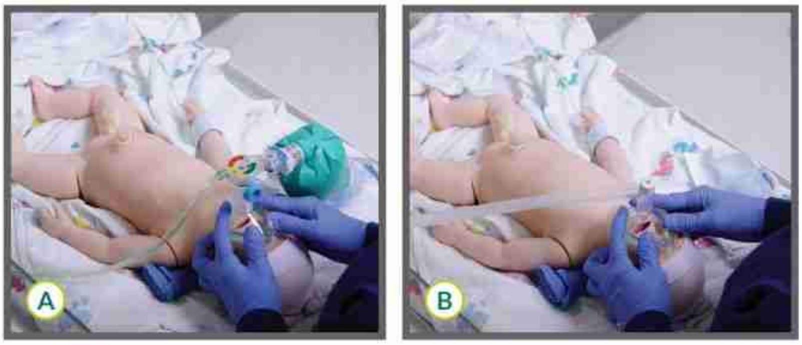


Figure 3.17. Administering CPAP using (A) a flow-inflating bag or (B) a T-piece resuscitator. The newborn infant must have spontaneous breathing and a heart rate greater than 100 bpm. For CPAP, the mask is held tightly against the face to create a seal.

Meconium-stained amniotic fluid

The presence of meconium-stained amniotic fluid may indicate fetal distress and increases the risk that the newborn infant will require resuscitation.

- At least 2 qualified people who can initiate resuscitation should be present at the time of birth solely to manage the infant.
- An individual with intubation skills should be identified and immediately available if needed.
- If additional risk factors indicate that an extensive resuscitation is likely, a qualified team with full resuscitation skills should be present at the time of birth.

Meconium-stained fluid and a vigorous newborn infant

If the infant is vigorous with good respiratory effort and muscle tone, the infant may stay with the parent to receive the initial steps of newborn care and to continue transition.

Meconium-stained fluid and a non-vigorous newborn infant

If an infant is born through meconium-stained amniotic fluid and has depressed respirations or poor muscle tone, it may be reasonable to briefly defer umbilical cord clamping and begin the initial steps of newborn care.

- If the infant does not improve with a brief period of stimulation, clamp the umbilical cord and bring the infant to the radiant warmer for completion of the initial steps of newborn care and to undergo additional assessment as described in this lesson.
- If secretions appear to be obstructing the airway, clear them from the mouth and nose with a bulb syringe.

- If the infant is not breathing or if the infant is breathing and the heart rate is less than 100 bpm after the initial steps are completed, proceed with assisted ventilation by 1 minute after birth as described in Lesson 4.

Routine laryngoscopy with or without intubation for tracheal suction is not suggested. Historically, routine intubation and suction immediately after birth was recommended in an effort to reduce the chance of developing meconium aspiration syndrome; however, a systematic review of randomized trials found no evidence to support this practice. Intubation and tracheal suction may be necessary if assisted ventilation does not inflate the lungs and airway obstruction is suspected.

Focus on Teamwork

The initial steps of resuscitation highlight several opportunities for effective teams to use the Neonatal Resuscitation Program® (NRP®) Key Behavioral Skills.

Behavior	Example
Anticipate and plan.	Ensure that you have enough personnel present at the time of delivery based on the identified risk factors.
Communicate effectively. Use available information.	Immediately after birth, the obstetric and neonatal care teams need to share their assessment of the newborn infant. Subsequent interventions will be based on this assessment. The care teams need to communicate their findings clearly and efficiently.
Know your environment.	Know how the pulse oximeter, compressed air and oxygen source, oxygen blender, and flowmeters work in your practice setting. Know what device is available to administer CPAP in your hospital. Know how to obtain a cardiac monitor if needed.
Use available resources.	If you cannot auscultate a heart rate and the infant is not vigorous, quickly place a pulse oximeter sensor or cardiac monitor leads and attach them to the appropriate monitor.
Call for additional help when needed.	After the initial steps, if you identify apnea, gasping, or a heart rate less than 100 bpm and you are alone, call for additional help. Assisted ventilation is required, and you will need additional personnel.

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own hospital setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. Are vigorous newborn infants placed skin-to-skin with their parent?
2. How are the findings of the infant's initial assessment communicated between the obstetric and pediatric providers?
3. Do vigorous newborn infants routinely have their mouth and nose suctioned even when there is no concern for airway obstruction?

Process and outcome measures

1. What percentage of vigorous newborn infants have umbilical cord clamping deferred for at least 60 seconds?
2. What percentage of newborn infants are crying or breathing after drying and stimulation?
3. What percentage of newborn infants with meconium-stained fluid still undergo laryngoscopy and tracheal suction?

Frequently Asked Questions

Does it matter if the pulse oximeter sensor is attached to the newborn infant's hand or wrist?

For a small newborn infant, some health care providers find it easier to secure the sensor to the wrist; however, some manufacturers recommend placing the pulse oximeter sensor only on the infant's hand. There is evidence that an accurate reading can be obtained using a sensor placed on the infant's wrist. In the studies that established the normal progression of oxygen saturation in healthy newborns, the pulse oximeter sensor was placed on the infant's wrist. Placement on either the hand or wrist is acceptable as long as the transmitted light is detected by the sensor and a reliable signal is obtained.

Previously, the Neonatal Resuscitation Program recommended routine endotracheal intubation and suction for non-vigorous infants born through meconium-stained amniotic fluid. Why is this no longer recommended? Does this change who should attend the birth of the infant with meconium-stained amniotic fluid?

Prior to each edition of the *Textbook of Neonatal Resuscitation,* questions are identified by the International Liaison Committee on Resuscitation (ILCOR) Neonatal Task Force. The scientific evidence is reviewed using a systematic approach, and treatment recommendations are developed using a method that evaluates the strength of the supporting evidence (GRADE). Before the *Textbook of Neonatal Resuscitation,* 7th edition (2016), the NRP recommendation for tracheal suction was based on small observational studies that did not use currently accepted research methods for comparing treatments. As a result, the conclusions from those studies are subject to bias and the strength of evidence is considered very weak.

Subsequently, several small, randomized trials enrolling non-vigorous newborn infants have been conducted, the results of which do not show benefit to tracheal suction. The updated ILCOR reviews determined that the existing evidence did not support routine tracheal suction. Routine tracheal suction has not been recommended since publication of the 7th-edition textbook. Observational studies have attempted to determine if outcomes have worsened since the recommendation was changed and have reached varying conclusions. At this time, there remains no conclusive evidence that routine tracheal suction for non-vigorous newborns with meconium-stained fluid improves important clinical outcomes.

The NRP Steering Committee's values include avoiding invasive procedures without good evidence of benefit for important outcomes. As a result, the NRP Steering Committee does not currently suggest routine laryngoscopy with or without tracheal suction for non-vigorous infants delivered through meconium-stained fluid. If higher-certainty evidence becomes available that indicates an important benefit from routine tracheal suction, the ILCOR Neonatal Task Force and NRP Steering Committee will reevaluate this recommendation.

The presence of meconium-stained fluid is still considered a perinatal risk factor that increases the likelihood that the newborn infant will require resuscitation. At least 2 qualified people who can initiate resuscitation should be present at the time of birth solely to manage the infant. An individual with intubation skills should be identified and immediately available. If additional risk factors indicate that an extensive resuscitation is likely, a qualified team with full resuscitation skills should be present at the time of birth.

LESSON 3 REVIEW

1. List the 3 initial evaluation questions that determine which newborn infants should be brought to the radiant warmer after umbilical cord clamping.

2. List the 3 routine initial steps of newborn care for vigorous infants.

3. You count a newborn infant's heartbeat for 6 seconds and count 6 beats. You report the heart rate as (36 beats per minute)/(60 beats per minute).

4. A newborn infant's oxygen saturation should be 85% to 95% by (2 minutes of age)/(10 minutes of age).
5. Which image shows the correct way to position a newborn infant's head to open the airway (A, B, or C)?

6. You have provided warmth, dried the infant, positioned the infant's head and neck, and provided additional tactile stimulation. It is now 60 seconds after birth, and the infant is still apneic and limp. What is your next action?
7. If an infant is breathing, the heart rate is greater than 100 beats per minute, the airway is clear and correctly positioned, but the respirations are labored, you may consider (deep pharyngeal suction)/continuous positive airway pressure [CPAP]).

Answers

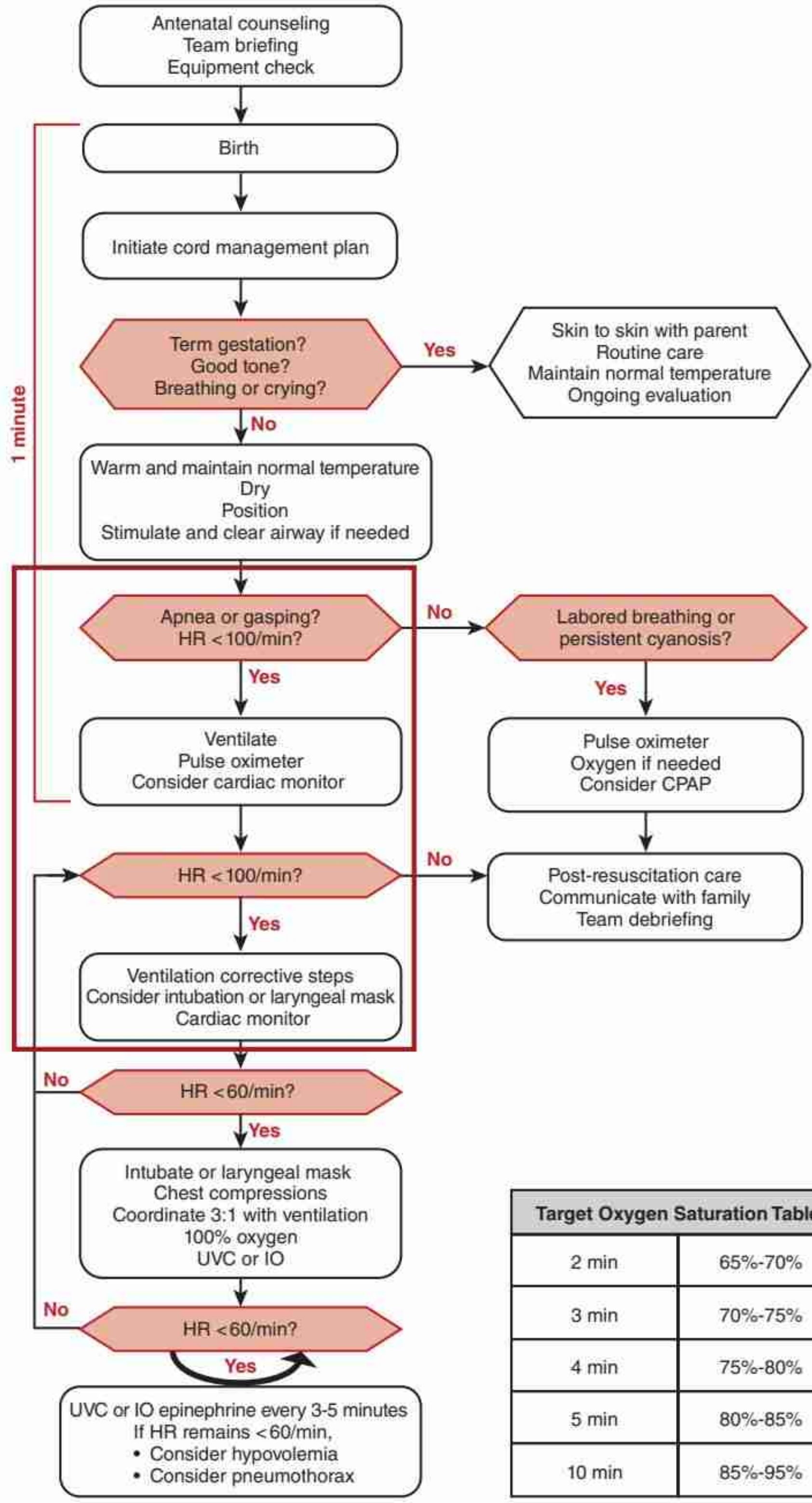
1. Is the newborn infant term? Does the infant have good tone? Is the infant breathing or crying?
2. Providing warmth, drying, and positioning the infant to ensure an open airway.
3. You report the heart rate as 60 beats per minute.
4. A newborn infant's oxygen saturation should be 85% to 95% by 10 minutes of age.
5. Image B shows the correct way to position a newborn infant's head to open the airway.
6. Your next action is to start assisted ventilation. Call for help if you are alone.
7. You may consider continuous positive airway pressure (CPAP).

Lesson
4

Ventilation

What you will learn

- The characteristics of self-inflating bags, flow-inflating bags, and T-piece resuscitators
- When to assist ventilation
- How to position the newborn infant's head for assisted ventilation
- How to place a resuscitation mask on the newborn infant's face
- How to provide ventilation and assess effectiveness
- How to use the ventilation corrective steps
- How to insert a laryngeal mask for ventilation
- How to administer continuous positive airway pressure
- How to insert an orogastric tube



Target Oxygen Saturation Table	
2 min	65%-70%
3 min	70%-75%
4 min	75%-80%
5 min	80%-85%
10 min	85%-95%

Key Points

1. Ventilation of the newborn infant's lungs is the single most important and most effective step in neonatal resuscitation.
2. After completing the initial steps, assisted ventilation is indicated if the newborn infant is not breathing (apneic), *OR* is gasping, *OR* if the heart rate is less than 100 beats per minute (bpm). When indicated, assisted ventilation should be started within 1 minute of birth.
3. In most cases, ventilation is initiated with a face mask or laryngeal mask.
4. For newborn infants with a gestational age of 35 weeks or greater, set the initial oxygen concentration (FIO_2) to 21%. For newborn infants with a gestational age of 32 to 34 weeks, set the initial FIO_2 to 21% to 30%. For newborn infants with a gestational age of less than 32 weeks, an initial FIO_2 greater than or equal to 30% may be considered.
5. Based on pre-ductal pulse oximetry, adjust the FIO_2 to meet the minute-specific oxygen saturation targets.
6. The ventilation rate is 30 to 60 breaths per minute. The initial peak inflation pressure is 25 cm H_2O (acceptable range, 25 to 30 cm H_2O for term newborn infants and preterm newborn infants with a gestational age of $\geq$ 32 weeks and 20 to 25 cm H_2O for preterm newborn infants with a gestational age of less than 32 weeks). If used, the positive end-expiratory pressure is 5 cm H_2O.
7. The most important indicator of successful ventilation is a rising heart rate.
8. If the heart rate is not increasing within 15 to 30 seconds of starting ventilation and you do not observe chest movement, start the ventilation corrective steps.
9. The ventilation corrective steps (*MR SOPA*) are Mask adjustment, Reposition the head and neck, Suction the mouth and nose, Open the mouth, Pressure increase, Alternative airway.
10. If the heart rate remains less than 60 bpm despite at least 30 seconds of face mask ventilation that inflates the lungs (chest movement), insert an alternative airway (laryngeal mask or endotracheal tube) if not already done; provide 30 seconds

of ventilation through the alternative airway; and adjust the FIO_2 as needed. If the heart rate remains less than 60 bpm despite 30 seconds of ventilation through an alternative airway, increase the FIO_2 to 100% and begin chest compressions.

11. If you continue face mask or laryngeal mask ventilation or use continuous positive airway pressure (CPAP) for more than several minutes, an orogastric tube should be inserted to remove gas from the stomach.

Case: Resuscitation with ventilation using a resuscitation bag and mask

Your team is called to attend a cesarean birth at 34 weeks' gestation. The pregnancy and induced labor have been complicated by preeclampsia, fetal growth restriction, and a Category II fetal heart rate pattern. The amniotic fluid is clear. You complete a pre-resuscitation team briefing and prepare your supplies and equipment. After birth, the obstetrician dries the newborn infant with a warm blanket, positions the head and neck to open the airway, and gently stimulates the infant by rubbing the back, but the infant remains limp and apneic. The umbilical cord is clamped and cut, the infant is handed to the waiting neonatal care provider and moved to the radiant warmer.

You place the infant in a midline, neutral position and provide brief additional stimulation, but the infant is still not breathing. Within 1 minute of birth, you place a resuscitation face mask and initiate ventilation with 30% oxygen. An assistant reports that the infant's heart rate is 70 beats per minute (bpm), not increasing, and the chest is not moving. Another team member places a pulse oximeter sensor on the infant's right hand and cardiac monitor leads on the infant's chest. An additional team member documents the events as they occur.

You initiate the ventilation corrective steps. First, you reapply the resuscitation mask to the face and reposition the infant's head and neck. You restart ventilation while your assistant watches the newborn infant's chest. After several breaths, the assistant reports that there is still no chest movement. You suction the mouth and nose and open the infant's mouth. Again, you start ventilation, but there is still no chest movement. You gradually increase the inflation pressure and the assistant calls out, "The chest is moving now." Within 30 seconds of achieving ventilation that inflates the infant's lungs, the heart rate is greater than 100 bpm and oxygen saturation is 64%. The assistant adjusts the oxygen concentration (FIO_2) to maintain the infant's oxygen saturation within the target range.

You continue ventilation while monitoring the infant's respiratory effort. The infant begins to breathe, and you gradually decrease the ventilation rate and inflation pressure. When the infant is 4 minutes of age, there is good spontaneous breathing effort, the heart rate is 140 bpm, and oxygen saturation is 85%. You discontinue ventilation and monitor the infant's oxygen saturation. While your team prepares to move the infant to the nursery for post-resuscitation care, you explain the next steps to the parents. Shortly afterward, you meet with your team and conduct a debriefing to evaluate your preparation, teamwork, and communication.

Ventilation is the foundation of neonatal resuscitation

Ventilation of the newborn infant's lungs is the single most important and effective step in neonatal resuscitation. Learning how to provide assisted ventilation is the foundation of neonatal resuscitation. This lesson focuses on ventilation through a resuscitation face mask or laryngeal mask. The next lesson describes how to ventilate through an endotracheal tube.

Common terminology used to describe ventilation

Several terms and abbreviations are used to describe ventilation (Figure 4.1).

- *Peak inflation pressure (PIP):* The highest pressure administered with each breath
- *Positive end-expiratory pressure (PEEP):* The gas pressure maintained in the lungs between breaths when the infant is receiving **assisted breaths**
- *Continuous positive airway pressure (CPAP):* The gas pressure maintained in the lungs between breaths when an infant is **breathing spontaneously**
- *Rate:* The number of assisted breaths administered per minute
- *Inflation time (IT):* The duration (seconds) of the inflation phase of each assisted breath
- *Manometer:* A gauge used to measure gas pressure

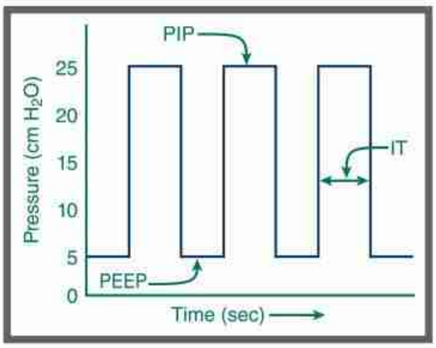


Figure 4.1. Pressure tracing during 3 assisted breaths.
Abbreviations: IT, inflation time; PEEP, positive end-expiratory pressure; PIP, peak inflation pressure.

Enhanced Learning

https://bcove.video/3UPabJA

QR 4.1 Scan here to see a 2-minute video about ventilation terminology.

Devices used for ventilation

Three devices are commonly used for ventilation.

1. A **self-inflating bag** fills spontaneously with gas (air, oxygen, or a blend of both) after it has been squeezed and released (Figure 4.2).
2. A **flow-inflating bag** (also called an anesthesia bag) only fills when gas from a compressed source flows into it and the outlet is sealed (Figure 4.3).
3. A **T-piece resuscitator** continuously directs compressed gas toward the infant. Pressure increases when an opening on the top of the T-shaped device is occluded (Figure 4.4).

Figure 4.2. Self-inflating bag.

Figure 4.3. Flow-inflating bag.

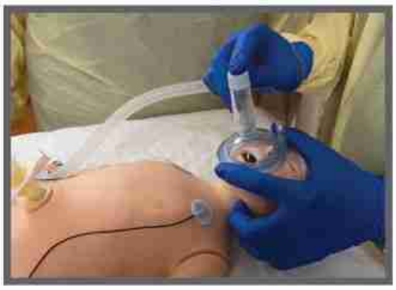


Figure 4.4. T-piece resuscitator.

All 3 devices used for ventilation during neonatal resuscitation can be attached to a resuscitation face mask, a laryngeal mask, or an endotracheal tube.

Find out what kind of resuscitation devices are used in your hospital. If your hospital uses flow-inflating bags or T-piece resuscitators, you should still learn how to use a self-inflating bag. A self-inflating bag should be readily available as a backup wherever resuscitation may be needed in case compressed gas is not available. The 3 devices are briefly described in the following text. Additional details are found in the Appendix to this lesson. You should read those sections of the Appendix that apply to the devices used in your hospital.

Self-inflating bags

A self-inflating bag remains fully inflated unless it is being squeezed (Figure 4.5). Once you release the bag, it recoils and draws fresh gas into the bag. If the bag is attached to an oxygen source, it fills with gas at the supplied FiO_2. If the bag is not attached to an oxygen source, it fills by drawing air (21% oxygen) into the bag. Because the bag self-inflates, it does not require compressed gas or a tight seal at the gas outlet to remain inflated.

- The ventilation rate is determined by how often you squeeze the bag, and the inflation time is determined by how quickly you squeeze the bag.
- PIP is controlled by how hard the bag is squeezed.
- PEEP may be administered if an additional valve is attached to the bag.
- Because gas does not flow toward the infant unless the bag is being squeezed, a self-inflating bag and mask **cannot** be used to administer CPAP or free-flow supplemental oxygen.
- Free-flow supplemental oxygen may be administered through the open reservoir ("tail") on some self-inflating bags.

Most self-inflating bags have a pressure-release valve, also called a pop-off valve, which limits the peak inflation pressure. These valves are usually set to release at 30 to 40 cm H_2O pressure, but they are not reliable and may not release until higher pressures are achieved. Some self-inflating bags have a device that allows the pressure-release valve to be temporarily occluded, allowing higher pressures to be administered. Occluding the pop-off valve should be an unusual occurrence and care must be taken not to use excessive pressure.

Enhanced Learning

https://bcove.video/4mFPJHb

QR 4.2 Scan here to see a 1.5-minute video about use of the self-inflating bag.

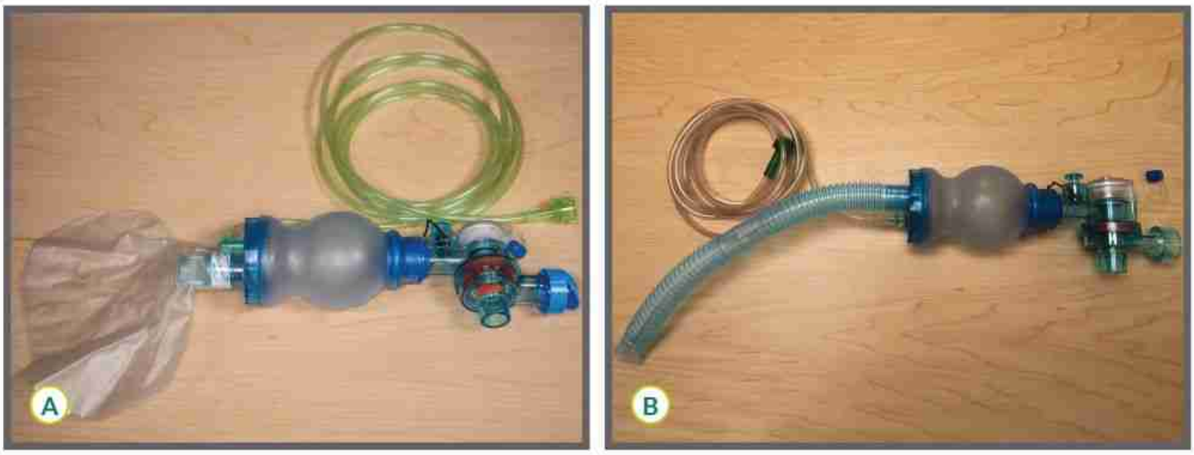


Figure 4.5. Self-inflating bags with a closed reservoir (A) and an open "tail" reservoir (B). Both bags reinflate without compressed gas.

To ensure the appropriate pressure is used, a manometer should always be used. The manometer may be built into the bag or there may be an attachment site for an external manometer. If the attachment site is left open without a manometer attached, it will cause a large gas leak and prevent the infant from receiving the desired inflation pressure.

Enhanced Learning

https://bcove.video/4mxBNPb

QR 4.3 Scan here to see a 20-second video about testing the self-inflating bag.

Testing a self-inflating bag during the equipment check and before use

Block the face mask or gas outlet with the palm of your hand and squeeze the bag (Figure 4.6).

Figure 4.6. Testing a self-inflating bag.

Testing a self-inflating bag	
Block the face mask or gas outlet and squeeze the bag. • Do you feel pressure against your hand? • Does the manometer register pressure? • Does the pressure-release valve open when the manometer registers 30 to 40 cm H_2O pressure? • Does the bag reinflate quickly when you release your grip?	If not, • Is there a crack or leak in the bag? • Is the manometer missing, resulting in an open attachment site? • Is the pressure-release valve missing or blocked?

Enhanced Learning

https://bcove.video/4mz614f

QR 4.4 Scan here to see a 1-minute video about testing and using the flow-inflating bag.

Flow-inflating bags

A flow-inflating bag inflates only when compressed gas is flowing into the bag and the gas outlet is sealed, such as when the face mask is applied to the infant's face (Figure 4.7A). If compressed gas is not flowing into the bag or the outlet is not sealed, the bag collapses and looks like a deflated balloon (Figure 4.7B).

- The ventilation rate is determined by how often you squeeze the bag, and the inflation time is determined by how quickly you squeeze and release the bag.
- PIP is controlled by how hard the bag is squeezed and the balance between the amount of gas flowing into the bag and the gas escaping through an adjustable flow-control valve.

- PEEP, CPAP, and free-flow oxygen can be administered with a flow-inflating bag and are adjusted by the balance between the gas flow into the bag and the gas escaping through the flow-control valve.

Similar to a self-inflating bag, a manometer should always be used to accurately measure the gas pressure. If the manometer attachment site is left open, it will cause a large leak and prevent the flow-inflating bag from filling.

Figure 4.7. Flow-inflating bag inflated with compressed gas and a seal against the infant's face (A). If compressed gas is not flowing into the bag or the outlet is not sealed, the bag collapses (B).

Testing a flow-inflating bag during the equipment check and before use

Block the mask or gas outlet with the palm of your hand and squeeze the bag (Figure 4.8).

Figure 4.8. Testing a flow-inflating bag.

Testing a flow-inflating bag

Block the face mask or gas outlet.

- Does the bag fill properly?
- Adjust the flow-control valve so the manometer registers 5 cm H_2O PEEP.

Squeeze the bag 30 to 60 times per minute.

- Does the bag reinflate quickly when you release your grip?
- Adjust the flow-control valve so the manometer registers 30 to 40 cm H_2O when the bag is squeezed firmly.
- Check to be sure that the manometer still registers 5 cm H_2O when the bag is not being squeezed (PEEP).

If the bag does not fill correctly,

- Is there a crack or hole in the bag?
- Is the flow-control valve open too far?
- Is the manometer attached?
- Is the gas tubing connected securely?
- Is the gas outlet sufficiently blocked?

Enhanced Learning

https://bcove.video/4mU7JxF

QR 4.5 Scan here to see a 45-second video about use of the T-piece resuscitator.

T-piece resuscitators

A T-piece resuscitator is a mechanical device that uses valves to regulate the flow of compressed gas directed toward the patient (Figure 4.9). Similar to the flow-inflating bag, the device requires a compressed gas source. A breath is delivered by using a finger to alternately occlude and release a gas escape opening on the top of the T-piece cap. When the opening is occluded, gas is directed through the device and toward the infant. When the opening is released, some gas escapes through the cap. The position and function of control dials on the T-piece resuscitator may vary by manufacturer. The operation of one example is described below.

- The ventilation rate is determined by how often you occlude the opening on the cap, and the inflation time is controlled by how long the opening is occluded.
- Two control dials are used to limit the inflation pressure. The **peak inflation pressure** control limits the peak pressure during each assisted breath. The **maximum pressure-relief control** is a safety feature, similar to the pop-off valve on a self-inflating bag, which prevents the user from increasing the peak inflation pressure beyond a preset value. This control dial may be covered by a removable shield.
- An adjustable dial on the T-piece cap controls how much gas is allowed to escape between breaths and, therefore, adjusts the PEEP and CPAP.
- A built-in manometer measures the inflation and expiratory pressure.

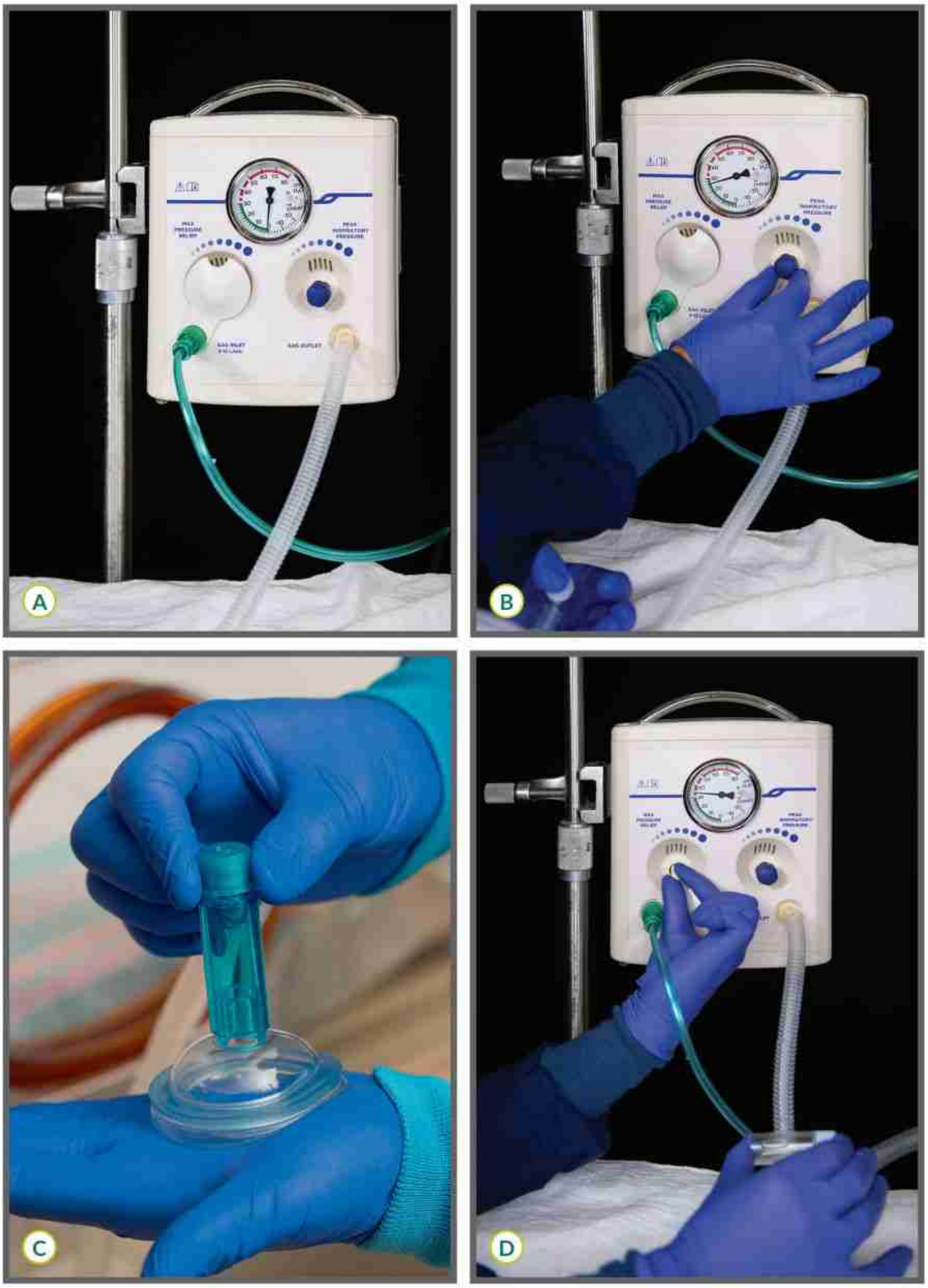


Figure 4.9. An example of a T-piece resuscitator (A). The T-piece resuscitator's pressure is controlled by adjustable valves. PIP is adjusted by a dial on the machine (B) and PEEP is controlled by a dial on the T-piece cap (C). For this example, the maximum pressure-relief valve is adjusted by turning the small white dial on the left side of the device (D).

Enhanced Learning

https://bcove.video/45k3Jk5

QR 4.6 Scan here to see a 1-minute video about how to set up the T-piece resuscitator.

Testing a T-piece resuscitator during the equipment check and before use

Block the face mask or gas outlet with the palm of your hand or the occlusion device provided by the manufacturer. First leave the opening on the T-piece cap open, then occlude the opening with your finger (Figure 4.10).

Testing a T-piece resuscitator	
Block the face mask or T-piece gas outlet with your palm or the provided occlusion device. Do not occlude the opening on the T-piece cap. • Does the manometer register 5 cm H_2O pressure (PEEP)? Occlude the opening on the T-piece cap. • Does the manometer register 25 cm H_2O pressure (PIP)?	If the pressure is not correct, • Is the T-piece gas outlet sealed? • Is the gas tubing connected to the gas inlet? • Is the gas flow set at 10 L/min? • Is the proximal gas outlet tubing disconnected? • Is the maximum circuit pressure, PIP, or PEEP incorrectly set?

Figure 4.10. Testing a T-piece resuscitator. The operator's finger is occluding the T-piece cap.

Indications for assisted ventilation

After completing the initial steps, assisted ventilation is indicated if the newborn infant is not breathing (apneic), *OR* is gasping, *OR* if the heart rate is less than 100 bpm. When indicated, assisted ventilation should be started within 1 minute of birth.

In addition, a trial of ventilation may be considered if the newborn infant is breathing and the heart rate is greater than or equal to 100 bpm, but the oxygen saturation cannot be maintained within the target range despite the use of free-flow supplemental oxygen or CPAP.

Immediately call for help if you are alone. Your assistant(s) will monitor the heart rate response to ventilation, watch for chest movement, monitor the oxygen saturation with pulse oximetry, and document events as they occur.

Enhanced Learning

https://bcove.video/45Ir276

QR 4.7 Scan here to see a 2-minute video about how to administer ventilation.

Preparing to begin ventilation

1. Position yourself at the newborn infant's head.

The person responsible for positioning the airway, holding a resuscitation face mask on the newborn infant's face, or inserting a laryngeal mask is positioned at the infant's head (Figure 4.11). It is difficult to maintain the head, neck, and face mask in the correct position, or insert a laryngeal mask, when standing at the side or foot of the bed. Team members at the side of the bed are better positioned to assess chest movement, listen to heart rate and breath sounds, and assist with pulse oximeter and cardiac monitor placement.

Figure 4.11. Position yourself at the newborn infant's head to provide assisted ventilation.

2. Position the newborn infant's head and neck for ventilation.

The newborn infant's head and neck should be positioned midline and neutral, or slightly extended, in the sniffing position so that the infant's eyes are directed straight upward toward the ceiling (Figure 4.12A). Improper positioning is a common reason for ineffective face mask ventilation. The airway will be obstructed if the neck is excessively flexed or extended. Because the back of a newborn infant's head (occiput) is prominent, it may be helpful to lift the shoulders slightly by placing a small towel or small blanket under the shoulders (Figure 4.12B).

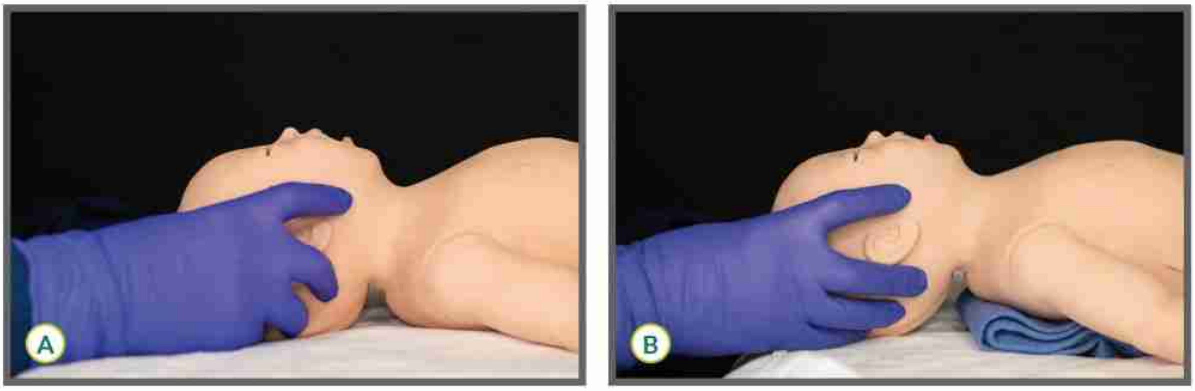


Figure 4.12. The sniffing position (A). A small shoulder roll used to position the head and neck (B).

3. If using a resuscitation face mask, position the mask on the newborn infant's face.

In most cases, ventilation during neonatal resuscitation is initiated with a resuscitation face mask or laryngeal mask. Instructions for selecting and using a resuscitation face mask are described here. Instructions for using a laryngeal mask are described later in this lesson.

Select the correct resuscitation face mask

A variety of resuscitation face mask sizes should be available at every birth. Neonatal face masks have a cushioned or soft pliable rim and come in 2 shapes—anatomic and round (Figure 4.13). Anatomically shaped masks are placed with the pointed part of the mask over the newborn infant's nose. The mask should rest on the chin and cover the mouth and nose, but not the eyes. The correct mask will create a tight seal on the face. If the rim of a cushioned mask is improperly inflated, it may be difficult to achieve a good seal.

Figure 4.13. Correctly sized anatomic (A) and round (B) resuscitation face masks.

Place the mask on the newborn infant's face

An airtight seal between the rim of the mask and the face is necessary to achieve the pressure that will inflate the lungs. Ventilation will not be successful if there is a large air leak from an improperly placed face mask.

One-hand hold

- Begin by cupping the infant's chin in the bottom of an anatomic face mask and then bring the mask over the mouth and nose (Figure 4.14).
- The bottom of the mask should rest on the infant's chin, not below it. The tip of the mask should rest at or just below the nasal bridge to avoid putting pressure on the eyes or causing a large leak around the eyes.
- Hold the mask on the face with the thumb and index finger encircling the rim.
- Place the other 3 fingers under the bony angle of the jaw and gently lift the jaw upward toward the mask.
- Once the mask is positioned, an airtight seal can be formed by using even, downward pressure on the rim of the mask while holding the infant's head in the sniffing position (Figure 4.15).

Some round face masks are designed to be placed directly over the nose and mouth and held in place by the stem rather than the rim (Figure 4.16). These masks have a thin membrane that creates a seal on the infant's face without the use of an inflated rim. If you apply pressure to the rim of this type of mask, the mask will be deformed and will leak.

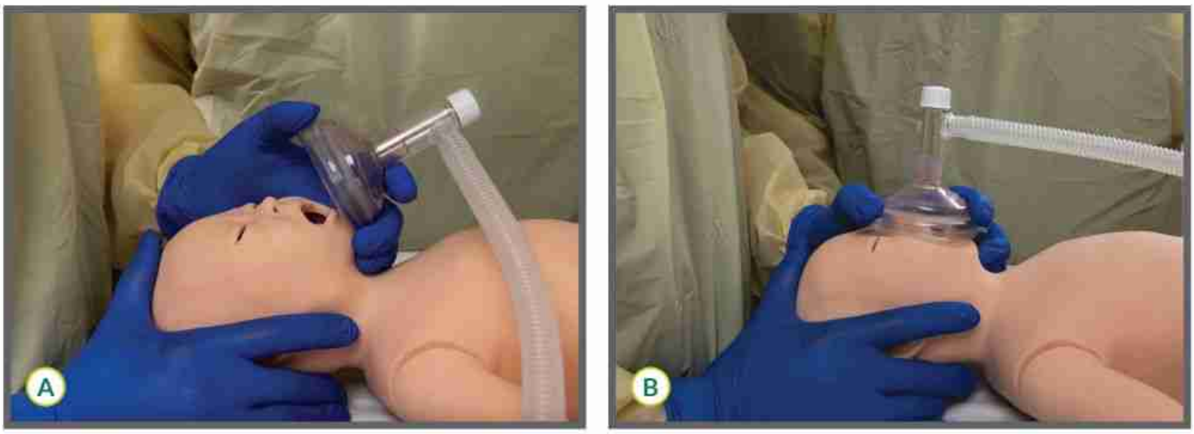


Figure 4.14. Cup the chin in the anatomic face mask (A). Bring the mask over the mouth and nose (B).

Figure 4.15. Maintaining a seal with the 1-hand hold using an anatomic mask.

Figure 4.16. Maintaining a seal with the 1-hand hold using the stem of a round mask without an inflatable rim.

Two-hand hold with jaw thrust

It can be difficult to maintain a good seal and the correct head position with 1 hand. If you cannot achieve a good seal, use both hands to hold the face mask and lift the jaw.

- Use the thumb and first finger of both hands to hold the mask against the newborn infant's face.
- Place the other 3 fingers of each hand under the bony angle of the jaw and gently lift the jaw upward toward the mask (Figure 4.17A).

- While you concentrate on making a good seal and maintaining the correct midline head position, another team member stands at the infant's side and squeezes the bag or occludes the T-piece cap (Figure 4.17B) while a third person monitors the infant's response.

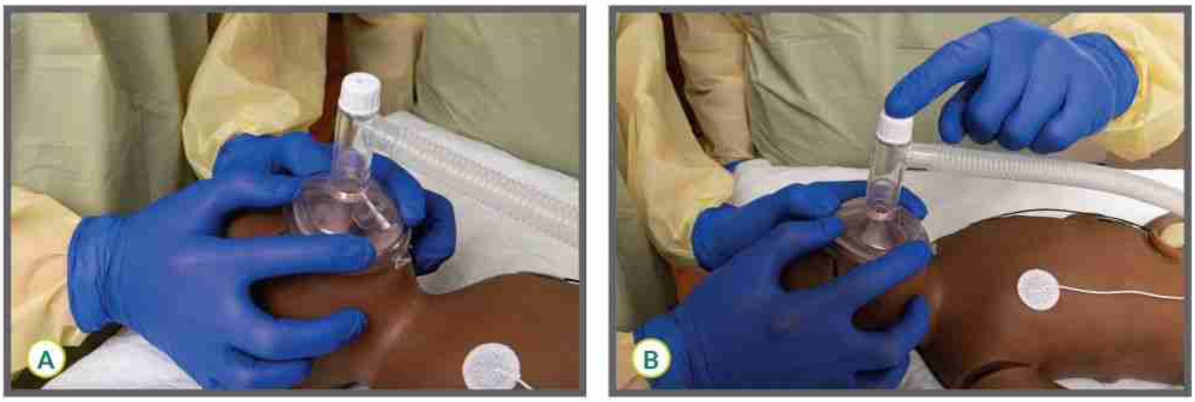


Figure 4.17. Two-hand hold with jaw thrust (A). An assistant delivers the breath (B).

Precautions

Care must be taken when holding the face mask.

- Do not attempt to resolve mask leak by applying excessive downward force on the mask. Too much pressure can obstruct the mask, cause air to leak around the side of the mask, inadvertently flex the neck, or injure the eyes and face.
- Be careful not to rest your hand on the infant's eyes.
- Be careful not to compress the soft tissue of the neck.
- Recheck the position of the mask, head, and neck at intervals to make sure they are still correctly positioned.

Assisting ventilation

When providing assisted ventilation, you will select an initial oxygen concentration (F_{IO_2}), ventilation rate, PIP, and PEEP.

Oxygen concentration

Before birth, the fetus has a blood oxygen saturation of approximately 60%. After birth, the oxygen saturation gradually increases to above 90%. However, even healthy term newborn infants may take 10 minutes or longer to reach this saturation.

Although the ideal oxygen saturation during the transition to extrauterine life is not known, to balance the hazards possibly associated with extremes of oxygenation, this program recommends attempting to maintain a pre-ductal oxygen saturation close to the saturation measured in healthy infants born at term. Among preterm newborn infants with a gestational age of less than 32 weeks, emerging evidence suggests that it is important to achieve an oxygen saturation of 80% to 85% by 5 minutes. To achieve this target, very preterm newborn infants may require a higher initial oxygen concentration or more rapid titration. Ongoing research may inform future recommendations.

Select the initial FIO_2 and use the oxygen blender to increase or decrease the FIO_2 based on the oxygen saturation measured with a pulse oximeter. The suggested initial FIO_2 varies by gestational age.

- **For newborn infants with a gestational age of 35 weeks or greater, set the initial FIO_2 to 21%.**
- **For newborn infants with a gestational age of 32 to 34 weeks, set the initial FIO_2 to 21% to 30%.**
- **For newborn infants with a gestational age of less than 32 weeks, an initial FIO_2 greater than or equal to 30% may be considered.**

Set the flowmeter to 10 L/minute (Figure 4.18).

An assistant should place a pulse oximeter sensor on the right hand or wrist as soon as possible after ventilation is started. Once the pulse oximeter is reading reliably, compare the newborn infant's pre-ductal oxygen saturation with the range of target values summarized in Table 4-1 and use the blender to increase or decrease the FIO_2 as needed. There is insufficient evidence to recommend a specific approach to adjusting the FIO_2. A reasonable approach is to adjust the FIO_2 in increments of 20% to 30% every 30 seconds until the oxygen saturation target is achieved.

Figure 4.18. Flowmeter set to 10 L/minute. Adjust blender to desired FIO_2.

Table 4-1. Target Pre-Ductal Oxygen Saturation

Target Oxygen Saturation Table	
2 minutes	65%-70%
3 minutes	70%-75%
4 minutes	75%-80%
5 minutes	80%-85%
10 minutes	85%-95%

Ventilation rate

Breaths should be given at a rate of **30 to 60 breaths per minute**.

- Count out loud to help maintain the correct rate.
- Use the rhythm, "**Breathe,** two, three; **breathe,** two, three; **breathe,** two, three."
- Say "Breathe" as you squeeze the bag or occlude the T-piece cap and release while you say "two, three."

Peak inflation pressure (PIP)

After birth, fetal lung fluid within the alveoli must be replaced with air for gas exchange to occur. If the newborn infant has not taken a spontaneous breath, the first few assisted breaths may require higher than usual pressure to move fluid out of the air spaces and inflate the alveoli. However, excessively high lung volumes and airway pressures can cause lung injury. The goal is to use just enough pressure to inflate and aerate the lungs so that the heart rate and oxygen saturation increase.

- **The suggested initial PIP is 25 cm H_2O.**
  - An acceptable range for initiating ventilation in newborn infants with a gestational age of ≥ **32 weeks is a PIP of 25 to 30 cm H_2O.**
  - An acceptable range for initiating ventilation in newborn infants with a gestational age of < **32 weeks is a PIP of 20 to 25 cm H_2O.**
- Newborn infants may require a higher inflation pressure for the first few breaths to inflate their lungs. After the initial inflating breaths, you may be able to decrease the inflation pressure.
- Once you inflate the lungs, you should see a gentle rise and fall of the chest with each breath. If you observe what appear to be deep breaths during ventilation, you may be using too much pressure and the lungs may become overinflated. This increases the risk of producing an air leak within the lung (pneumothorax).
- If the infant is preterm, visual assessment of chest movement may be less reliable and there may be a greater risk of injury from overinflation. In preterm infants, it is possible to achieve successful ventilation without apparent chest movement. Additional details about providing assisted ventilation to preterm newborn infants are included in Lesson 8.

Positive end-expiratory pressure (PEEP)

Administering PEEP with the initial inflating breaths helps to achieve stable lung inflation more quickly, remove fluid, and prevent the air spaces from collapsing during exhalation.

- **When PEEP is used, the suggested initial setting is 5 cm H_2O.**

The initial settings used to administer ventilation are summarized in Table 4-2.

Table 4-2. Initial Settings for Ventilation

Oxygen concentration (FIO_2)	≥ 35 weeks' gestation = 21% 32-34 weeks' gestation = 21%-30% < 32 weeks' gestation ≥ 30%
Gas flow	10 L/minute
Rate	30-60 breaths/minute
PIP	25 cm H_2O Range: 25-30 cm H_2O ≥ 32 weeks' gestation 20-25 cm H_2O < 32 weeks' gestation
PEEP	5 cm H_2O

Evaluate the newborn infant's response to ventilation

The most important indicator of successful ventilation is a rising heart rate. When you start ventilation, an assistant will monitor the newborn infant's heart rate response. The initial heart rate assessment may be made with a stethoscope. Once ventilation begins, an assistant should apply a pulse oximeter sensor to continuously assess the oxygen saturation and heart rate response. Continuous monitoring with a cardiac monitor may be considered.

- Shortly after starting ventilation, the infant's heart rate should increase. **If the heart rate is increasing, continue ventilation.** You will check the heart rate response after 30 seconds of ventilation.
- **If the infant's heart rate is not increasing, ask your assistant if the chest is moving.**
  - **If the chest is moving,** continue ventilation while you monitor your ventilation technique. You will check the infant's heart rate response after 30 seconds of ventilation.
  - **If the chest is *not* moving,** you may not be ventilating the infant's lungs. Perform the ventilation corrective steps described below until you achieve chest movement with ventilation.

Enhanced Learning

https://bcove.video/3J94Hqw

QR 4.8 Scan here to see a 1-minute video about heart rate assessment during assisted ventilation.

The ventilation corrective steps

The ventilation corrective steps are adjustments you may make if the newborn infant's heart rate is not increasing and the chest is not moving. The most likely reasons for ineffective mask ventilation are leak around the mask, airway obstruction, and insufficient ventilating pressure. Airway obstruction can be due to incorrect head and neck positioning, decreased tone resulting in airway collapse, secretions in the airway, or closed vocal cords (laryngeal adduction). Based on your assessment of the infant and clinical situation, you may choose the steps that are most likely to be helpful and prioritize the order in which you perform them. After performing corrective steps, attempt ventilation and reassess the chest movement.

You may use the **MR SOPA** mnemonic to remember the 6 corrective steps (Table 4-3).

- **M**ask adjustment.
- **R**eposition the head and neck.
- **S**uction the mouth and nose.
- **O**pen the mouth.
- **P**ressure increase.
- **A**lternative airway.

Enhanced Learning

https://bcove.video/41yRYnc

QR 4.9 Scan here to see a 3-minute video of the MR SOPA steps.

Figure 4.19. Inadequate mask seal on the face may result in ineffective ventilation. Air leaks between the cheek and bridge of the nose are common.

Table 4-3. The MR SOPA Ventilation Corrective Steps

	Corrective Step	Actions
M	Mask adjustment.	Reapply the mask and lift the jaw forward. Consider the 2-hand hold.
R	Reposition the head and neck.	Place head neutral or slightly extended.
S	Suction the mouth and nose.	Use a bulb syringe.
O	Open the mouth.	Use a finger to gently open the mouth.
P	Pressure increase.	Increase in 5-cm H_2O increments until you achieve chest movement. Maximum recommended pressure is 40 cm H_2O term, 30 cm H_2O preterm.
A	Alternative airway.	Insert a laryngeal mask or an endotracheal tube.

Mask adjustment

Adjust the face mask position to create a better seal. Indicators of a good seal include achieving the desired PIP, maintaining the desired PEEP, and rapid reinflation of a flow-inflating bag between breaths.

- If a leak is present, lift the infant's jaw upward into the mask. You may need to use a little more pressure on the rim of an anatomic mask. Do not press the mask down hard on the infant's face.
- The most common place for a leak to occur is between the infant's cheek and bridge of the nose (Figure 4.19). If you continue to have difficulty achieving a tight seal, use the **2-hand hold** described previously.

Reposition the head and neck

The airway may be obstructed because the neck is flexed too far forward or is overextended. Reposition the infant's head and neck to ensure that they are neutral or slightly extended (the sniffing position).

Suction the mouth and nose

The airway may be blocked by thick secretions. Suction the mouth and nose with a bulb syringe. In unusual situations, thick secretions may be blocking the trachea, and tracheal intubation for suction may be required.

Open the mouth

Opening the infant's mouth may decrease the resistance to airflow. Use your finger to open the infant's mouth and reapply the mask.

Pressure increase

Although you have an adequate seal and an open airway, inflating the infant's lungs may require a higher inflation pressure.

- Use the manometer to guide adjustments of the inflation pressure. **Increase the pressure by 5-cm H_2O increments until you achieve chest movement.**
- The maximum recommended pressure with face mask ventilation is **40 cm H_2O for a term newborn infant and 30 cm H_2O for a preterm newborn infant**.

Alternative airway

Mask ventilation is not always sufficient to inflate the lungs. If you have completed the first 5 corrective steps and you still cannot achieve chest movement, you should insert an alternative airway such as a laryngeal mask or an endotracheal tube. Once an alternative airway is inserted, begin ventilation and evaluate the infant's chest movement. Instructions for inserting a laryngeal mask are included in this lesson. Endotracheal intubation is addressed in Lesson 5.

Using a carbon dioxide detector to help assess the effectiveness of ventilation

Using a carbon dioxide (CO_2) detector during the ventilation corrective steps can provide a visual cue that helps you and your team identify when you have achieved ventilation that inflates and aerates the newborn infant's lungs. You may use either a colorimetric CO_2 detector, which changes color when CO_2 is detected, or a capnometer that continuously measures CO_2. Place the CO_2 detector between the ventilation device and mask. If the lungs are being effectively ventilated and gas exchange is occurring, CO_2 should be exhaled through the mask.

If you are effectively ventilating the lungs, you should see a colorimetric CO_2 detector turn yellow during each exhalation (Figure 4.20).

- If the colorimetric CO_2 detector is purple or blue and turns yellow after a corrective step, the step was effective and the infant's heart rate will likely improve quickly.
  - If the CO_2 detector does not turn yellow, your mask ventilation attempts may not be ventilating the lungs.
  - If the detector remains purple or blue after the first 5 corrective steps and the heart rate has not improved, it may be another indication that you have not achieved effective ventilation and an alternative airway is needed.
- **Caution:** If the infant's heart rate is very low or the heart is not pumping blood, the detector may not change color because there is insufficient cardiac output to carry CO_2 to the lungs even though you are ventilating the lungs.

Figure 4.20. Colorimetric carbon dioxide detector used with resuscitation face mask during ventilation corrective step. Yellow color on the device, as shown, suggests successful ventilation with gas exchange in the lungs.

Continue ventilation after completing the ventilation corrective steps

Once you achieve chest movement with each assisted breath, announce, *"The chest is moving NOW."* This ensures that your team is aware of your assessment and knows that additional corrective steps are not necessary.

Continue ventilation that moves the chest for 30 seconds while you monitor your ventilation rate, pressure, and the infant's heart rate response.

If you have difficulty maintaining chest movement during this time, repeat the ventilation corrective steps as needed. Insert an alternative airway if you have persistent difficulty maintaining effective ventilation with a resuscitation face mask.

Check the heart rate response after 30 seconds of effective ventilation

After 30 seconds of ventilation that aerates the lungs, as indicated by an increasing heart rate or chest movement, you will check the infant's heart rate response.

- **If the heart rate is 100 bpm or greater:**

  Assisted ventilation has been successful.

  - Continue ventilating at a rate of 30 to 60 breaths per minute.
  - Monitor the infant's chest movement, heart rate, and respiratory effort.
  - Adjust the FIO_2 to meet the target saturation range.
  - When the heart rate is consistently greater than 100 bpm, gradually reduce the ventilation rate and inflation pressure, observe for effective spontaneous respirations, and gently stimulate the infant to breathe.
  - Assisted ventilation may be discontinued when the infant has a heart rate continuously greater than 100 bpm and sustained spontaneous breathing.

- **If the heart rate is at least 60 bpm but less than 100 bpm:**

  If the heart rate is improving, continue to ventilate as long as the infant is showing steady improvement. Monitor your ventilation technique and the infant's response. Adjust the F_{IO_2} as needed to meet the target oxygen saturation range shown in Table 4-1.

  If the heart rate is not improving, consider each of the following:

  - Quickly reassess your ventilation technique. Is the chest moving? Are you ventilating at a rate of 30 to 60 breaths/minute? Do you hear breath sounds? If necessary, perform the ventilation corrective steps.
  - Adjust the F_{IO_2} to meet the target saturation.
  - If not already done, consider placing cardiac monitor leads for continuous monitoring.
  - If not already done, consider inserting a laryngeal mask or an endotracheal tube to improve the effectiveness of ventilation.
  - If available, call for additional expertise to help resolve this situation.

- **If the heart rate is less than 60 bpm:**

  This uncommon situation occurs when the heart cannot respond to ventilation alone and requires additional support to bring oxygenated blood to the coronary arteries.

  Consider each of the following:

  - Quickly reassess your ventilation technique. Is the chest moving? Are you ventilating at a rate of 30 to 60 breaths/minute? Do you hear breath sounds? If necessary, perform the ventilation corrective steps.
  - If the pulse oximeter has a reliable signal, adjust the F_{IO_2} to meet the target saturation.
  - If not already done, place cardiac monitor leads and begin continuous monitoring.
  - If not already done, insert a laryngeal mask or an endotracheal tube to improve the effectiveness of ventilation.
  - If available, call for additional expertise to help resolve this situation.
  - **If the infant's heart rate remains less than 60 bpm after at least 30 seconds of ventilation that moves the chest, preferably through a laryngeal mask or an endotracheal tube, increase the F_{IO_2} to 100% and begin chest compressions as described in Lesson 6.**

Laryngeal masks

A laryngeal mask is a small mask attached to an airway tube (Figure 4.21). The mask is inserted into the infant's mouth and advanced into the throat until it makes a seal over the entrance to the infant's trachea (the glottis) (Figure 4.22). The laryngeal mask makes a better seal than a mask applied to the infant's face and may improve the effectiveness of ventilation. It may be used as the initial ventilation device instead of a resuscitation face mask or it may be used as an alternative to endotracheal intubation.

Enhanced Learning

https://bcove.video/45pvyG7

QR 4.10 Scan here to see a 20-second video about using the CO_2 detector on the ventilation device.

Figure 4.21. Examples of neonatal laryngeal masks.

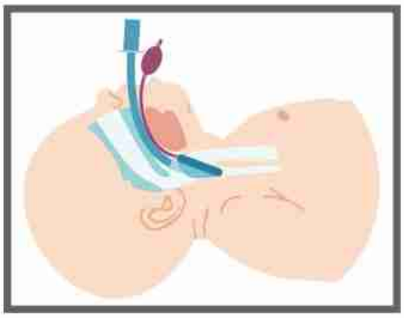


Figure 4.22. Laryngeal mask forming a seal over the glottis.

Unlike endotracheal intubation, no instruments are required to insert a laryngeal mask, and you do not need to visualize the infant's vocal cords during insertion. If the infant cannot be successfully ventilated with a face mask and intubation is unfeasible or unsuccessful, a laryngeal mask may provide a successful rescue airway.

Several variations are available, including devices with an inflatable mask, a soft-gel mask that does not require inflation, a pre-curved airway tube, and a port for a gastric drainage tube. The dimensions of the mask and airway tube may vary between designs and device manufacturers. There is no industry standard for designating the device size. At the present time, devices designated as size 0 to size 1 may be appropriate for newborn infants. The use of a laryngeal mask in extremely preterm newborn infants is limited because even the smallest available laryngeal mask may be too large.

To learn more about limitations of the laryngeal mask, see the Frequently Asked Questions section in this lesson on page 81.

Enhanced Learning

https://bcove.video/4mAG04S

QR 4.11 Scan here to see a 2-minute video about inserting the laryngeal mask with no inflatable rim.

Enhanced Learning

https://bcove.video/47n3PIS

QR 4.12 Scan here to see a 2.5-minute video about inserting the laryngeal mask with an inflatable rim.

Laryngeal mask insertion

The following instructions and images apply to one example of a disposable laryngeal mask with a pre-curved airway tube and a soft-gel mask that does not require inflation. It is intended for infants weighing 2 to 5 kg. Insertion instructions vary by manufacturer and device design. You should refer to the manufacturer's instructions for the specific device used at your institution.

1. If not already done, attach cardiac monitor leads for accurate assessment of the infant's heart rate.
2. Using a clean technique, remove the device from the sterile package and protective container. You may place a thin layer of water-based lubricant onto the back and sides of the mask, but this may not be necessary because newborn infants often have sufficient oral secretions to lubricate the device (Figure 4.23).
3. Stand at the infant's head and position the infant in the sniffing position.

Figure 4.23. Open the protective container and remove the device. You may lubricate the back and sides of the device (optional) by applying a small amount of water-soluble lubricant to the inside of the protective container and rubbing the device through the lubricant.

4. Hold the device along the airway tube with the closed bottom of the mask facing the infant's palate and the open portion of the mask facing the infant's chin (Figure 4.24).
5. Open the infant's mouth by using a thumb or finger to press gently downward on the chin.
6. Insert the leading tip of the mask into the infant's mouth between the tongue and palate, with the bottom of the mask pressed against the infant's palate (Figure 4.25).
7. Glide the device downward and backward, following the contour of the palate, with a continuous but gentle push until you feel definitive resistance (Figure 4.26).
8. Holding the tube in place, attach a CO_2 detector and ventilation device (Figure 4.27). Begin ventilation and secure the device in place.

Figure 4.24. Preparing for insertion.

If the laryngeal mask is correctly inserted and you are providing ventilation that inflates the lungs, you should detect exhaled CO_2 within 8 to 10 breaths. You should see chest wall movement and hear equal breath sounds when you listen with a stethoscope. You should not hear a large leak of air coming from the infant's mouth or see a growing bulge in the infant's neck, suggesting the device is improperly seated.

Figure 4.25. Insert the mask into the infant's mouth between the tongue and palate with the closed bottom of the mask pressed against the infant's palate.

Figure 4.26. Advance the device with a continuous gentle push following the contour of the palate.

Figure 4.27. Once inserted, start ventilation and confirm placement with a CO_2 detector.

Removing a laryngeal mask

The laryngeal mask can be removed when the infant establishes effective spontaneous respirations and the device is no longer needed or when an endotracheal tube can be inserted successfully. Infants can breathe spontaneously through the device, and crying and grunting sounds may be audible.

- Suction secretions from the mouth and throat before you remove the device.
- If the device has an inflatable rim, deflate the rim before removal.

Labored breathing or low oxygen saturation

If a newborn infant is breathing spontaneously and has a heart rate of at least 100 bpm but has labored or grunting respirations or low oxygen saturation, continuous positive airway pressure (CPAP) may be considered. **CPAP is *not* appropriate if the infant is apneic or gasping or if the infant's heart rate is less than 100 bpm.**

- CPAP is a technique for maintaining pressure within the lungs of a **spontaneously breathing** infant.
- CPAP keeps the lungs slightly inflated at all times and may be helpful for preterm newborn infants whose lungs are surfactant deficient, causing the alveoli to collapse at the end of each exhalation. When CPAP is provided, the infant does not have to work as hard to inflate the lungs with each breath.
- Using early CPAP for preterm newborn infants may avoid the need for intubation and mechanical ventilation.
- Administering CPAP may increase the chance of developing a pneumothorax (air leak). Providers should be aware of this potential complication and be prepared to address it.

Administering CPAP during the initial stabilization period

Enhanced Learning

https://bcove.video/3UPbqZg

QR 4.13 Scan here to see a 2-minute video about CPAP administration.

CPAP is administered by making a seal between the newborn infant's face and a face mask attached to either a T-piece resuscitator or a flow-inflating bag. CPAP **cannot** be administered with a self-inflating bag even if a PEEP valve has been placed. The desired CPAP is achieved by adjusting the PEEP dial on the cap of the T-piece resuscitator or the flow-control valve on the flow-inflating bag (Figure 4.28).

- Test the amount of CPAP before applying the resuscitation face mask to the infant's face by holding the mask tightly against your hand (or using the manufacturer's occluding device) and reading the pressure on the manometer (pressure gauge).

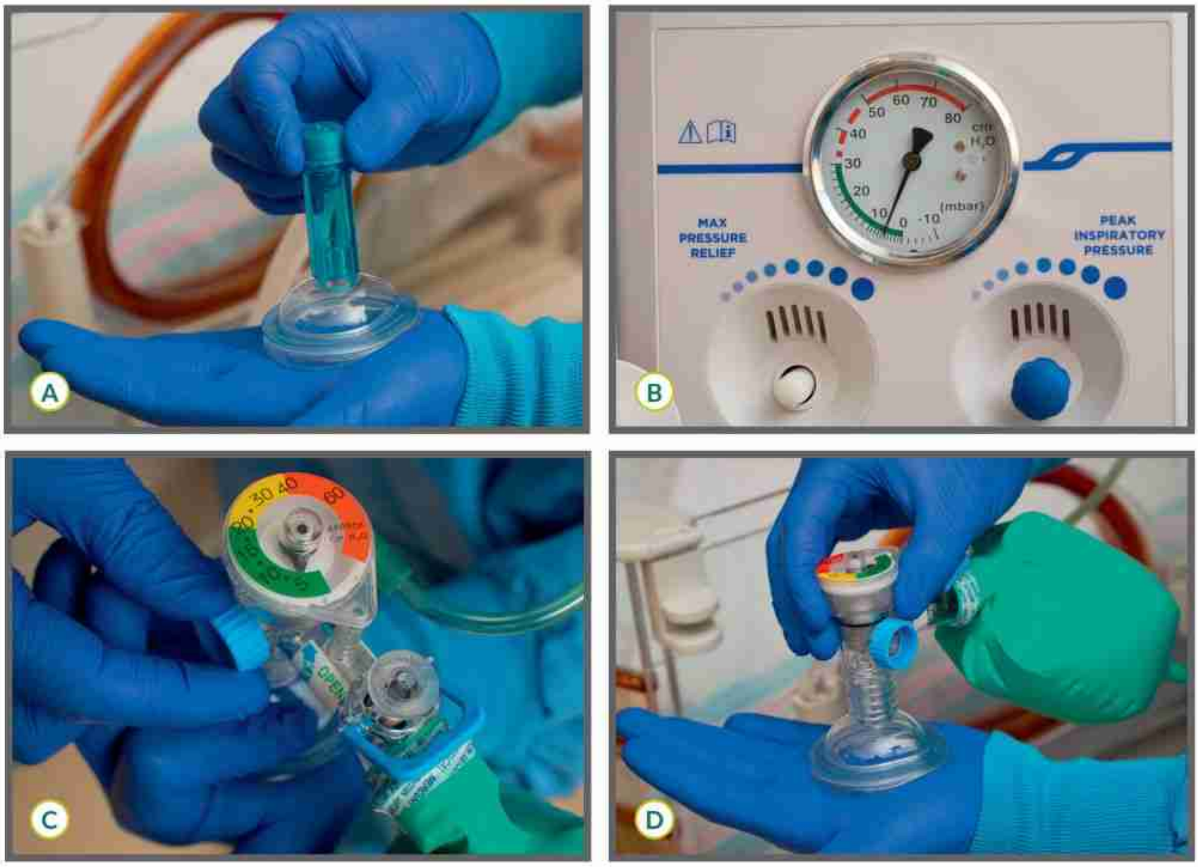


Figure 4.28. Adjust the CPAP pressure by turning the cap on a T-piece resuscitator (A). The resulting CPAP pressure is shown on the manometer (B). Adjust the CPAP pressure using the flow-control valve on a flow-inflating bag (C). The resulting CPAP pressure is shown on the manometer (D). For both, adjust the CPAP pressure before placing the mask on the infant's face.

- Adjust the PEEP cap or the flow-control valve so that the manometer reads 5 to 6 cm H_2O pressure.
- After you have adjusted the CPAP to the desired pressure, place the mask firmly against the infant's face (Figure 4.29) using the 2-hand hold with jaw thrust. Lift the infant's jaw into the mask.
- Check that the pressure displayed on the manometer is still at the desired level. If it is lower, you may not have an airtight seal of the mask on the infant's face.
- You may adjust the CPAP depending on how hard the infant is working to breathe. Do not use more than 8 cm H_2O.
- To apply CPAP, do *not* occlude the T-piece cap or squeeze the flow-inflating bag.
- If the infant cannot maintain a heart rate of at least 100 bpm with spontaneous respirations, you need to start assisted ventilation instead of CPAP.

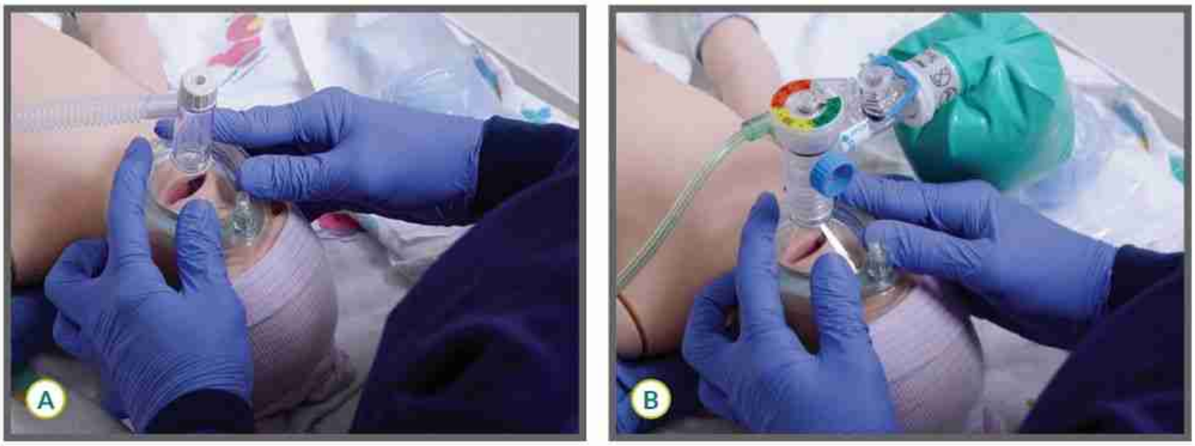


Figure 4.29. Administering face mask CPAP with a T-piece (A) and flow-inflating bag (B). The manometer shows the amount of CPAP administered. An airtight seal must be maintained with the mask.

Figure 4.30. CPAP administered to a preterm newborn infant with a nasal mask.

Enhanced Learning

https://bcove.video/4frVhmd

QR 4.14 Scan here to see a 45-second video about orogastric tube insertion.

If CPAP is administered for a prolonged period, you will use nasal prongs or a nasal mask (Figure 4.30). After the initial stabilization, CPAP can be administered with a bubbling water system, a dedicated CPAP device, or a mechanical ventilator.

Inserting an orogastric tube

When providing ventilation or CPAP with a resuscitation face mask or laryngeal mask, gas enters the esophagus and stomach. Gas may distend the stomach and interfere with ventilation. If a newborn infant requires ventilation or CPAP for longer than several minutes, consider placing an orogastric tube and leaving it uncapped to remove air from the stomach.

Equipment needed

- 8F orogastric tube
- 20-mL syringe
- Tape

Insertion steps

1. Measure the distance from the bridge of the nose to the earlobe and from the earlobe to a point halfway between the xiphoid process (the lower tip of the sternum) and the umbilicus. Note the centimeter mark at this place on the tube (Figure 4.31). To minimize interruption of ventilation, measurement of the orogastric tube can be approximated with the resuscitation mask in place.
2. Insert the tube through the mouth (Figure 4.32A). Ventilation can be resumed as soon as the tube has been inserted. Reassess the mask seal.

3. Once the tube is inserted the desired distance, attach a syringe and remove the gastric contents (Figure 4.32B).
4. Remove the syringe from the tube and leave the end of the tube open to provide a vent for air entering the stomach (Figure 4.32C).
5. Tape the tube to the infant's cheek (Figure 4.32D).

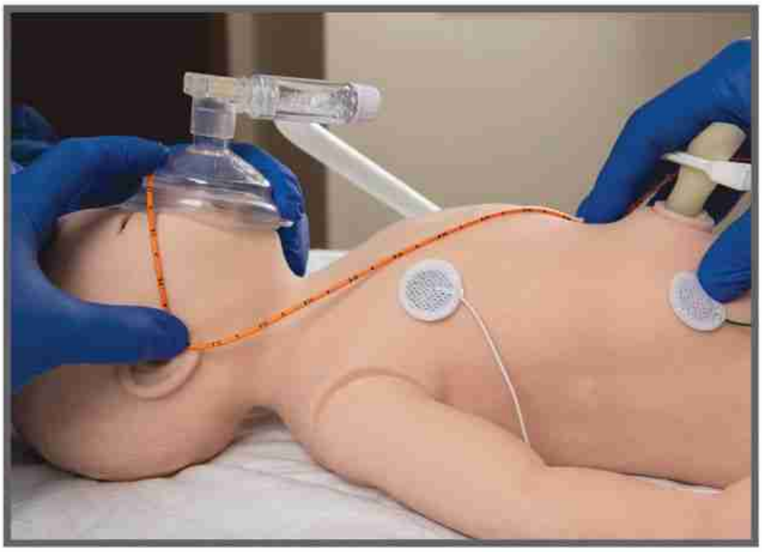


Figure 4.31. Measuring the insertion depth for an orogastric tube. In this example, the tube should be inserted 26 cm.

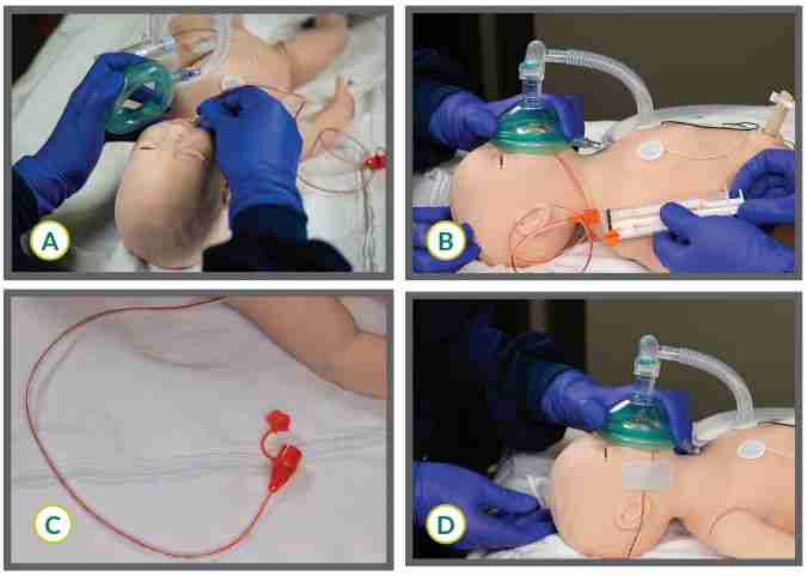


Figure 4.32. Inserting an orogastric tube (A), aspirating the orogastric tube (B), opening the orogastric tube to vent the stomach (C), and securing the orogastric tube with tape (D).

Focus on Teamwork

Providing ventilation highlights several opportunities for effective teams to use the Neonatal Resuscitation Program® (NRP®) Key Behavioral Skills.

Behavior	Example
Anticipate and plan.	Ensure that you have enough personnel present at the time of birth based on the risk factors you identified. During your pre-resuscitation team briefing, determine who provides ventilation, auscultates the heart rate, assesses chest movement, places the pulse oximeter and cardiac monitor, and documents events as they occur. Delegate workload optimally.
Call for additional help when needed.	If ventilation is required, at least 2 or 3 qualified providers are needed to perform all of the tasks quickly. If you have difficulty maintaining a good seal, the 2-hand hold may be needed, which requires a second person to administer the assisted breath and a third person to evaluate the response. You may need to call for additional help if intubation is required.
Communicate effectively.	The individuals providing ventilation and assessing the effectiveness of ventilation must share information and communicate clearly with each other. If the ventilation corrective steps are required, frequent information sharing after each step is crucial. It is important to announce when chest movement has been achieved (*"Chest is moving NOW"*) so that the team knows that the heart rate should be assessed in 30 seconds.
Know your environment. Use available resources.	Know how to operate and troubleshoot your ventilation device. Know how to obtain a laryngeal mask and cardiac monitor.

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own hospital setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. Who provides ventilation in your birth setting?
2. Who monitors the heart rate response during assisted ventilation?
3. Is a cardiac monitor for the newborn infant readily available in your birth setting?
4. How often do providers in your birth setting practice ventilation?
5. Do providers know where to find a laryngeal mask and how to insert it?

Process and outcome measures

- How often is ventilation given in your birth setting?
- How often do newborn infants without any risk factors require ventilation?
- When ventilation is required, how often is a second trained provider present at the time of birth?
- How often are the ventilation corrective steps performed in your birth setting?
- How often are chest compressions performed in your birth setting?
- How often is a complete resuscitation record completed for newborn infants who have received ventilation?

Frequently Asked Questions

Why are the guidelines for initial oxygen concentration different for term and preterm infants? Why are the guidelines for very preterm infants not definitive?

A series of human randomized and quasi-randomized studies over the last 3 decades have suggested that, for term and late-preterm infants, resuscitation with 21% oxygen is at least as effective as resuscitation with 100% oxygen. In meta-analyses of these studies, mortality was decreased among term and late-preterm infants resuscitated with 21% oxygen compared with 100% oxygen. Intermediate initial oxygen concentrations, between 21% and 100%, have not been studied.

In preterm infants, the ideal FIO_2 is less clear. Among preterm newborn infants with a gestational age $<$ 35 weeks, a meta-analysis performed by the International Liaison Committee on Resuscitation (ILCOR) Neonatal Life Support Task Force showed no difference in outcomes between those resuscitated with low oxygen (21%-30%) and those resuscitated with high oxygen (60%-100%). Although no difference was found, the recommendation to start with low FIO_2 reflected a preference to avoid exposing preterm newborn infants to additional oxygen without a clear benefit.

The science related to initial FIO_2 for very preterm infants is evolving. Data suggest that it may be important for newborn infants with a gestational age of $<$ 32 weeks to achieve an oxygen saturation of 80% to 85% by 5 minutes. Starting resuscitation with a higher FIO_2 may increase the chance of reaching that target. A recent meta-analysis using a different method to summarize data suggested that starting with a higher FIO_2 may have important benefits, but the certainty of evidence from this analysis was low. As long as pulse oximetry is used to guide therapy to avoid the extremes of oxygenation, it may be reasonable to initiate ventilation for very preterm infants across a wide range of oxygen concentrations. Additional studies that may inform future recommendations are underway.

What are the advantages and disadvantages of each resuscitation device?

The *self-inflating bag* is often considered easier to use than the other devices and requires little time to set up. It does not require a compressed gas source and can be used in an emergency setting when compressed gas may not be readily available. Because it fully reinflates even without a seal, you will be less likely to know if you have a large leak around the face mask or laryngeal mask. It is difficult to control the inflation time with a self-inflating bag. In addition, a self-inflating bag and face mask **cannot** be used to administer free-flow oxygen or CPAP to an infant.

The *flow-inflating bag* is more complicated to set up than the other devices and takes more practice to use effectively. It requires a compressed gas source and adjustments to find the correct balance between gas inflow and outflow. The advantage is that you will know immediately if you lose gas pressure or have a leak because the bag will deflate. Absent or partial inflation of the bag indicates that a tight seal has not been established or the bag has a leak. An effective face mask or laryngeal mask seal is indicated by observing stable PEEP/CPAP on the manometer. The inflation time can be increased, if needed, by squeezing the bag for a longer period of time. The flow-inflating bag can deliver CPAP, PEEP, and free-flow oxygen.

The *T-piece resuscitator* also requires some preparation time for setup. Similar to the flow-inflating bag, it requires a compressed gas source and an adjustment to the dials controlling the PIP and PEEP. The primary advantage of the T-piece resuscitator is that it provides more consistent pressure with each breath than either the self-inflating or flow-inflating bag. An effective face mask or laryngeal mask seal is indicated by observing stable PEEP/CPAP on the T-piece manometer. In addition, users may not become fatigued because they are not repeatedly squeezing a bag. The inflation time can be increased, if needed, by occluding the hole on the T-piece cap for a longer period of time. The T-piece resuscitator can deliver CPAP, PEEP, and free-flow oxygen.

Can a nurse or respiratory therapist insert a laryngeal mask?

Each health care provider's scope of practice is defined by their state licensing board, and each hospital determines the level of competence and qualifications required for licensed providers to perform clinical skills. Although laryngeal mask insertion is consistent with the general guidelines for nurse and respiratory therapist practice, you must check with your state licensing board and institution.

What are the limitations of a laryngeal mask?

Laryngeal masks have several limitations to consider during neonatal resuscitation.

- The device has not been studied for suctioning secretions from the airway.

- If you need to use high ventilation pressures, air may leak through the seal between the pharynx and the mask, resulting in insufficient pressure to inflate the lungs.
- Few reports describe the use of a laryngeal mask during chest compressions. However, if tracheal intubation is not feasible or is unsuccessful, it is reasonable to attempt compressions with the device in place.
- There is insufficient evidence to recommend using a laryngeal mask to administer emergency intratracheal medications. Intratracheal medications may leak from the mask into the esophagus and not enter the lungs.
- Laryngeal masks may not be successful in very preterm newborn infants. Laryngeal masks for preterm infants weighing less than 2 kg are now available, but the lower weight limit for successful insertion has not been established. Older devices intended for larger infants have been used in many studies of infants who weigh 1.5 to 2.5 kg. Some studies have described using a laryngeal mask successfully in newborn infants who weigh less than 1 kg.

LESSON 4 REVIEW

1. The single most important and most effective step in neonatal resuscitation is (aggressive stimulation)/(ventilation of the lungs).

2. After the initial steps, assisted ventilation is indicated if the infant is ______, OR ________, OR if the heart rate is less than ______ beats per minute (bpm). *(Fill in the blanks.)*

3. A newborn infant is born limp and apneic. You place the infant under a radiant warmer, position the head and neck to open the airway, and gently stimulate. It has been 1 minute since birth and the infant remains apneic. The next step is to (stimulate more)/(begin assisted ventilation).

4. For assisted ventilation, adjust the flowmeter to (5 L/min)/(10 L/min).

5. Administer ventilation at a rate of (10 to 15 breaths per minute)/(30 to 60 breaths per minute).

6. Begin ventilation with an inflation pressure of (25 cm H_2O)/(40 cm H_2O).

7. Ventilation of the term newborn infant begins with (21% oxygen)/(100% oxygen).

8. If you are using a device that administers positive end-expiratory pressure (PEEP), the recommended initial pressure is (5 cm H_2O)/(10 cm H_2O).

9. You have started ventilation for an apneic infant. The heart rate is 40 bpm and is not improving. Your assistant does not see chest movement. You should (start the ventilation corrective steps)/(proceed to chest compressions).

10. Inflation and aeration of the lungs is suggested by a carbon dioxide (CO_2) detector that turns (yellow)/(purple).

11. You have started ventilation for an apneic newborn infant. The heart rate has remained at 40 bpm despite performing all of the ventilation corrective steps and ventilating through an endotracheal tube for 30 seconds. Your assistant observes chest movement with ventilation. You should (increase the ventilation rate to 100 breaths/minute)/(proceed to chest compressions).

12. A laryngeal mask is inserted into the newborn infant's mouth and advanced into the throat until it (passes between the vocal cords)/(makes a seal over the entrance to the trachea).

13. To insert an orogastric tube, measure the distance from the bridge of the nose to the earlobe and from the earlobe (to the nipples)/(to a point halfway between the xiphoid process and the umbilicus).

Answers

1. The single most important and most effective step in neonatal resuscitation is ventilation of the lungs.

2. After the initial steps, assisted ventilation is indicated if the infant is apneic, OR gasping, OR if the heart rate is less than 100 bpm.

3. The next step is to begin assisted ventilation.

4. For ventilation, adjust the flowmeter to 10 L/min.

5. Administer ventilation at a rate of 30 to 60 breaths per minute.

6. Begin ventilation with an inflation pressure of 25 cm H_2O.

7. Ventilation of the term newborn infant begins with 21% oxygen.

8. If you are using a device that administers PEEP, the recommended initial pressure is 5 cm H_2O.

9. You should start the ventilation corrective steps.

10. Inflation and aeration of the lungs is suggested by a CO_2 detector that turns yellow.

11. You should proceed to chest compressions.
12. A laryngeal mask is inserted into the newborn infant's mouth and advanced into the throat until it makes a seal over the entrance to the trachea.
13. Measure the distance from the bridge of the nose to the earlobe and from the earlobe to a point halfway between the xiphoid process and the umbilicus.

Appendix

Read the section(s) that refers to the type of device used in your hospital.

A. Self-inflating resuscitation bag

What are the parts of a self-inflating bag?

There are 8 basic parts to a self-inflating bag (Figure 4A.1).

1. Gas outlet
2. Positive end-expiratory pressure (PEEP) valve (optional)
3. Manometer
4. Pressure-release valve
5. Gas inlet
6. Gas tubing
7. (A) Oxygen reservoir (closed type), (B) Oxygen reservoir (open type)
8. Valve assembly (Figure 4A.2)

The self-inflating bag reexpands after being squeezed and fills with gas from 3 locations. As the bag reinflates, air from the room is drawn in from openings in the back of the bag. Gas from the blender and flowmeter travels through *gas tubing* and enters the bag at the *gas inlet*. Gas from the blender collects in the *oxygen reservoir* and provides a third source for gas to fill the bag. Oxygen tubing does not need to be attached for the bag to provide ventilation with 21% oxygen. Oxygen tubing must be attached to a compressed gas source to deliver more than 21% oxygen. The *gas outlet* is where gas exits from the bag to the infant and where a resuscitation mask, a laryngeal mask, or an endotracheal tube is attached.

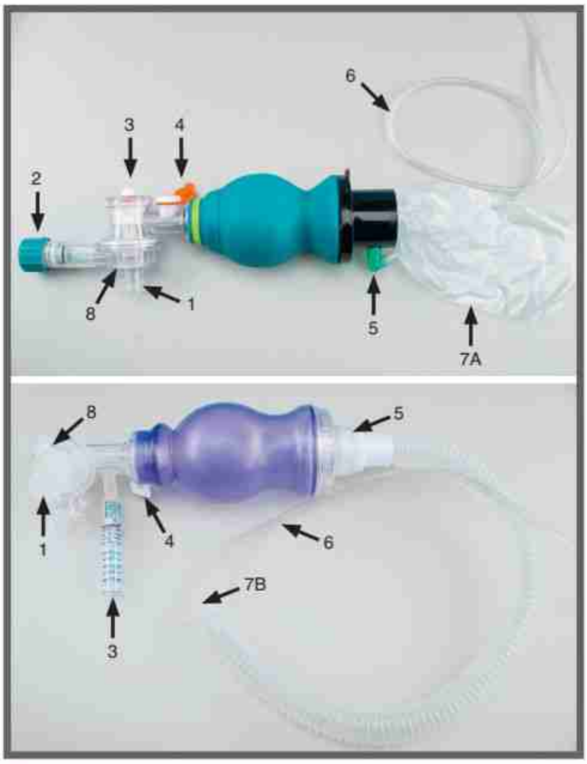


Figure 4A.1. Self-Inflating bags with a closed (7A) and open (7B) reservoir.

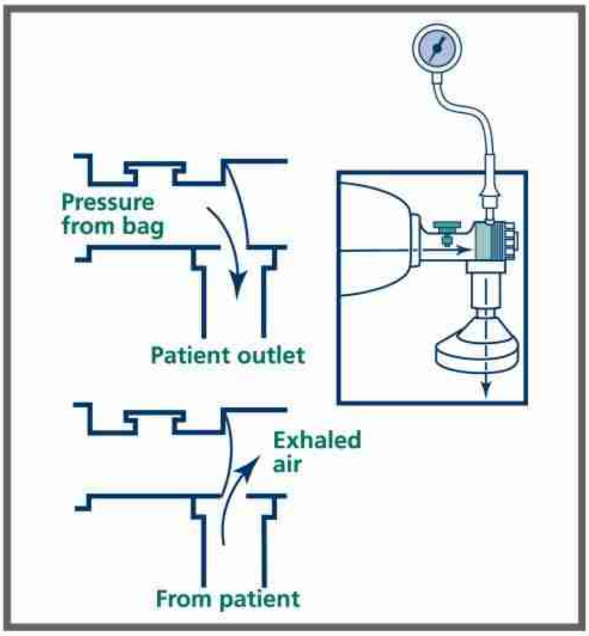


Figure 4A.2. Valve assembly within a self-inflating bag.

A *manometer* (pressure gauge) measures the inflating pressure used during assisted ventilation. Some bags have a built-in manometer and others need to have one attached. The attachment site is usually close to the patient outlet. If the manometer attachment site is left open, without a manometer attached, air will leak out and prevent you from achieving inflation pressure. Do not attach the oxygen inflow tubing to the manometer attachment site. This could generate undesired high pressure. Most self-inflating bags also have a *pressure-release (pop-off) valve.* These valves are usually set to release at 30 to 40 cm H_2O pressure, but they are not reliable and may not release until higher pressures are achieved.

Self-inflating bags have a *valve assembly* positioned between the bag and the patient outlet (Figure 4A.2). When the bag is squeezed during ventilation, the valve opens and directs gas to the patient. When the bag reinflates, the valve is closed. This prevents the patient's exhaled air from entering the bag and being rebreathed. Some self-inflating bags also have an adjustable *PEEP valve.*

Why is an oxygen reservoir used on a self-inflating bag?

An oxygen reservoir is an appliance that can be placed over the bag's air inlet. Gas from the blender collects in the reservoir. At very low flow rates, the reservoir prevents blended gas from being diluted with room air. Several different types of oxygen reservoirs are available, but they all perform the same function. Some have open ends ("tails") and others look like a bag covering the air inlet.

B. Flow-inflating resuscitation bag

What are the parts of a flow-inflating bag?

There are 6 parts to a flow-inflating bag (Figure 4A.3).

1. Gas outlet
2. Manometer
3. Gas inlet
4. Pressure-release valve (optional)
5. Gas tubing
6. Flow-control valve

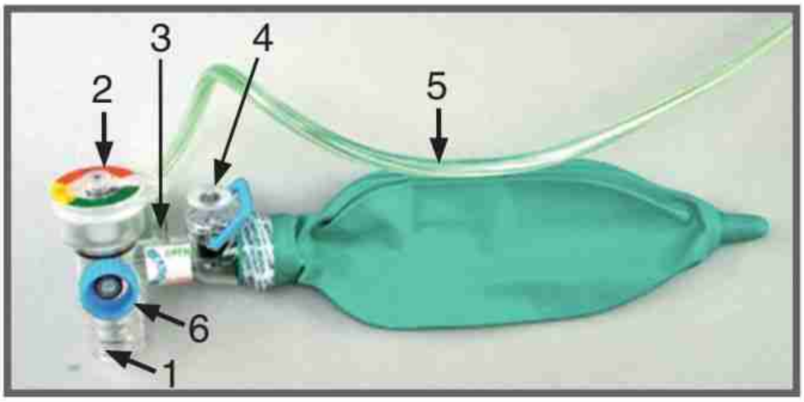


Figure 4A.3. Parts of a flow-inflating bag.

Compressed gas from the blender and flowmeter enters the bag through oxygen tubing attached to the *gas inlet*. The *gas outlet* is where gas exits from the bag to the infant and where a resuscitation mask, a laryngeal mask, or an endotracheal tube is attached. Even if you plan to use 21% oxygen for ventilation, you must have a compressed gas source to fill the flow-inflating bag.

The *flow-control valve* provides an adjustable leak that allows you to regulate the pressure in the bag. The adjustable leak allows excess gas to escape rather than overinflate the bag or be forced into the patient. The flow-control valve adjusts both the peak inflation pressure (PIP) and the PEEP.

Flow-inflating bags have a site for attaching a *manometer*. The attachment site usually is close to the patient outlet. A manometer must be attached or the site will be a source of leak and the bag will not inflate properly. A *pressure release (pop-off) valve* may also be present.

How does a flow-inflating bag work?

For a flow-inflating bag to work properly, there must be adequate gas flow from the source and a sealed system. The bag inflation is controlled by the balance between gas entering the bag, gas exiting the adjustable flow-control valve, and gas exiting the gas outlet. A flow-inflating bag will not inflate adequately if the mask is not properly sealed; if flow from the gas source is insufficient, disconnected, or occluded; if there is a hole in the bag; if the flow-control valve is open too far; or if the manometer attachment site has been left open (Figure 4A.4).

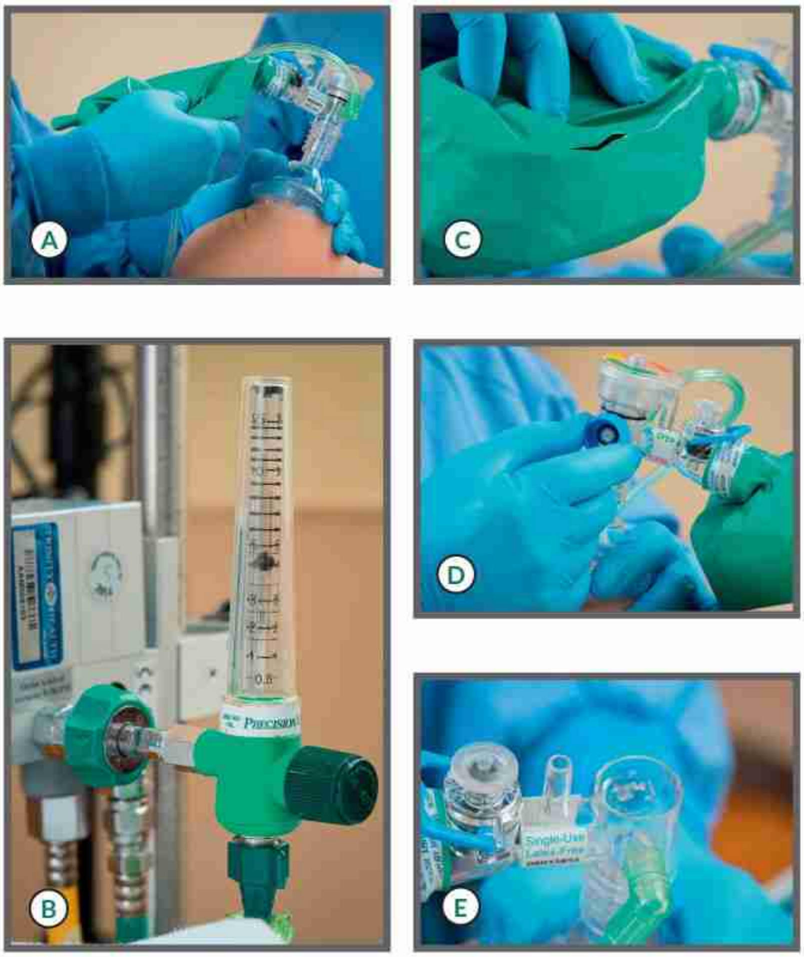


Figure 4A.4. Reasons for insufficient inflation of a flow-inflating bag: (A) inadequate mask seal with leak, (B) insufficient gas inflow, (C) hole in bag, (D) flow-control valve open too far, (E) manometer attachment site open.

How do you adjust the inflation of a flow-inflating bag?

There are 2 ways that you can adjust the pressure in the bag and thus the amount of inflation of the bag.

- By adjusting the incoming gas from the flowmeter, you regulate how much gas enters the bag.
- By adjusting the flow-control valve on the bag, you regulate how much gas escapes from the bag.

The flowmeter and flow-control valve should be set so that the bag is inflated to the point where it is comfortable to handle and does not completely deflate with each assisted breath (Figure 4A.5A). An

Figure 4A.5. Correct flow-inflating bag inflation (A), overinflation (B), and underinflation (C).

overinflated bag (Figure 4A.5B) is difficult to manage and may deliver high pressure to the infant; a pneumothorax or other air leak may develop. An underinflated bag (Figure 4A.5C) makes it difficult to achieve the desired inflation pressure. With practice, you will be able to make the necessary adjustments to achieve a balance. If there is a good seal between the infant's face and the mask, you should be able to maintain the appropriate amount of inflation with the flowmeter set at 8 to 10 L/min.

C. T-piece resuscitator

What are the parts of a T-piece resuscitator?

There are 9 parts to a T-piece resuscitator (Figure 4A.6). The position and function of control dials on the T-piece resuscitator may vary by manufacturer. The parts and operation of one example are described below.

1. Gas tubing
2. Gas inlet
3. Maximum pressure-relief control
4. Manometer
5. Inflation pressure control
6. Gas outlet (proximal)
7. T-piece gas outlet (patient)
8. T-piece PEEP adjustment dial
9. Opening on T-piece cap

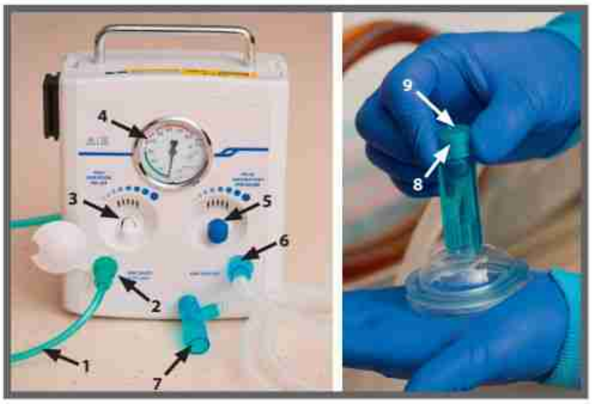


Figure 4A.6. Parts of a T-piece resuscitator.

How does a T-piece resuscitator work?

Gas from a compressed source enters the T-piece resuscitator through *gas tubing* at the *gas inlet*. Gas exits the control box from the *gas outlet (proximal)* and travels through corrugated tubing to the *T-piece gas outlet (patient)*, where a resuscitation mask, a laryngeal mask, or an endotracheal tube attaches. When the *opening on the T-piece cap* is occluded by the operator, the preset inflation pressure is delivered to the patient for as long as the T-piece opening is occluded. On the device in Figure 4A.6, the maximum pressure that can be used is regulated by the *maximum pressure-relief control* valve. PEEP is adjusted using a dial on the T-piece cap.

How do you prepare the T-piece resuscitator for use?

Assemble the parts of the T-piece resuscitator as instructed by the manufacturer. Occlude the patient outlet (using a test lung, outlet-occluding cap, or palm). Connect the device to the compressed gas source using gas tubing.

Adjust the pressure settings as follows:

- Adjust the blended gas flowmeter on the wall to regulate how much gas flows into the T-piece resuscitator. In most cases, **10 L/min is appropriate**.
- Set the *maximum pressure-relief control* by occluding the T-piece cap with your finger and adjusting the maximum pressure-relief dial to a selected value (40 cm H_2O is the recommended maximum for term infants, 30 cm H_2O is the recommended maximum for preterm infants). Some manufacturers recommend that the maximum relief control be adjusted to an institution-defined limit when the device is put into original service and not be readjusted during regular use.
- Set the desired PIP by occluding the T-piece cap with your finger and adjusting the *inflation pressure control* to the selected pressure (Figure 4A.7).
- Set the PEEP by removing your finger from the T-piece cap and adjusting the dial on the cap to the desired setting (5 cm H_2O is recommended) (Figure 4A.8).

Figure 4A.7. Adjusting the peak inflation pressure (PIP).

Figure 4A.8. Adjusting the positive end-expiratory pressure (PEEP).

When the device is used to ventilate the infant, either by applying the mask to the infant's face or by connecting the device to a laryngeal mask or an endotracheal tube, you administer a breath by alternately covering and releasing the opening on the T-piece cap. The inflation time is controlled by how long your finger covers the opening. Be careful not to become distracted and inadvertently cover the opening on the T-piece cap with your finger for a prolonged time.

How do you adjust the concentration of oxygen in a T-piece resuscitator?

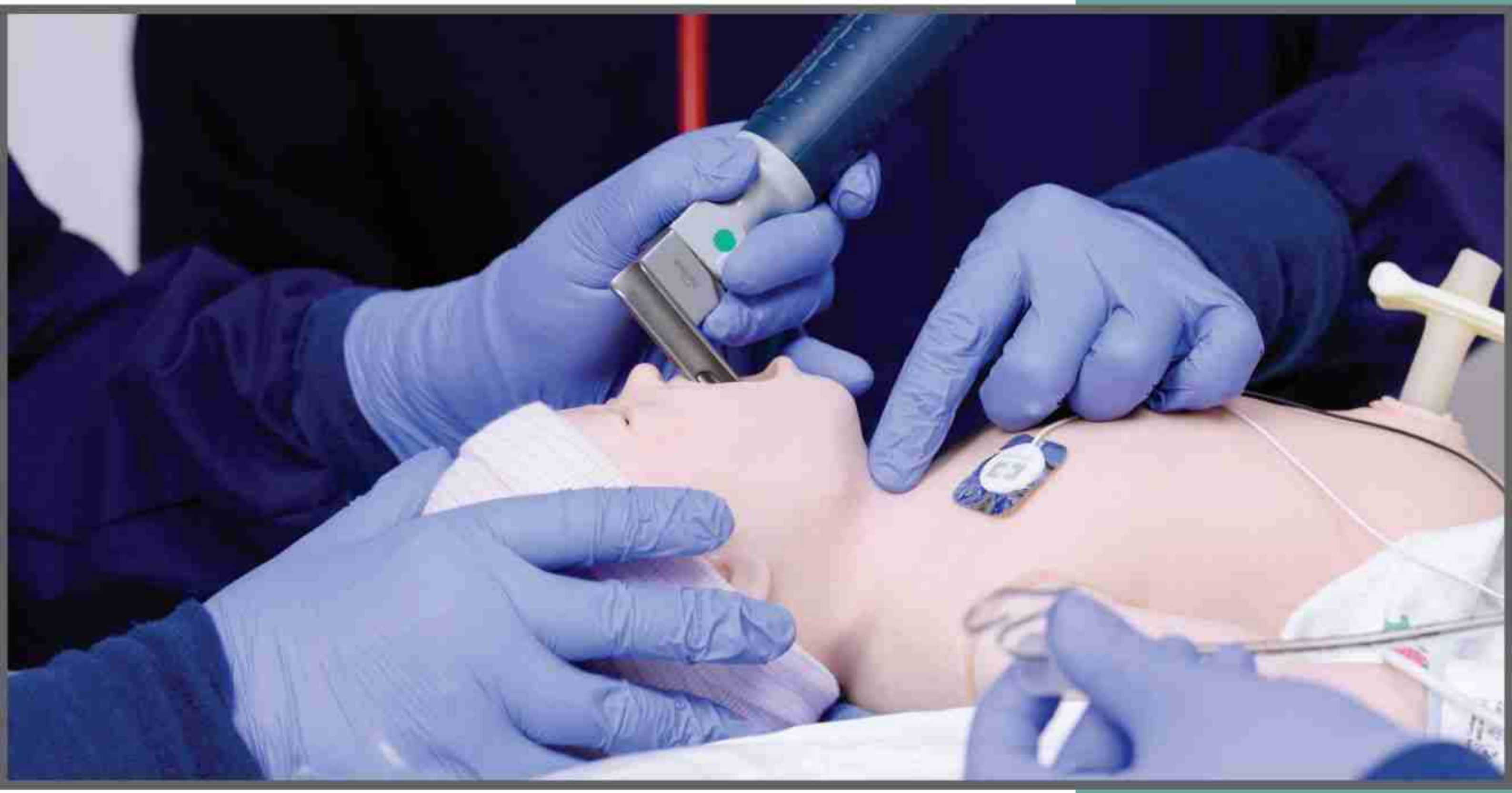
The concentration of oxygen delivered by the T-piece resuscitator is controlled by the oxygen blender.

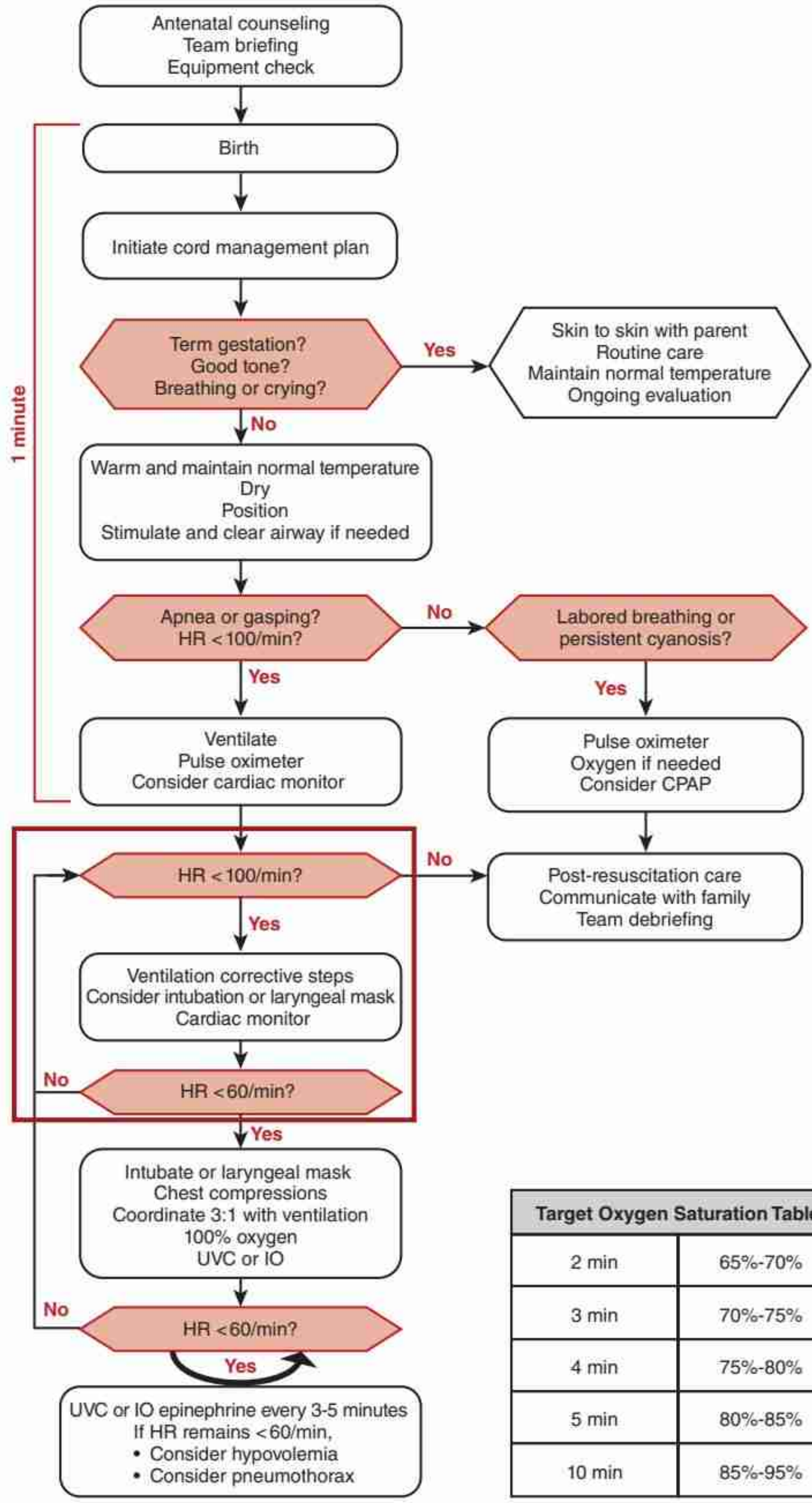
Lesson 5

Endotracheal Intubation

What you will learn

- The indications for endotracheal intubation during resuscitation
- How to select and prepare the equipment for endotracheal intubation
- How to assist with endotracheal intubation
- How to use a laryngoscope to insert an endotracheal tube
- How to determine if the endotracheal tube is in the trachea
- How to use an endotracheal tube to suction thick secretions from the trachea





Target Oxygen Saturation Table	
2 min	65%-70%
3 min	70%-75%
4 min	75%-80%
5 min	80%-85%
10 min	85%-95%

Key Points

1. Insertion of an endotracheal tube (intubation) is strongly recommended if the newborn infant's heart rate remains less than 100 beats per minute and is not increasing after optimizing ventilation with a resuscitation face mask or laryngeal mask.

2. Insertion of an endotracheal tube is strongly recommended before starting chest compressions. If intubation is not successful or feasible, it is reasonable to use a correctly inserted laryngeal mask that achieves chest movement with ventilation during chest compressions.

3. An endotracheal tube should be inserted for direct tracheal suction if obstruction with thick secretions is suspected and for stabilization of a newborn infant who has certain congenital anomalies such as a suspected diaphragmatic hernia. An endotracheal tube may also be used for surfactant administration.

4. If ventilation is prolonged, insertion of an endotracheal tube may be considered to improve the efficacy and ease of assisted ventilation.

5. A person with intubation skills should be available to be called for immediate assistance if needed. If the need for intubation is anticipated, this person should be present at the time of birth. It is not sufficient to have someone on call at home or in a remote area of the hospital.

6. The appropriate straight Miller laryngoscope blade for a term newborn infant is size No. 1. The correct blade for a preterm infant is size No. 0 (size No. 00 *optional* for an extremely preterm infant).

7. Once started, the intubation procedure ideally should be completed within approximately 30 seconds. Effective teamwork is required to perform this procedure quickly.

8. Demonstrating exhaled carbon dioxide and observing a rapidly increasing heart rate are the primary methods of confirming endotracheal tube insertion within the trachea.

9. Endotracheal tube insertion depth can be estimated using the nasal-tragus length or the newborn infant's gestational age; however, the depth estimate should be confirmed by auscultating equal breath sounds. If the tube is to remain in place, obtain a chest radiograph for final confirmation.

10. If ventilation with a correctly inserted endotracheal tube does not result in chest movement, suspect airway obstruction and suction the trachea with a suction catheter or tracheal aspirator.

11 If a newborn infant's condition worsens after endotracheal intubation, the tube may have become displaced or obstructed, or there may be a pneumothorax or ventilation equipment failure (**DOPE** mnemonic).

12 Avoid repeated unsuccessful attempts at endotracheal intubation. A laryngeal mask may provide a rescue airway when ventilation with a face mask fails to achieve effective ventilation and intubation is unsuccessful or not feasible.

Case: Resuscitation with ventilation using an endotracheal tube

Your team is called to attend a birth at 37 weeks' gestation. Labor has been complicated by chorioamnionitis and fetal heart rate decelerations. The amniotic fluid is clear and deferred cord clamping is planned. You complete a pre-resuscitation briefing and prepare your supplies and equipment. At the time of vaginal birth, a tight nuchal cord is reduced, and the obstetrician briefly dries and stimulates the infant, but the infant remains limp and apneic. The obstetrician milks the intact umbilical cord toward the infant 4 times over 15 to 20 seconds and clamps and cuts the umbilical cord; the infant is then moved to the radiant warmer. You position the infant's airway while providing brief additional stimulation, but the infant is still not breathing. You start assisted ventilation while a team member places a pulse oximeter sensor on the infant's right hand and another team member documents the events as they occur. The infant's heart rate is 50 beats per minute (bpm) and not increasing. You observe that the chest is not moving with assisted ventilation and begin the ventilation corrective steps, but the chest still does not move and the infant's heart rate is not improving. A carbon dioxide (CO_2) detector placed between the ventilation device and mask remains purple with assisted breaths. You decide to insert an endotracheal tube to improve the effectiveness of ventilation.

Leads are placed on the newborn infant's chest and attached to a cardiac monitor. An assistant holds a 3.5-mm endotracheal tube, provides cricoid pressure, and monitors the procedure time while a qualified provider uses a size 1 laryngoscope to insert the endotracheal tube. A CO_2 detector is placed on the tube, ventilation is resumed, and the detector turns yellow, indicating that the tube is in the trachea and the lungs are being ventilated. The infant's chest is moving, and the heart rate rapidly increases above 100 bpm. Based on the nasal-tragus length (NTL) measurement, the endotracheal tube is held with the 8-cm marking adjacent to the infant's gum in the midline. Breath sounds are equal in both axillae, the tube is rapidly secured, and ventilation continues. You adjust the inspiratory pressure to achieve a gentle rise and fall of the chest with each breath and adjust the oxygen concentration based on pulse oximetry. The infant still has poor tone and inconsistent respiratory effort. You quickly update the parents and transfer the infant to the nursery for a chest radiograph and post-resuscitation care. Shortly afterward, your resuscitation team conducts a debriefing to discuss preparation, teamwork, and communication.

Endotracheal tubes

An endotracheal tube (Figure 5.1) is a thin tube that is inserted through the glottis, between the vocal cords, and advanced into the trachea. Although digital intubation using only the operator's finger has been described, endotracheal intubation typically involves the use of a lighted instrument (laryngoscope [Figure 5.2]) to visualize the larynx and guide the insertion of the tube between the vocal cords.

Indications for insertion of an endotracheal tube

- **Insertion of an endotracheal tube (intubation) is strongly recommended if the newborn infant's heart rate remains less than 100 bpm and is not increasing after optimizing ventilation with a face mask or laryngeal mask.**

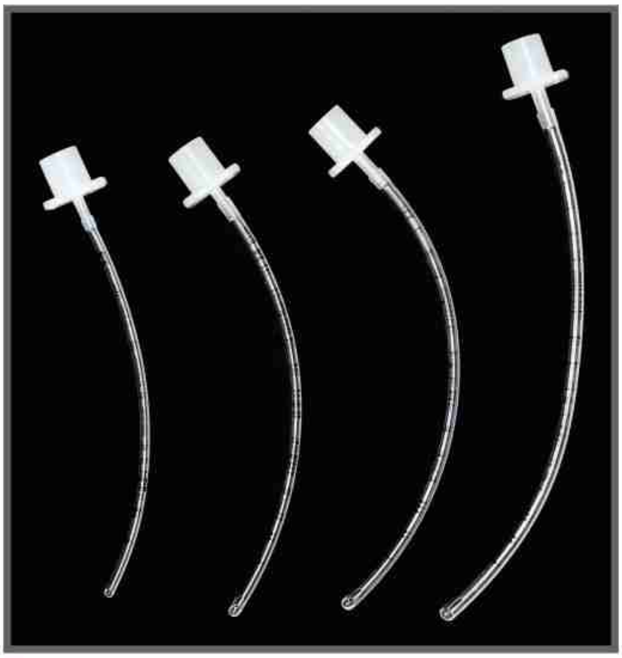


Figure 5.1. Endotracheal tubes (size 2.0, 2.5, 3.0, 3.5).

Figure 5.2. Laryngoscopes (straight Miller blade).

- **Insertion of an endotracheal tube is strongly recommended before starting chest compressions.** If intubation is not successful or feasible, it is reasonable to use a laryngeal mask during chest compressions.
  - Ventilation through an endotracheal tube for 30 seconds may improve ventilation efficacy and avoid the need to proceed to chest compressions.
  - If chest compressions are needed, ventilation through an endotracheal tube may improve coordination with compressions.
  - Intubation allows the compressor to give compressions from the head of the bed.
- An endotracheal tube should be inserted for direct tracheal suction if obstruction by thick secretions is suspected and for stabilization of a newborn infant with certain congenital anomalies such as a suspected diaphragmatic hernia. An endotracheal tube may also be used for surfactant administration.
- If ventilation is prolonged, an endotracheal tube may be considered to improve the efficacy and ease of assisted ventilation.

When endotracheal intubation is needed, it must be performed without significant delay. A person with intubation skills should be available to be called for immediate assistance if needed. If the need for intubation is anticipated, this person should be present at the time of birth.

Anatomic landmarks for intubation

The important anatomic landmarks are labeled in Figures 5.3 and 5.4.

- **Esophagus:** The passageway extending from the throat to the stomach
- **Epiglottis:** The lid-like structure overhanging the glottis
- **Vallecula:** The pouch formed by the base of the tongue and the epiglottis
- **Larynx:** The portion of the airway connecting the pharynx and trachea
- **Glottis:** The opening of the larynx leading to the trachea, flanked by the vocal cords
- **Vocal cords:** Mucous membrane–covered ligaments on both sides of the glottis
- **Trachea:** The portion of the airway extending from the larynx to the carina
- **Thyroid and cricoid cartilage:** The lower portion of the cartilage protecting the larynx
- **Carina:** Where the trachea branches into the 2 main bronchi
- **Main bronchi:** The 2 air passageways leading from the trachea to the lungs

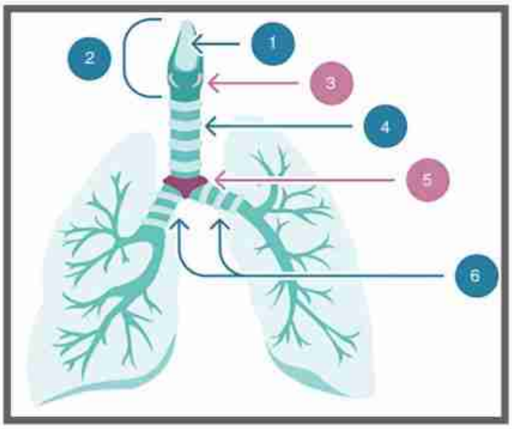


Figure 5.3. Airway anatomy. 1. Glottis 2. Larynx 3. Thyroid and cricoid cartilage 4. Trachea 5. Carina 6. Main bronchi.

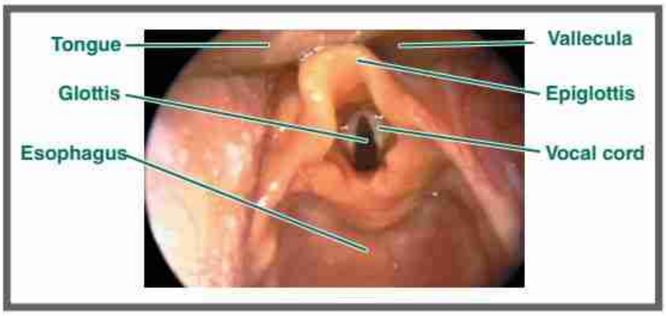


Figure 5.4. Laryngoscopic view of vocal cords and surrounding structures.

Preparing for intubation

Supplies and equipment for intubation

Intubation supplies and equipment should be kept together and readily accessible. It is important to anticipate the need for intubation and prepare the supplies and equipment before a high-risk delivery.

Each birth setting, nursery, and emergency department should have at least 1 complete set of the following items (Figure 5.5):

1. Laryngoscope handle*
   a. If the handle uses replaceable batteries and bulbs, an extra set should be available.
2. Laryngoscope blades (straight Miller)*
   a. No. 1 (term newborn infant)
   b. No. 0 (preterm infant)
   c. No. 00 *(optional for extremely preterm infant)*
3. Endotracheal tubes with inside diameters of 2.5, 3.0, and 3.5 mm
   a. Size 2.0 mm (*optional for extremely preterm infant*)
   b. Size 4.0 mm and tubes with inflatable cuffs (*optional*) are available and may be considered for specific indications but are not routinely used during neonatal resuscitation.
4. Stylet that fits into the endotracheal tube (*optional*)
5. Laryngeal mask as a rescue airway (5-mL syringe if using a laryngeal mask with an inflatable rim)

*A video laryngoscope with an integrated camera that displays a magnified view of the airway structures on a video screen is an option.

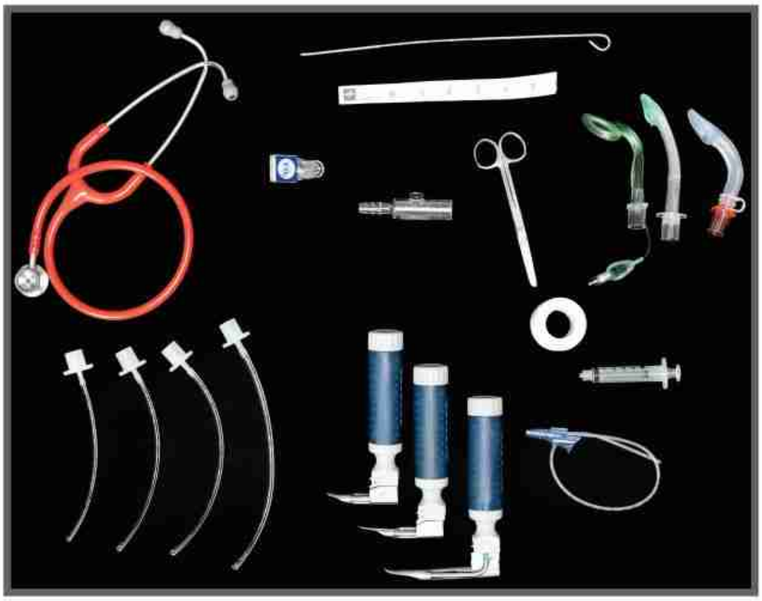


Figure 5.5. Neonatal airway supplies and equipment. (Supplies have been removed from packaging for demonstration purposes.)

6. CO_2 detector
7. Suction setup with suction catheters: size 10F or larger (for suctioning the pharynx), size 8F and either size 5F or 6F (for suctioning the endotracheal tube)
8. Waterproof adhesive tape (½ or ¾ inch) or other tube-securing device
9. Measuring tape and/or endotracheal tube insertion depth table
10. Scissors to cut tape
11. Tracheal aspirator
12. Stethoscope (with neonatal head)
13. Ventilation device (bag or T-piece resuscitator) and tubing for blended air and oxygen
14. Pulse oximeter, sensor, and cover

Intubation should be performed as a clean procedure. All supplies should be protected from contamination by being opened, assembled, and placed back in their packaging until just before use. To avoid contamination, laryngoscope blades should not be placed directly on hospital linen.

When intubation becomes necessary, an electronic cardiac monitor is recommended for the most accurate assessment of the infant's heart rate. During resuscitation, auscultation can be difficult and pulse oximetry may not reliably detect the infant's pulse. A cardiac monitor is a valuable tool at this point in resuscitation because an increasing heart rate is a critical indicator of proper endotracheal tube insertion, and because your decision to proceed with chest compressions after intubation depends on rapid and accurate assessment of the newborn infant's heart rate.

Select the correct type of endotracheal tube

The endotracheal tube should have a uniform diameter throughout the length of the tube (Figure 5.6A). Tapered tubes are not recommended for neonatal resuscitation. Endotracheal tubes have centimeter markings along the side to measure the distance to the tip of the tube. Many tubes also have lines or markings (Figure 5.6B) near the tip that are intended to be a vocal cord guide. When the tube is inserted so that the vocal cords are positioned between the 2 sets of lines, the tip of the tube is expected to be above the carina; however, the location and design of the lines vary considerably between manufacturers. **The vocal cord guide is only an approximation and may not reliably indicate the correct insertion depth.**

Select the correct size endotracheal tube

Endotracheal tubes are described by the size of their internal diameter (mm ID). The suction catheter that fits within an endotracheal tube to remove secretions is described in French units (F). The appropriate endotracheal tube diameter is estimated from the infant's weight or gestational age. Table 5-1 presents the recommended endotracheal tube and suction catheter size for various weight and gestational-age categories. Using a tube that is too small increases leakage around the tube, the resistance to air flow, and the chance that it will become obstructed by secretions. Using a tube that is too large may traumatize

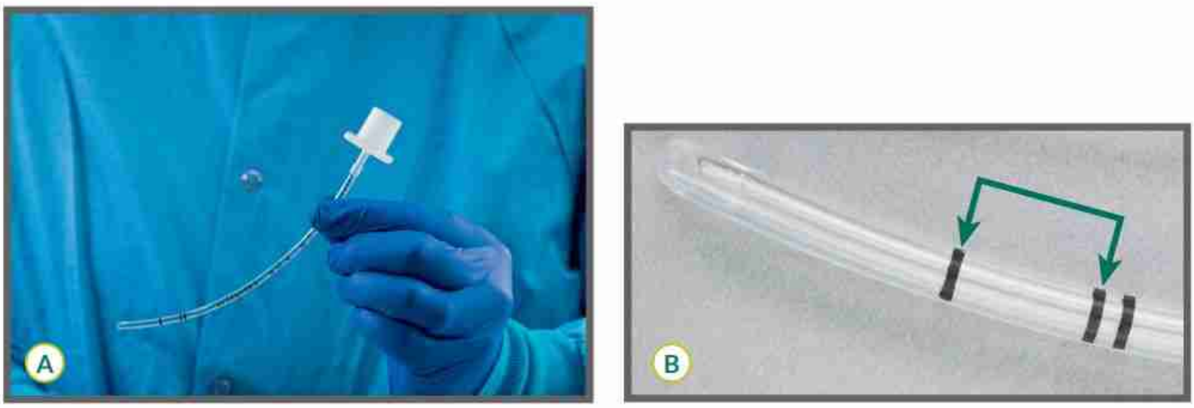


Figure 5.6. Neonatal endotracheal tube with uniform diameter (A). This tube has a vocal cord guide that is used to approximate the insertion depth (B). The tube is inserted so that the vocal cards are positioned between the double line and single line (indicated by the arrows). The vocal cord guide is only an approximation and may not reliably indicate the correct insertion depth.

Table 5-1. Endotracheal Tube and Suction Catheter Size for Newborn Infants of Various Weights and Gestational Ages

Weight (grams)	Gestational Age (weeks)	Endotracheal Tube Size (mm ID)	Suction Catheter (F)
< 800	22-25	2.5*	5
800-1,200	26-28	2.5	5 or 6
1,201-2,200	29-34	3.0	6 or 8
> 2,200	> 34	3.5	8

*A 2.0 mm ID endotracheal tube (optional) may be considered.

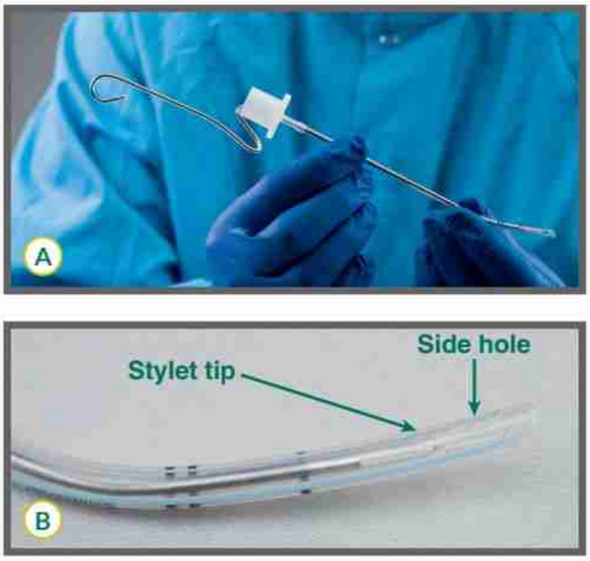


Figure 5.7. Optional stylet for increasing endotracheal tube stiffness and maintaining curvature during intubation (A). It is important to ensure that the tip is not protruding from either the end or side hole of the endotracheal tube (B).

the airway. A 2.0 mm ID endotracheal tube (*optional*) may be considered for extremely preterm infants weighing less than approximately 750 g. Size 4.0-mm tubes and tubes with inflatable cuffs are available and may be considered for specific indications but are not routinely used during neonatal resuscitation.

Consider using a stylet

Many operators find it helpful to use a stylet with the endotracheal tube to provide additional rigidity and curvature (Figure 5.7A). If a stylet is used, make a gentle (10°-15°) curve at the tip to facilitate precise adjustment of the tube position during intubation. Do not bend the tip into an acute angle.

Use of a stylet is optional and depends on the operator's preference. When inserting a stylet, it is important to ensure that the tip is not protruding from either the end or side hole of the endotracheal tube (Figure 5.7B). If the tip protrudes, it may cause trauma to the tissues. The stylet should be secured with a plug, or bent at the top, so that it cannot advance farther into the tube during the insertion procedure. It is important to ensure that the stylet is easily removable from the endotracheal tube because aggressive attempts to remove the stylet after intubation can accidentally displace the tube.

Enhanced Learning

https://bcove.video/40XzWuQ

QR 5.1 Scan here to see a 30-second video about intubation supplies.

Prepare the supplies and equipment for intubation

The following steps describe how to prepare the supplies and equipment used for intubation:

- If not already done, attach cardiac monitor leads for accurate assessment of the infant's heart rate.

- Select the appropriate laryngoscope blade and attach it to the handle.
  - Use a No. 1 blade for term newborn infants.
  - Use a No. 0 blade for preterm infants. Some operators may prefer to use a No. 00 blade for extremely preterm infants.
- Turn on the light by clicking the blade into the open position to verify that the laryngoscope is working. Depending on the type of laryngoscope used, if the light is dim or flickers, tighten or replace the bulb, insert a new battery, or replace the laryngoscope. If you are using a light-bulb laryngoscope, close the laryngoscope until ready for use to avoid overheating the blade and potentially injuring the infant.
- Prepare the suction equipment.
  - Occlude the end of the suction tubing to ensure that the suction is set to 80 to 100 mm Hg.
  - Connect a size 10F (or larger) suction catheter to remove secretions, if needed, from the mouth and pharynx.
  - Smaller suction catheters (size 8F and size 5F or 6F) should be available for removing secretions from an obstructed endotracheal tube, if necessary, after insertion (Table 5-1).
  - A tracheal aspirator can be attached to the endotracheal tube to directly suction meconium or thick secretions that obstruct the trachea. Some endotracheal tubes have an integrated suction port that can be attached directly to suction tubing and do not require use of a tracheal aspirator.
- Prepare a ventilation device with a face mask or laryngeal mask to ventilate the infant, if necessary, between intubation attempts. Check the operation of the device as described in Lesson 4.
- Place a CO_2 detector, stethoscope, measuring tape or insertion depth table, waterproof adhesive tape (½ or ¾ inch) and scissors, or other tube-securing device within reach.

The direct laryngoscopy intubation procedure

The steps for endotracheal intubation using direct laryngoscopy (visualizing the larynx directly through the open channel of the laryngoscope) are briefly described as follows; however, proficiency requires considerable supervision and practice. The steps to perform video laryngoscopy (inserting a laryngoscope with a camera and visualizing the larynx on an attached video monitor) are very similar. Even if you are not performing the procedure, it is helpful to understand the steps so you can effectively assist the operator.

Enhanced Learning

https://bcove.video/4IDiHGN

QR 5.2 Scan here to see a 2-minute video of the intubation procedure.

Position yourself and the newborn infant for intubation

Adjust the height of the bed, if possible, so that the infant's head is level with the operator's upper abdomen or lower chest; this will bring the infant's head closer to the operator's eye level and improve the view of the airway (Figure 5.8).

Place the infant's head in the midline, the neck neutral or slightly extended in the sniffing position, and the body straight. It may be helpful to place a **small roll under the infant's shoulders** to maintain slight neck extension. This position aligns the trachea for optimal viewing by allowing a straight line of sight into the glottis once the laryngoscope has been properly inserted. A team member should help to maintain good positioning throughout the procedure.

Both overextension and flexion of the neck will obstruct your view of the airway. If the shoulder roll is too large or the neck is overextended, the glottis will be raised above your line of sight. If the neck is flexed toward the chest, you will be viewing the posterior pharynx and will not be able to visualize the glottis (Figure 5.9).

Figure 5.8. Positioning the infant for intubation.

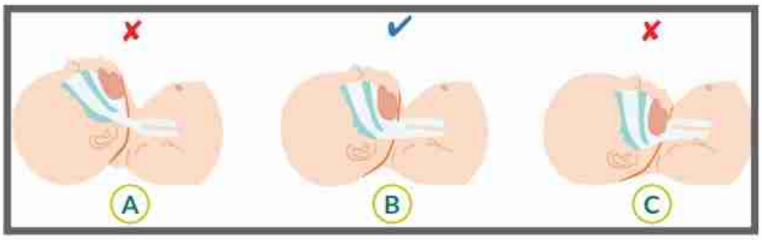


Figure 5.9. Incorrect positioning for intubation—line of sight obstructed (A and C). Correct positioning for intubation—line of sight clear, tongue will be lifted by laryngoscope blade (B).

Hold the laryngoscope

Always hold the laryngoscope in your left hand. The laryngoscope is designed to be held in the left hand by both right- and left-handed users. If held in the right hand, your view through the open, curved portion of the blade will be obstructed.

Grasp the lower portion of the handle, near the hinge, with your thumb resting on the handle (Figure 5.10). The laryngoscope blade will be pointing away from you. Keep your elbow close to your body.

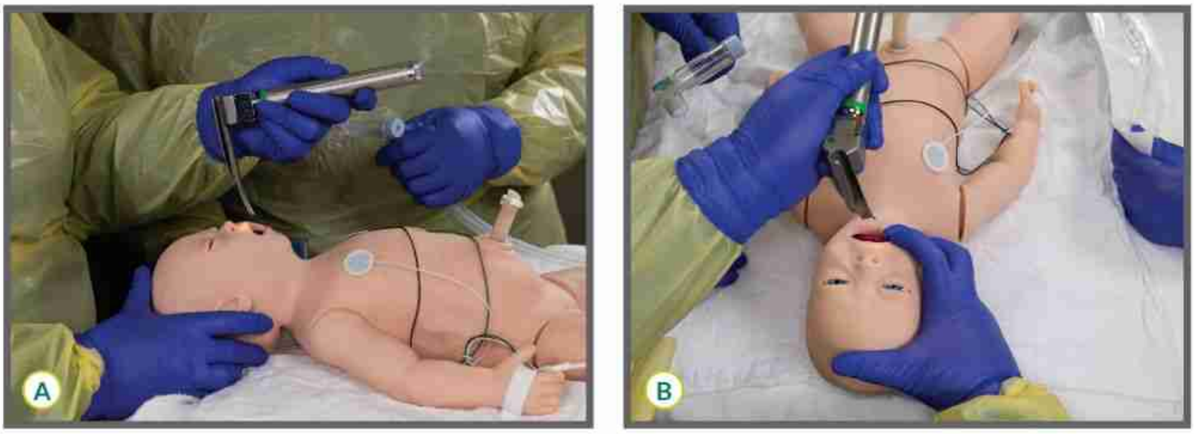


Figure 5.10. Hold the laryngoscope blade in your left hand. Rest your thumb on the surface of the handle (A and B).

Insert the laryngoscope and identify key landmarks

Use your right index finger or thumb to gently open the infant's mouth. Alternatively, an assistant can help open the infant's mouth.

Insert the laryngoscope blade in the midline, or slightly to the right of midline, and gently advance it over the tongue into the posterior pharynx until the tip of the blade lies in the space between the base of the tongue and the epiglottis. This space is called the *vallecula* (Figure 5.11). In extremely preterm infants, the vallecula may be very small and you may need to gently insert the blade farther until the laryngoscope tip is placed directly under the epiglottis.

When the blade is correctly positioned, the tip of the blade will be in the midline and the tongue will be in the midline or gently displaced to the left. If the tongue bulges to the right side of the blade, it may interfere with visualization of the glottis and insertion of the tube.

Lift the entire laryngoscope in the direction in which the handle is pointing, opening the mouth and moving the tongue out of the way to expose the glottis (Figure 5.11). You may need to tilt the tip of the blade very slightly to lift the epiglottis and see the glottis and vocal cords.

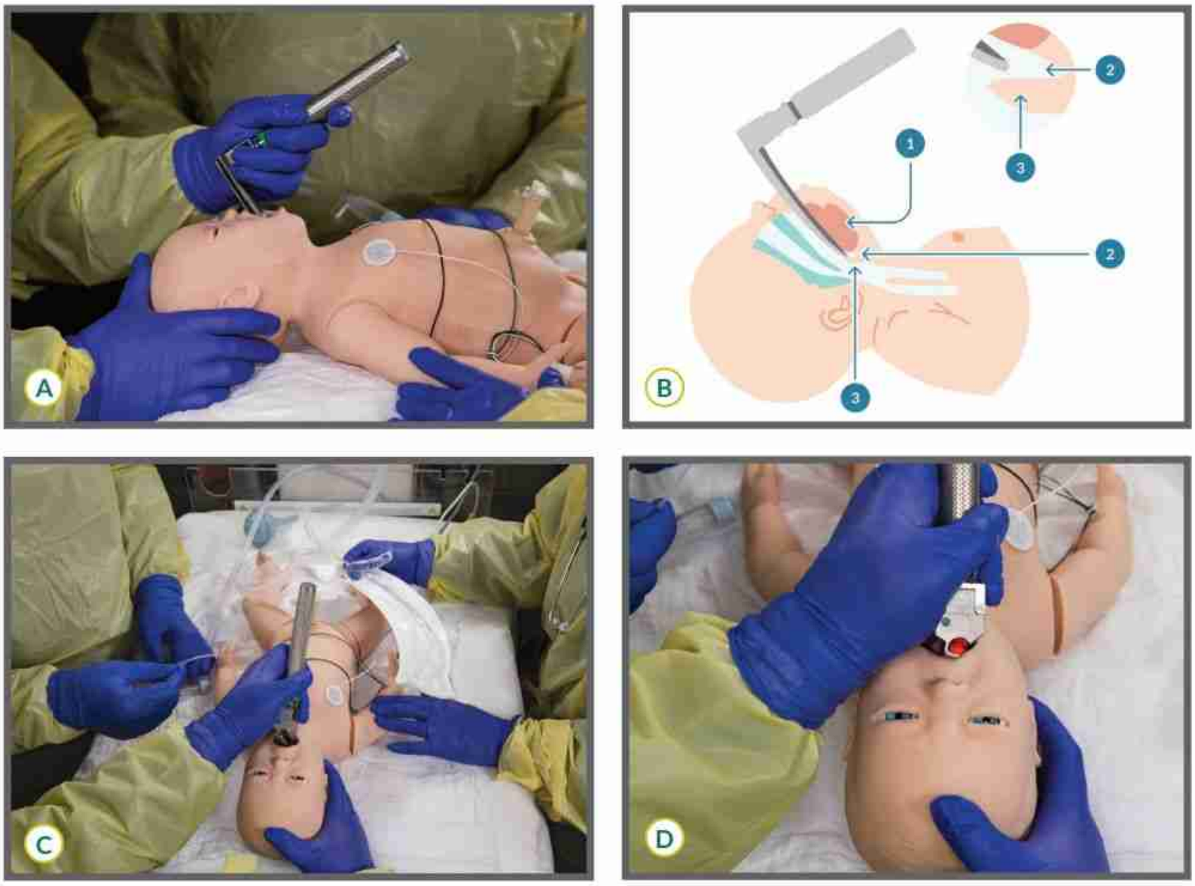


Figure 5.11. Insert the laryngoscope blade in the midline or slightly to the right of midline (A) and advance it until the tip lies in the vallecula (1. Tongue, 2. Vallecula, 3. Epiglottis) (B). Lift the entire laryngoscope in the direction in which the handle is pointing (C) to identify landmarks through the open, curved portion of the laryngoscope blade (D).

When first learning the procedure, operators tend to bend their wrist, pulling the top of the handle toward themselves in a "rocking" motion against the infant's upper (maxillary) gum, attempting to pry open the mouth. This will not produce the desired view and may injure the infant's lips and gums (Figure 5.12).

Note: This lesson describes placing the tip of the blade in the vallecula to lift the epiglottis. **In some cases, where the vallecula is small or the epiglottis is large and floppy, it may be necessary to use the blade tip to gently lift the epiglottis directly.**

The vocal cords and glottis appear at the very top of your view as you look down the laryngoscope.

- An assistant can help bring the glottis into view by using their thumb and first finger to provide gentle pressure on the infant's thyroid and cricoid cartilage (Figure 5.13). **They should direct the pressure downward and toward the infant's right ear.**

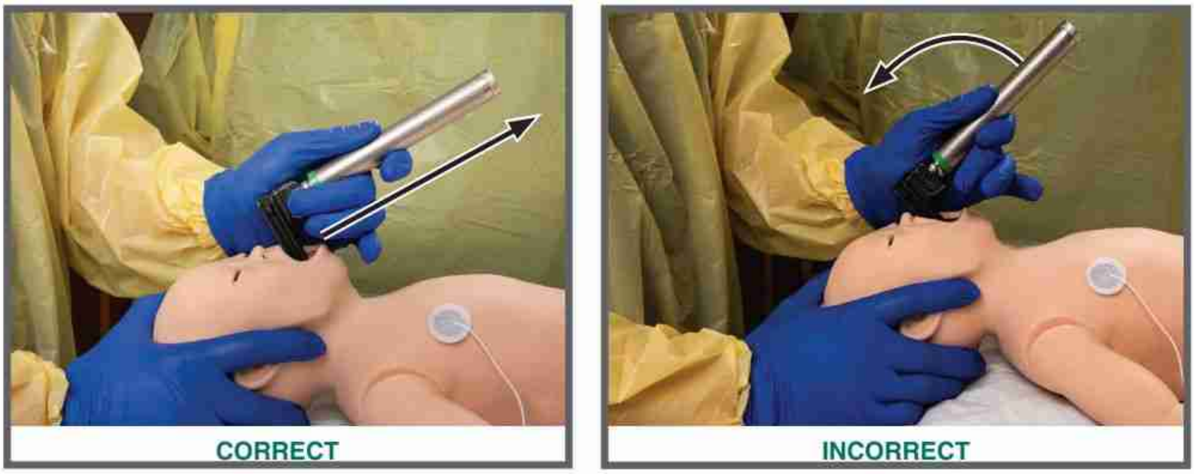


Figure 5.12. Correct (left) and incorrect (right) method for lifting the laryngoscope. Lift the entire laryngoscope in the direction in which the handle is pointing; do not rotate or "rock" the handle against the infant's upper (maxillary) gum.

- Experienced operators may prefer to use their right hand to manipulate the thyroid and cricoid cartilage until an optimal view is achieved (bimanual laryngoscopy). Once the view is optimized, an assistant takes over holding the thyroid and cricoid cartilage in the same position.

Identify the key landmarks (Figure 5.14). If the tip of the blade is correctly positioned in the vallecula, you should see the epiglottis hanging down from the top and the vocal cords directly below. **The vocal cords appear as thin vertical stripes in the shape of an inverted letter "V."**

If these structures are not immediately visible, adjust the blade until the structures come into view. You may need to move the blade back to the midline; insert or withdraw the blade slowly to see the vocal cords (Figure 5.15).

Figure 5.13. Thyroid and cricoid pressure provided by an assistant may improve visualization of the vocal cords and glottis. Press downward and toward the infant's right ear. Experienced operators may prefer to manipulate the thyroid and cricoid cartilage (bimanual laryngoscopy) with their right hand until the optimal view is achieved.

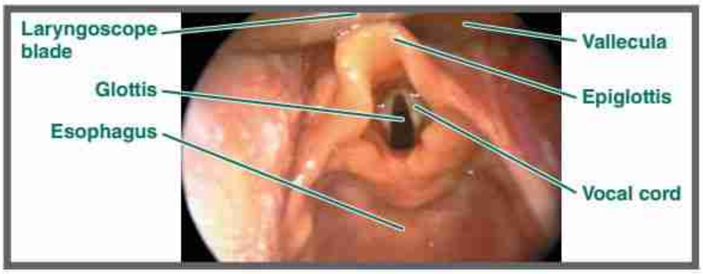


Figure 5.14. Key landmarks. The infant is lying supine. The laryngoscope blade is at the top of the photo, in the vallecula, holding the tongue up and out of the way.

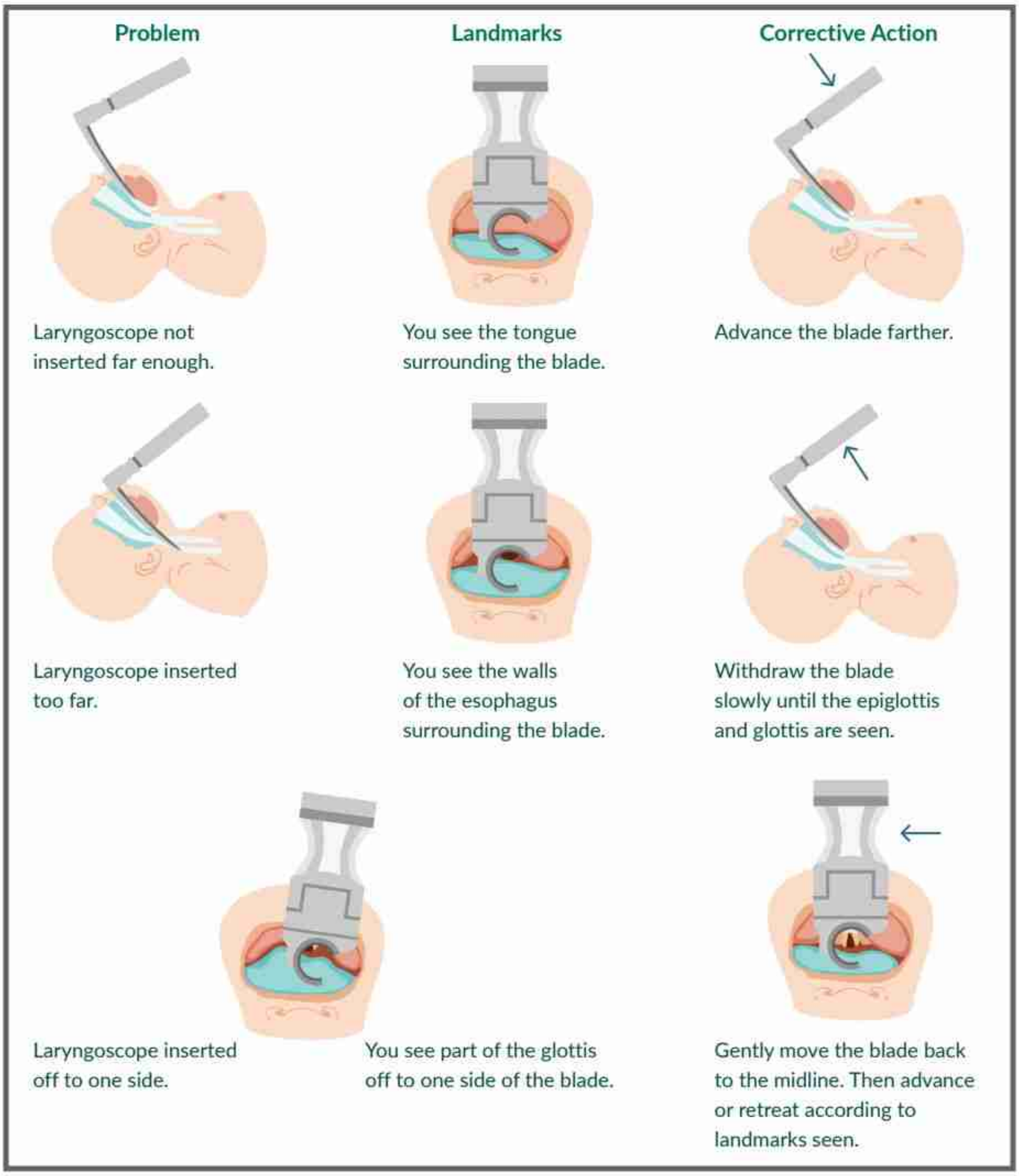


Figure 5.15. Corrective actions for poor visualization of landmarks during laryngoscopy.

If the blade is not inserted far enough, you will see the base of the tongue and posterior pharynx (Figure 5.16). Advance the blade slightly until the epiglottis comes into view. If the blade is inserted too far, you will see only the esophagus (Figure 5.17) and will need to withdraw the blade slightly until the epiglottis drops down from above.

If the anatomic landmarks are obstructed by secretions, use a size 10F or 12F catheter to remove secretions from the mouth and pharynx.

Figure 5.16. Laryngoscope not inserted far enough. Tongue and posterior pharynx obscure view of the glottis.

Figure 5.17. Laryngoscope inserted too far. Only the esophagus is visible.

Insert the endotracheal tube

Once you have identified the vocal cords, hold the laryngoscope steady and maintain your view of the vocal cords, while an assistant places the endotracheal tube in your right hand.

- **Insert the tube into the right side of the infant's mouth** with the tube's concave curve in the horizontal plane (Figure 5.18).
- **Do not insert the tube through the laryngoscope's open channel.** This will obstruct your view of the vocal cords.
- An assistant can improve the operator's view and make it easier to insert the tube by lifting the upper right corner of the infant's lip.

Figure 5.18. Insert the endotracheal tube into the right side of the infant's mouth. Avoid placing the tube in the open channel of the laryngoscope blade. An assistant can help by lifting the corner of the infant's lip.

Pass the tube along the right side of the infant's mouth toward the vocal cords

- As the tip approaches the vocal cords, rotate the tube's curvature into the vertical plane so the tip is directed upward.
- When the vocal cords open, advance the tube until the infant's vocal cords are positioned between the marked guide lines on the tube. If your assistant is providing gentle thyroid and cricoid pressure, they may feel the tube pass beneath their fingers.
- Note the centimeter depth marking on the outside of the tube that aligns with the infant's upper lip.

If the vocal cords are closed, wait for them to open. Do not touch the closed cords with the tip of the tube and never try to force the tube between closed cords. If the cords do not open within approximately 30 seconds, stop and resume ventilation with a mask until you are prepared to reattempt insertion.

Remove the laryngoscope

Use your right index finger to hold the tube securely against the infant's hard palate.

- **Carefully remove the laryngoscope without displacing the tube** (Figure 5.19).
- If a stylet was used, an assistant should remove it from the endotracheal tube, making sure that you are holding the tube in place (Figure 5.20). Although it is important to hold the tube firmly, be careful not to squeeze the tube so tightly that the stylet cannot be removed.

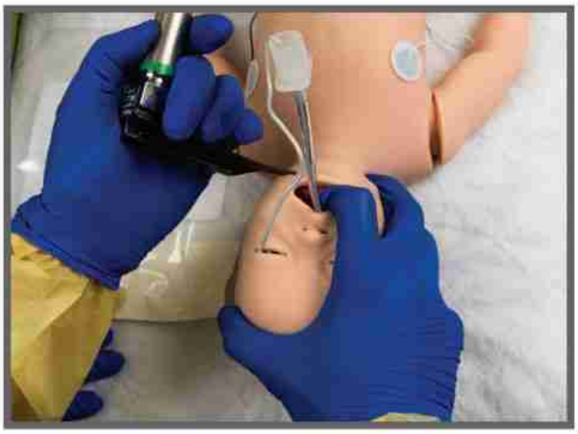


Figure 5.19. Stabilize the tube against the infant's palate while carefully removing the laryngoscope.

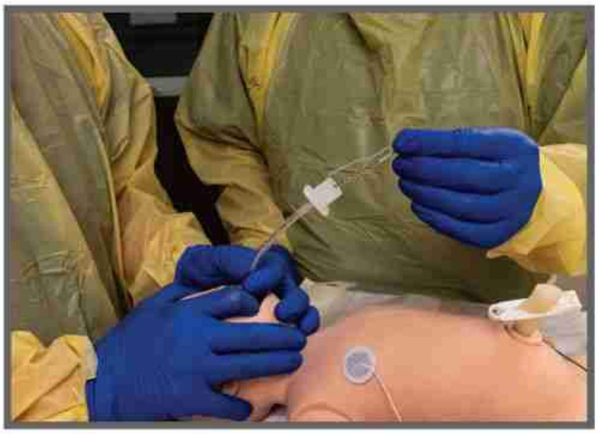


Figure 5.20. An assistant removes the optional stylet while the operator holds the tube securely in place.

Figure 5.21. Attach a CO_2 detector and ventilation device to the endotracheal tube and begin ventilation. Observe for color change on the CO_2 detector. Assess the infant's heart rate and breath sounds. Note the secure hand position used to hold the endotracheal tube in place.

Ventilate through the endotracheal tube

An assistant should **attach a CO_2 detector and ventilation device to the endotracheal tube** (Figure 5.21). Once the ventilation device is attached, begin ventilation through the tube. Having the same person hold the endotracheal tube and the ventilation device may help to avoid accidental extubation.

Limit the procedure time

Once started, the steps of intubation ideally should be completed within approximately 30 seconds. During the intubation procedure, the infant is not receiving assisted ventilation. It is common for infants to develop worsening oxygen saturation and bradycardia if the intubation procedure lasts longer than 30 to 50 seconds. If the infant's vital signs worsen during the procedure (severe bradycardia or decreased oxygen saturation), it is usually preferable to stop, resume ventilation with a resuscitation mask or laryngeal mask, and then try again. Deliberate practice and effective teamwork are required to perform this procedure quickly.

Repeated attempts at intubation are not advised because you will increase the likelihood of soft-tissue trauma and make subsequent airway management more difficult. If the initial attempts are unsuccessful, evaluate other options, including using a video laryngoscope if available, requesting assistance from another provider with intubation expertise (eg, anesthesiologist, emergency department physician), inserting a laryngeal mask, or continuing face mask ventilation.

Confirm the endotracheal tube is in the trachea

The primary methods of confirming endotracheal tube insertion within the trachea are detecting exhaled CO_2 and a rapidly rising heart rate.

- As soon as you insert the endotracheal tube, connect a CO_2 detector (Figure 5.21) and confirm the presence of CO_2 during exhalation.
- If the tube is correctly inserted and you are providing effective ventilation through the tube, you should detect exhaled CO_2 within 8 to 10 positive pressure breaths.

Two types of CO_2 detectors are available. Colorimetric devices change color in the presence of CO_2 (Figure 5.22). These are the most commonly used devices for neonatal intubation. Capnographs are electronic monitors that display the CO_2 concentration with each breath.

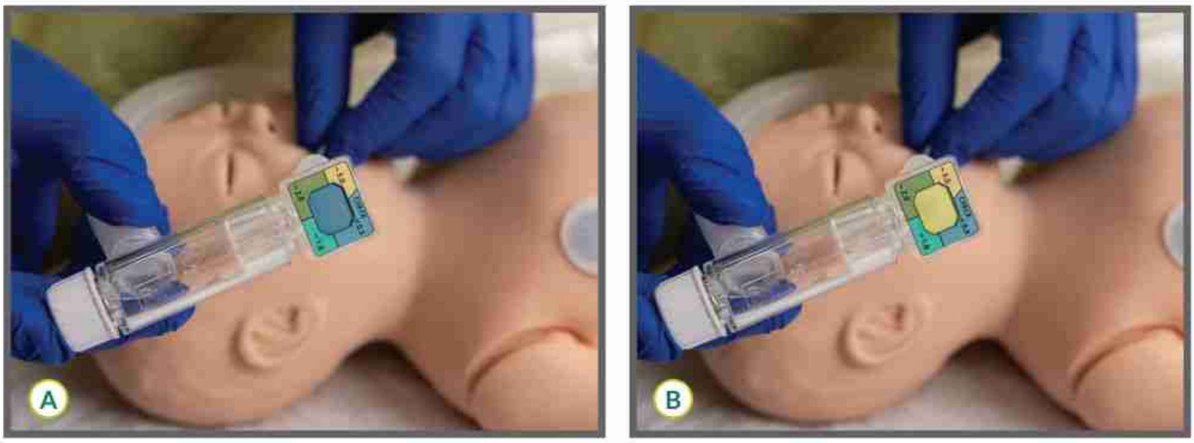


Figure 5.22. The colorimetric CO_2 detector is purple or blue before detecting exhaled CO_2 (A). The detector turns yellow in the presence of exhaled CO_2 (B).

There are limitations to the use of CO_2 detectors (Table 5-2). The endotracheal tube may be in the trachea, but CO_2 is not detected. If the tube is inserted in the trachea, but the lungs are not adequately ventilated, there may not be enough exhaled CO_2 to be detected. This may occur if the endotracheal tube or trachea is obstructed by secretions, you are not using enough ventilating pressure, or there are large bilateral pneumothoraces and the lungs are collapsed. **In addition, newborn infants with a very low heart rate or decreased cardiac function (low cardiac output) may not carry enough CO_2 to their lungs to be detected.**

Although uncommon, it is possible for a colorimetric CO_2 device to change color even though the tube is not in the trachea (Table 5-2). If the detector has already changed color in the package and is yellow when you remove it, the device is defective and should not be used. If epinephrine, surfactant, or atropine is administered through the endotracheal tube and touches the paper inside the CO_2 detector, or if gastric secretions touch the paper, they may permanently change the screen to yellow and make the detector unusable.

Table 5-2. **Colorimetric CO_2 Detector Problems**

False Negative (Tube *is in* trachea but *no* color change)	False Positive (Tube *is not* in trachea but color changes)
• Inadequate ventilating pressure • Collapsed lungs • Bilateral pneumothoraces • Very low heart rate • Low cardiac output • Obstructed endotracheal tube	• Defective device changed color in package before use • Contamination with acidic substance (epinephrine, surfactant, atropine, gastric contents)

Although demonstrating exhaled CO_2 and observing a rapidly increasing heart rate are the primary methods of confirming endotracheal tube insertion within the trachea, if the tube is positioned correctly, you should also observe

- Audible and equal breath sounds near both axillae during ventilation
- Symmetrical chest movement with each breath
- Little or no air leak from the mouth during ventilation
- Decreased or absent air entry over the stomach

Be cautious when interpreting breath sounds in newborn infants because sounds are easily transmitted. When listening to breath sounds, use a small stethoscope and place it near the axilla. A large stethoscope, or one placed near the center of the chest, may transmit sounds from the esophagus or stomach.

Remember that newborn infants with a very low heart rate or decreased cardiac function may not carry enough CO_2 to their lungs for the color

to change on the CO_2 detector. If you believe that the tube is correctly inserted in the trachea despite the lack of exhaled CO_2, you may choose to stabilize the tube, reinsert the laryngoscope or insert a video laryngoscope, and attempt to confirm that the tube is passing between the vocal cords. This "second look" procedure can be difficult, particularly with direct laryngoscopy, and may delay establishing effective ventilation if the tube is not correctly inserted. If available, video laryngoscopy may be a helpful alternative for a "second look." If the tube position is confirmed and the infant's heart rate does not improve with ventilation through the endotracheal tube, chest compressions are indicated. Once cardiac output is improved, CO_2 will be detected.

Estimate the insertion depth

The goal is to insert the endotracheal tube tip in the middle portion of the trachea. This generally requires inserting the tube so that the tip is only 1 to 2 cm below the vocal cords. It is important not to insert the tube too far so that the tip touches the carina or enters a main bronchus. Two methods may be used for estimating the insertion depth. Your team should determine which method is preferred in your practice setting.

The nasal-tragus length (NTL) is a method that has been validated in both term and preterm infants. The NTL method uses a calculation based on the distance (cm) from the infant's nasal septum to the ear tragus (Figure 5.23). Use a measuring tape to measure the NTL. The estimated insertion depth is NTL + 1 cm. Insert the endotracheal tube so that the marking on the tube corresponding to the estimated insertion depth is adjacent to the anterior edge of the infant's upper (maxillary) gum in the midline.

Enhanced Learning

https://bcove.video/45sgOqk

QR 5.3 Scan here to see a 30-second video about NTL measurement.

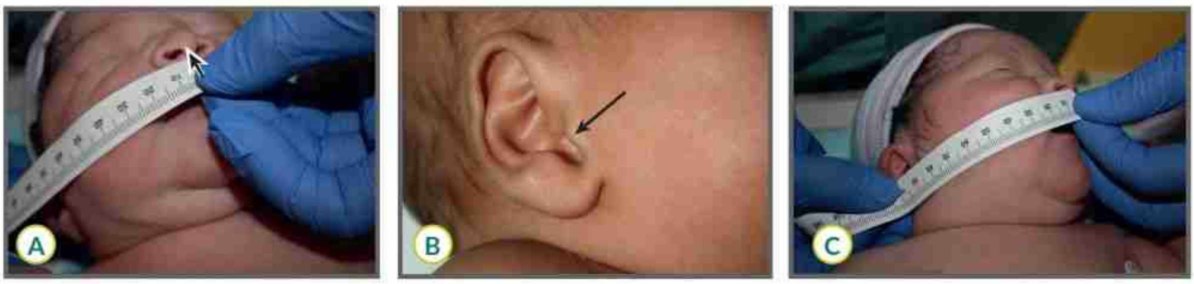


Figure 5.23. Measuring the NTL. Measure from the middle of the nasal septum (arrow, A) to the ear tragus (arrow, B) and add 1 cm to the measurement. C) Nasal septum to tragus measurement.

Studies have shown that gestational age can also be used to estimate the correct insertion depth (Table 5-3) and has the advantage of being known before birth. This table can be placed near the radiant warmer or with your intubation supplies.

Table 5-3. Initial Endotracheal Tube Insertion Depth ("Tip to Gum") for Orotracheal Intubation

Gestation	Insertion Depth at Gum	Infant's Weight
< 23 weeks	5.0-5.5 cm	< 500 grams
23-24 weeks	5.5 cm	500-600 g
25-26 weeks	6.0 cm	700-800 g
27-29 weeks	6.5 cm	900-1,000 g
30-32 weeks	7.0 cm	1,100-1,400 g
33-34 weeks	7.5 cm	1,500-1,800 g
35-37 weeks	8.0 cm	1,900-2,400 g
38-40 weeks	8.5 cm	2,500-3,100 g
41-43 weeks	9.0 cm	3,200-4,200 g

Adapted from Kempley ST, Moreiras JW, Petrone FL. Endotracheal tube length for neonatal intubation. *Resuscitation.* 2008;77(3):369–373 and Naseh N, Wallström L, Sindelar R, Ågren J. Standardized endotracheal tube and intravascular access placement in infants born at 22-23 weeks gestation. *Pediatr Res.* Published online June 18, 2025.

Remember that both of these methods are estimates of the correct endotracheal tube depth

After inserting the tube, use a stethoscope to listen for breath sounds in both axillae and over the stomach (Figure 5.24).

- If the tube is correctly positioned, the breath sounds should be equal on both sides.
- If the tube is inserted too far, the breath sounds may be decreased on one side.
  - Most often, if the tube is inserted too far, it will enter the right mainstem bronchus causing breath sounds to be louder on the right side and quieter on the left side. Slowly withdraw the tube while listening to the breath sounds on the quieter side.
  - When the tube is correctly positioned, the breath sounds should improve and become equal.

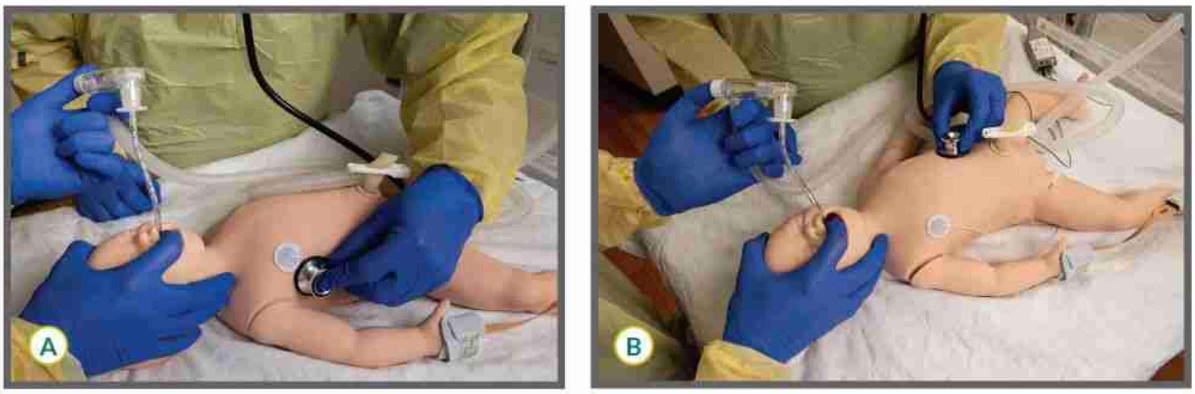


Figure 5.24. Listen for equal breath sounds in both axillae (A). Breath sounds should not be audible over the stomach (B).

Secure the endotracheal tube

Several methods of securing the tube have been described. Either water-resistant tape or a device specifically designed to secure an endotracheal tube may be used.

One method is described as follows:

1. After you have correctly positioned the tube, note the centimeter marking on the side of the tube adjacent to the infant's upper (maxillary) gum at the midline (Figure 5.25).

Figure 5.25. Note the marking adjacent to the infant's upper (maxillary) gum at the midline.

2. Cut a piece of ¾- or ½-inch tape approximately 5 to 6 cm in length so that it is long enough to cross the infant's upper lip and extend about 2-3 cm onto both cheeks.
3. Using scissors, split the tape on both sides leaving a small section of tape intact in the middle (Figure 5.26A).
4. Place the upper 2 segments of tape across the infant's upper lip and both cheeks (Figure 5.26B).
5. Turn the ends of the lower 2 tape segments onto themselves leaving small "tabs" that you can hold to unwind the tape when you want to adjust the insertion depth or remove the tube (Figure 5.26C).
6. Carefully wrap the lower 2 segments of the tape around the tube (Figures 5.26D and 5.26E). Be sure that the desired centimeter marking remains next to the infant's upper gum at the midline. It is easy to inadvertently push the tube in farther than desired during the taping procedure.
7. Listen with a stethoscope over both sides of the chest to be sure the tube has not been displaced. Assess color change on the CO_2 detector and rise and fall of the chest with each assisted breath.

Enhanced Learning

https://bcove.video/45vPojn

QR 5.4 Scan here to see a 45-second video about securing the endotracheal tube with tape.

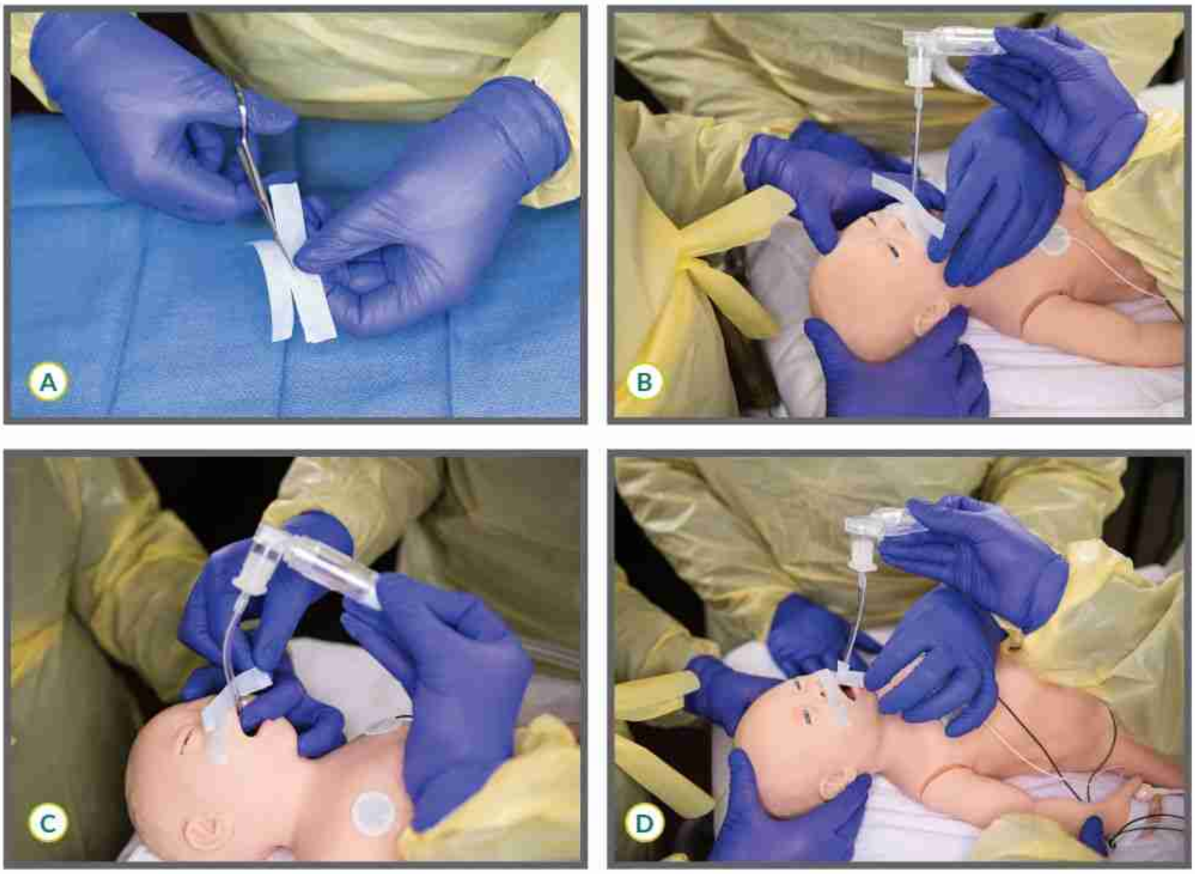


Figure 5.26. Cut a piece of ¾- or ½-inch tape approximately 5 to 6 cm in length. Split the tape on both sides (A). Place the upper 2 segments of tape across the infant's upper lip and both cheeks (B). Turn the ends of the lower 2 segments onto themselves leaving small "tabs" (C). Carefully wrap the lower 2 segments of tape around the tube (D and E).

If the tube will be left in place beyond the initial resuscitation, obtain a chest radiograph for final placement confirmation.

- **The tip of the tube should appear in the mid-trachea adjacent to the first or second thoracic vertebra** (Figure 5.27). The tip should be above the carina, which is generally adjacent to the third or fourth thoracic vertebra.

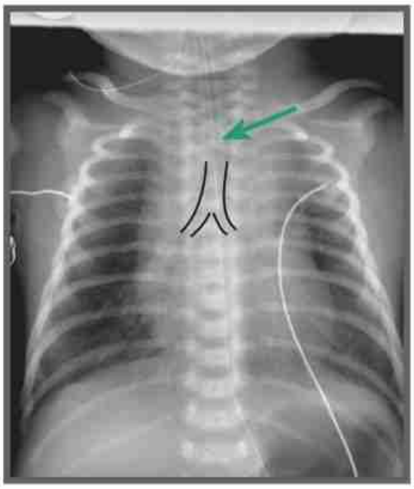


Figure 5.27. Correct placement. The tip of the endotracheal tube (arrow) is adjacent to the second thoracic vertebra.

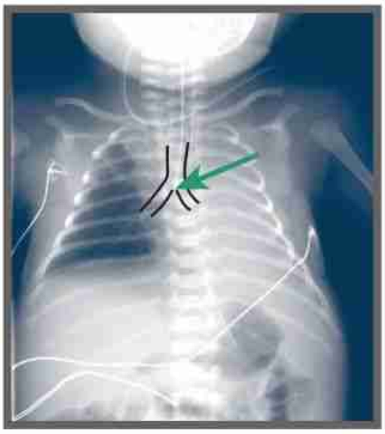


Figure 5.28. Incorrect placement. The tip of the endotracheal tube (arrow) is inserted too far. It is touching the carina, approaching the right main bronchus, and the left lung is collapsed.

- Avoid using the clavicles as a landmark because their location varies depending on the infant's position and the angle at which the radiograph is taken. If the tube has advanced too far, it may touch the carina or enter the right main bronchus and cause the right upper lobe or left lung to collapse (Figure 5.28).

A skilled assistant can improve the efficiency and success of the procedure

Effective teamwork is required to complete the intubation procedure quickly and efficiently. A skilled assistant can perform multiple steps that improve teamwork, shorten the duration of the intubation procedure, and increase the likelihood of first-attempt success.

- Check that the laryngoscope is working.
- Check that suction is set at 80 to 100 mm Hg.
- Prepare the tape or tube-securing device.
- Attach chest leads and begin cardiac monitoring if not already done.
- Ensure that the correct-sized laryngoscope blade and endotracheal tube are selected based on the newborn infant's expected gestational age or weight.
- Communicate with the operator about what method will be used to estimate the insertion depth—the NTL or the estimated insertion depth table.
- Check that the stylet, if used, does not protrude beyond the tube's side or end hole.

Enhanced Learning

https://bcove.video/4mioCSz

QR 5.5 Scan here to see a 2-minute video about the assistant's role during intubation.

- Ensure that the newborn infant and bed are correctly positioned before starting the procedure and are maintained in the correct position throughout the procedure.
- Hold the equipment and pass as directed so that the operator does not need to look away from anatomic landmarks to suction secretions or grasp the tube in preparation for insertion.
- Monitor the newborn infant's heart rate and alert the operator if the intubation attempt lasts longer than 30 seconds.
- Provide thyroid and cricoid pressure as directed.
- Lift the corner of the infant's mouth to make tube insertion easier.
- After tube insertion, carefully remove the stylet and attach the CO_2 detector.
- Assess CO_2 detector color change and listen for increasing heart rate.
- Check the tip-to-gum insertion depth.
- Listen for breath sounds in both axillae and assess chest movement with ventilation.
- Assist with securing the tube.

Enhanced Learning

https://bcove.video/3J8TmqE

QR 5.6 Scan here to see a 1-minute video about tracheal suction using a suction catheter and tracheal aspirator.

Use an endotracheal tube to suction thick secretions from the trachea

If a newborn infant's condition has not improved and you have not been able to achieve chest movement despite all the ventilation corrective steps and a correctly inserted endotracheal tube, there may be thick secretions obstructing the airway. Thick secretions may be from blood, cellular debris, vernix, or meconium. Initially, you may attempt to clear the airway using a suction catheter inserted through the endotracheal tube.

If you cannot quickly clear the airway with the suction catheter, you may be able to clear the airway by applying suction directly to the endotracheal tube using a tracheal aspirator. Although this device is often called a meconium aspirator, it may be used for any thick secretions that are obstructing the airway.

Once the endotracheal tube has been inserted,

- Connect a tracheal aspirator, attached to a suction source (80-100 mm Hg suction), directly to the endotracheal tube connector. Several types of tracheal aspirators are commercially available. Some endotracheal tubes have an integrated suction port.
- Occlude the suction-control port on the aspirator with your finger and gradually withdraw the tube over 3 to 5 seconds as you continue suctioning secretions in the trachea (Figure 5.29).
- Be prepared to resume face mask ventilation, insert a laryngeal mask, or re-intubate with a clean tube.

Figure 5.29. Suctioning thick secretions that obstruct ventilation using an endotracheal tube and a tracheal aspirator.

If the airway was obstructed by secretions that prevented you from achieving effective ventilation, you may need to repeat the suction procedure until you have cleared the airway sufficiently to inflate the lungs and achieve effective ventilation.

Considerations when a newborn infant's condition worsens after intubation

If a newborn infant's condition suddenly worsens after intubation, the endotracheal tube may have been inadvertently displaced. It may have advanced too far into the airway or retracted into the pharynx and outside the trachea. The tube may be obstructed by blood, meconium, or other thick secretions. The infant may have developed a tension pneumothorax that collapses the lungs and prevents gas exchange. Additional information about this complication is presented in Lesson 10 (Special Considerations). Finally, the device used to provide ventilation may have become disconnected from the endotracheal tube or compressed gas source, or it may have developed a leak.

The mnemonic "**DOPE**" can be used to help remember these potential problems (Table 5-4).

Table 5-4. Sudden Deterioration After Intubation (DOPE)

D	Displaced endotracheal tube
O	Obstructed endotracheal tube
P	Pneumothorax
E	Equipment failure

Adapted from Kleinman ME, Chameides L, Schexnayder SM, et al. Part 14: Pediatric advanced life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation.* 2010;122(18 Suppl):S876–S908.

Focus on Teamwork

Inserting an endotracheal tube highlights several opportunities for effective teams to use the Neonatal Resuscitation Program® (NRP®) Key Behavioral Skills.

Behavior	Example
Call for additional help when needed.	If unanticipated intubation is required, you will likely need 3 or more health care providers to quickly perform all of the required tasks without delay.
Communicate effectively.	When preparing to intubate, clearly and calmly request the desired supplies. Confirm the insertion depth with your team members before securing the tube.
Delegate workload optimally.	Determine which team member(s) will perform important tasks such as inserting the endotracheal tube, providing thyroid and cricoid pressure, monitoring the infant's heart rate, placing the CO_2 detector, auscultating breath sounds, assisting with securing the tube, and documenting events.
Allocate attention wisely.	Maintain situation awareness. At all times, a team member needs to be monitoring the infant's condition, the number of insertion attempts, and the duration of insertion attempts, and alerting the operators to any important changes (eg, heart rate, oxygen saturation).
Use available resources.	If an alternative airway is needed, but initial intubation attempts are unsuccessful, do not make repeated intubation attempts. Use your other resources, such as another individual with intubation expertise, a laryngeal mask, or a video laryngoscope. Allow all team members to use their unique skills during the resuscitation process. For example, respiratory therapists may have valuable skills specific to intubation. Using the respiratory therapist's skills during intubation may allow another provider to focus attention on preparing equipment for vascular access and medications.

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own hospital setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. Who is responsible for checking and preparing intubation supplies and equipment before every birth?
2. Who are the providers with intubation skills in your birth setting?
3. Is someone with intubation skills immediately accessible if needed?
4. How often do providers practice their intubation skills?
5. Do assistants know how to measure and secure an endotracheal tube?

Process and outcome measures

1. How often are newborn infants intubated in your birth setting?
2. When intubation is required, how often is a skilled provider present at the time of birth?
3. How often is intubation successful on the first attempt?
4. How often do adverse events occur during intubation?

Frequently Asked Questions

Why should I insert an endotracheal tube before starting chest compressions? Does that just delay the initiation of chest compressions?

In most situations, this program recommends inserting an endotracheal tube prior to starting chest compressions to ensure maximum ventilation efficacy both before and after chest compressions begin. In many cases, the infant's heart rate will increase during the 30 seconds of ventilation following intubation and compressions will not be necessary.

Can the provider with intubation skills be on call outside the hospital or in a distant location?

No. A person with intubation skills should be in the hospital and available to be called for immediate assistance if needed. If the need for intubation is anticipated, this person should be present at the time of birth. It is not sufficient to have someone on call at home or in a remote area of the hospital.

Can a video laryngoscope be useful for neonatal intubation?

Yes, a video laryngoscope may be a helpful device for training novice operators, intubating an infant with a difficult airway, and obtaining a "second look" to ensure the endotracheal tube is positioned in the trachea. A video laryngoscope is a laryngoscope that has an integrated camera that displays a magnified view of the airway structures on a video screen (Figure 5.30). Several types are available, including devices that have a large video monitor on a stand and devices with a small video monitor attached to the laryngoscope handle. When using a video laryngoscope, an instructor can watch the video screen and see what the trainee is seeing directly through the laryngoscope. This allows the instructor to give advice and feedback and confirm that the operator has inserted the tube into the glottis. Studies have shown that trainees and novice operators have improved first-attempt intubation success when guided by an instructor using a video laryngoscope. Other studies have demonstrated a decreased probability of adverse events when using a video laryngoscope. Some video laryngoscopes have a recording function that can be used for debriefing after the procedure is completed. For a newborn infant with a difficult airway, a video laryngoscope may allow

Figure 5.30. Use of a video laryngoscope to guide intubation.

the operator to see the airway structures more easily with less airway manipulation. Using a video laryngoscope does require training and practice, and the smallest blade on some video laryngoscopes is too large for very preterm infants.

Can you prevent oxygen desaturation during intubation by giving supplemental oxygen through a nasal cannula?

Neonatal intubations, both urgent and elective, are frequently complicated by oxygen desaturation. Providing supplemental oxygen through a high-flow nasal cannula before intubation and during the apneic phase of intubation prevents or delays oxygen desaturation in adults and older children. Emerging evidence suggests that providing supplemental oxygen through a high-flow nasal cannula during nonemergent intubation may increase the probability of successful intubation on the first attempt without physiologic instability and may decrease the probability of oxygen desaturation, particularly among those who receive premedication. Using a high-flow nasal cannula requires additional equipment and may not be feasible or effective during urgent intubations performed as part of neonatal resuscitation. Ongoing studies evaluating these questions may inform future recommendations.

Should sedative premedication be used before intubation?

When emergency intubation is performed as part of resuscitation, there is generally insufficient time or vascular access to administer sedative premedication. This program focuses on resuscitation of the newborn infant and, therefore, the details of premedication are not included. Premedication is recommended for nonemergent intubation in the neonatal intensive care unit.

LESSON 5 REVIEW

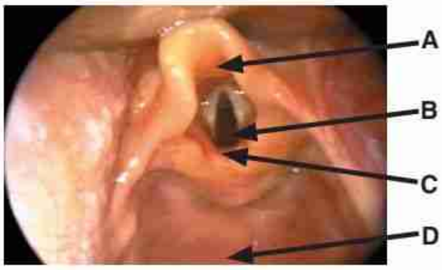
1. A newborn infant has been receiving face mask ventilation but is not improving. Despite performing the first 5 ventilation corrective steps, the heart rate is not rising and there is poor chest movement. An alternative airway, such as an endotracheal tube or a laryngeal mask, (should)/(should not) be inserted immediately.

2. For newborn infants weighing less than 1,200 g, the recommended endotracheal tube size is (2.5 mm)/(3.5 mm).

3. If using a stylet, the tip of the stylet (must)/(must not) extend beyond the endotracheal tube's side and end holes.

4. The preferred straight Miller laryngoscope blade size for use in a term infant is (No. 1)/(No. 0).

5. In the photograph, which arrow is pointing to the epiglottis?

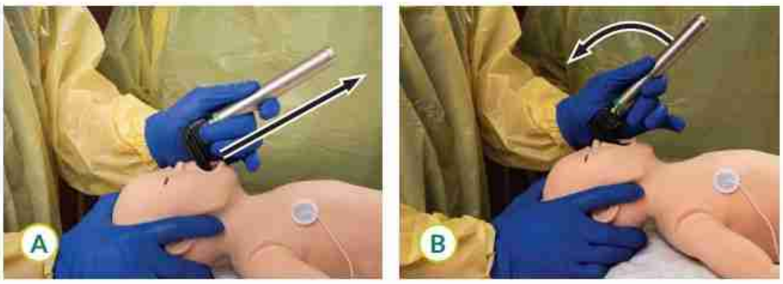


6. Once started, you should try to take no longer than (30)/(60) seconds to complete the endotracheal intubation procedure.

7. If a newborn infant's condition worsens after endotracheal intubation, list 4 possible causes.

   1._______, 2. _______, 3. _______, 4. _______

8. Which image shows the correct way to lift the tongue out of the way and expose the larynx?



9. You have inserted an endotracheal tube and are ventilating through it. The CO_2 detector does not change color and the infant's heart rate is decreasing. The tube is most likely inserted in the (esophagus)/(trachea).

10. The 2 most important indicators that the endotracheal tube has been inserted in the trachea are demonstrating exhaled ________ and observing a rapidly increasing __________.

11. You have inserted a laryngoscope and are attempting intubation. You see the view depicted in the following image. The correct action is to (advance the laryngoscope farther)/(withdraw the laryngoscope).

Answers

1. An alternative airway, such as an endotracheal tube or a laryngeal mask, should be inserted immediately.

2. For newborn infants weighing less than 1,200 g, the recommended endotracheal tube size is 2.5 mm. A 2.0-mm tube (*optional*) may be considered for extremely preterm infants weighing less than approximately 750 g.

3. The tip of the stylet must not extend beyond the endotracheal tube's side and end holes.

4. The preferred straight Miller laryngoscope blade size for use in a term newborn is No. 1.

5. Arrow A is pointing to the epiglottis.

6. Once started, you should try to take no longer than 30 seconds to complete the endotracheal intubation procedure.

7. Possible causes include (1) displaced endotracheal tube, (2) obstructed endotracheal tube, (3) pneumothorax, (4) equipment failure.

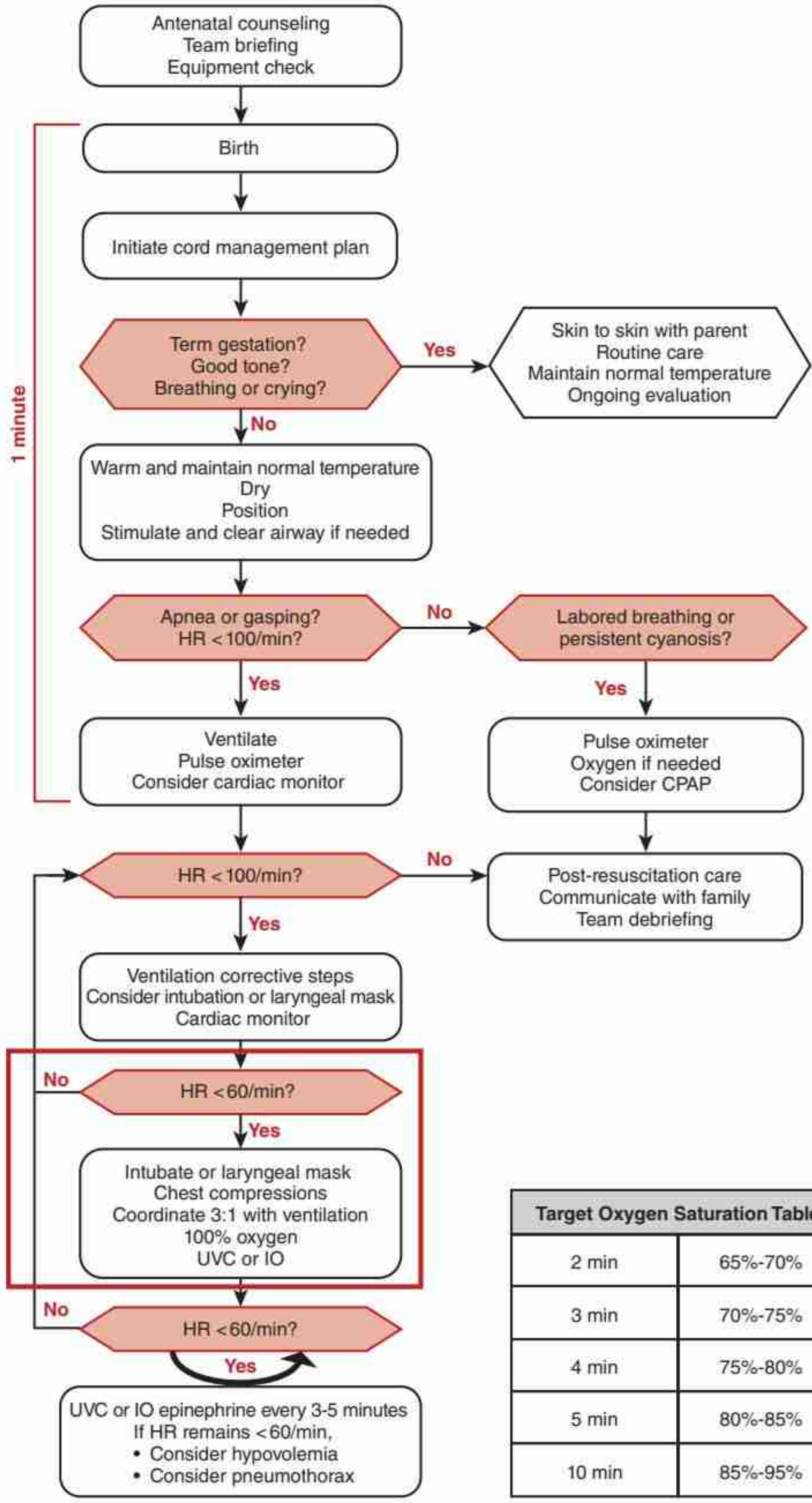
8. Image A shows the correct way to lift the tongue out of the way and expose the larynx.
9. The tube is most likely inserted in the esophagus.
10. The 2 most important indicators that the endotracheal tube has been inserted in the trachea are demonstrating exhaled CO_2 (CO_2 detector changes to yellow) and observing a rapidly increasing heart rate.
11. The correct action is to advance the laryngoscope farther.

Lesson 6

Chest Compressions

What you will learn

- When to begin chest compressions
- How to administer chest compressions
- How to coordinate chest compressions with ventilation
- When to stop chest compressions



Target Oxygen Saturation Table	
2 min	65%-70%
3 min	70%-75%
4 min	75%-80%
5 min	80%-85%
10 min	85%-95%

Key Points

1. Chest compressions are indicated when the heart rate remains less than 60 beats per minute (bpm) despite at least 30 seconds of ventilation that inflates the lungs (chest movement).

2. Chest compressions are not indicated before you have established ventilation that effectively inflates the lungs. Continue to focus on achieving effective ventilation.

3. In most cases, ventilation should have been provided through a properly inserted endotracheal tube.

4. If endotracheal intubation is not successful or not feasible, it is reasonable to administer ventilation during chest compressions with a properly inserted laryngeal mask.

5. If compressions are started, call for help if needed as additional personnel may be required to prepare for vascular access and epinephrine administration.

6. Inaccurate assessment of heart rate can result in unnecessary cardiac compressions. If perinatal risk factors suggest the likelihood of a complex resuscitation, consider placing cardiac monitor leads once assisted ventilation starts.

7. Once the alternative airway is secure, move to the head of the bed to give chest compressions. This provides space for safe insertion of an umbilical vein catheter and has mechanical advantages that result in less compressor fatigue.

8. If the heart rate is less than 60 bpm, cardiac output may be very low, and the pulse oximeter may not have a reliable signal. When chest compressions begin, ventilate using 100% oxygen until the heart rate is at least 60 bpm and the pulse oximeter has a reliable signal.

9. To administer chest compressions, place the tips of your thumbs on the sternum just below an imaginary line connecting the infant's nipples. The tips of your thumbs should be placed in the midline, not on either side. Encircle the torso with both hands. Support the back with your fingers. Your fingers do not need to touch each other.

10. Use enough downward pressure to depress the sternum approximately one-third of the anterior-posterior diameter of the chest.

11. The compression rate is 90 compressions per minute and the breathing rate is 30 breaths per minute. To achieve the correct rate, use the rhythm: "**One**-and-**Two**-and-**Three**-and-*Breathe*."

12. After 60 seconds of chest compressions and ventilation, briefly stop compressions and check the heart rate. A cardiac monitor is the preferred method for assessing heart rate during chest compressions. You may also assess the infant's heart rate by listening with a stethoscope. If necessary, you may briefly stop ventilation to auscultate the heart rate.

13. If the heart rate is at least 60 bpm, discontinue compressions and resume ventilation at 30 to 60 breaths per minute.

14. When a reliable pulse oximeter signal is achieved, adjust the oxygen concentration to meet the target oxygen saturation guidelines.

15. If the infant's heart rate remains less than 60 bpm despite 60 seconds of effective ventilation and high-quality, coordinated chest compressions, epinephrine administration is indicated and emergency vascular access is needed.

Case: Late preterm newborn infant who does not respond to effective ventilation

Your team is called to attend an emergency cesarean birth at 36 weeks' gestation because of fetal distress. The amniotic fluid is clear. You complete a pre-resuscitation briefing, assign roles and responsibilities, and prepare your supplies and equipment. After birth, the obstetrician dries and stimulates the infant to breathe, but the infant remains limp and apneic. The intact umbilical cord is milked toward the infant, the cord is clamped and cut, and the infant is moved to a radiant warmer. You position the infant's head and neck and provide brief additional stimulation, but the infant remains apneic. You begin assisted ventilation with 21% oxygen, while other team members assess the infant's heart rate with a stethoscope, place a pulse oximeter sensor on the right hand, and document the events as they occur. The pulse oximeter does not have a reliable signal and cardiac monitor leads are placed on the infant's chest. The heart rate is 40 beats per minute (bpm); it is not increasing; and the infant's chest is not moving with ventilation. You proceed through the ventilation corrective steps, including increasing the inflation pressure, but the infant's chest still does not move with ventilation and the infant's heart rate does not increase.

A team member inserts and secures an endotracheal tube, and ventilation resumes. The carbon dioxide (CO_2) detector does not change color;

however, there is good chest movement with ventilation through the tube, and breath sounds are equal in the axillae. Ventilation through the endotracheal tube is continued for 30 seconds, but the heart rate remains at 40 bpm. Your team increases the oxygen concentration (FIO_2) to 100%, begins chest compressions coordinated with ventilation, and calls for additional help. During compressions and coordinated ventilation, the CO_2 detector begins to change color to yellow. After 60 seconds of compressions and coordinated ventilation, you pause compressions to check the infant's heart rate and it is above 60 bpm. You stop compressions and continue ventilation as the heart rate continues to increase. Your team members frequently reevaluate the infant's condition and share their assessments with each other. The pulse oximeter shows a reliable signal and the FIO_2 is adjusted to meet the oxygen saturation target. As the infant's tone improves, you observe intermittent spontaneous respiratory effort and the infant's heart rate increases to 160 bpm. A team member gives both parents an interval update and explains the treatment plan. The infant is transferred to the special care nursery for post-resuscitation care. Shortly afterward, your team members conduct a debriefing to discuss their preparation, teamwork, and communication.

Chest compressions improve coronary artery blood flow

Newborn infants who do not respond to ventilation that inflates their lungs are likely to have very low blood oxygen levels, significant acidosis, and insufficient blood flow in their coronary arteries. As a result, cardiac muscle function is severely depressed. Improving coronary artery blood flow is crucial for restoring the heart's function.

The heart lies in the chest between the lower third of the sternum and the spine. Rhythmically depressing the sternum compresses the heart against the spine, pushes blood forward, and increases the blood pressure in the aorta. When pressure on the sternum is released, the heart refills with blood, and blood flows into the coronary arteries. By compressing the chest and ventilating the lungs, you help to restore the flow of oxygenated blood to the heart muscle.

Indications for chest compressions

- Chest compressions are indicated if the infant's **heart rate remains less than 60 bpm after at least 30 seconds of ventilation that inflates the lungs**, as evidenced by chest movement with ventilation.
- Chest compressions **are not indicated** before you have established ventilation that effectively inflates the lungs. Continue to focus on achieving effective ventilation.
  - In most cases, ventilation should have been provided through a properly inserted endotracheal tube.

- If endotracheal intubation is not successful or not feasible, it is reasonable to administer ventilation during chest compressions with a properly inserted laryngeal mask.

If compressions are started, call for help if needed as additional personnel may be required to prepare for vascular access and epinephrine administration.

Ventilation of the newborn infant's lungs is the single most important and effective step in neonatal resuscitation. If the lungs have been adequately ventilated, it is rare for a newborn infant to require chest compressions. Only approximately 1 to 3 per 1,000 newborn infants are expected to require chest compressions. To improve the efficacy and efficiency of ventilation, this program recommends ventilating through a properly inserted alternative airway for 30 seconds before starting chest compressions. In most cases, you should not begin chest compressions unless you have achieved chest movement with your ventilation attempts. If the chest is not moving, you are most likely not providing effective ventilation. Focus your attention on the ventilation corrective steps, including the insertion of an alternative airway and ensuring that the airway is not obstructed.

Sometimes a newborn infant receives unnecessary chest compressions because the heart rate is inaccurately assessed. If perinatal risk factors suggest the likelihood of a complex resuscitation, consider placing cardiac monitor leads once assisted ventilation starts. The cardiac monitor can then be used to assess the heart rate and support critical decision-making, such as beginning chest compressions and administering medication.

Administer compressions from the head of the bed

When chest compressions are started, you may be standing at the side of the warmer. One of your team members, standing at the head of the bed, will be providing coordinated ventilations through an endotracheal tube.

If chest compressions are required, there is a high probability that you will also need to insert an emergency umbilical vein catheter for intravascular access. It is difficult to insert an umbilical vein catheter if the person administering compressions is standing at the side of the warmer with their arms encircling the infant's chest. **Once intubation is completed and the tube is secure, the compressor should move to the head of the bed while the person operating the ventilation device moves to the side (Figure 6.1).** In addition to providing space for umbilical vein catheter insertion, this position has mechanical advantages that result in less fatigue for the compressor.

Figure 6.1. Compressor standing at the head of the bed.

Compression location

During chest compressions, apply pressure to the lower third of the sternum (Figure 6.2). Place your thumbs on the sternum, either side-by-side or one on top of the other, **just below an imaginary line connecting the infant's nipples** (Figure 6.3). The thumbs should be flexed at the first joint. The tips of your thumbs should be placed in the midline, not on either side. Do not place your thumbs on the ribs or on the xiphoid. The xiphoid is the small, pointed projection at the bottom of the sternum where the lower ribs meet at the midline.

Enhanced Learning

https://bcove.video/4ma9ira

QR 6.1 Scan here to see a 2.5-minute video about how to administer chest compressions.

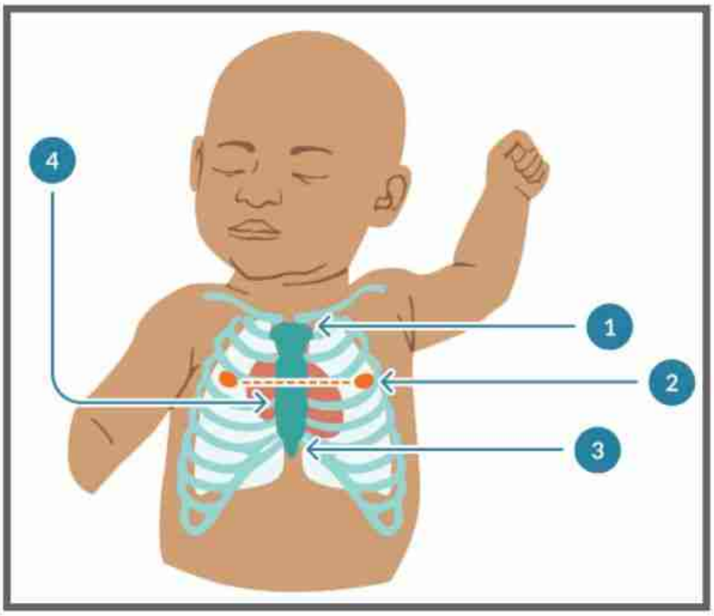


Figure 6.2. Landmarks for chest compressions. 1. Sternum, 2. Nipple line, 3. Xiphoid, 4. Compression area.

Figure 6.3. Chest compressions using 2 thumbs from the head of the bed. Thumbs are placed over the lower third of the sternum, in the midline, with hands encircling the chest. The thumbs are not placed on the ribs or the xiphoid.

Encircle the infant's chest with your hands. Place your fingers under the infant's back to provide support. Your fingers do not need to touch.

Compression depth

Using your thumbs, press the sternum downward to compress the heart between the sternum and the spine. Do not squeeze the chest with your encircling hands. **With your thumbs correctly positioned, use enough pressure to depress the sternum approximately one-third of the anterior-posterior diameter of the chest** (Figure 6.4)**, and then release**

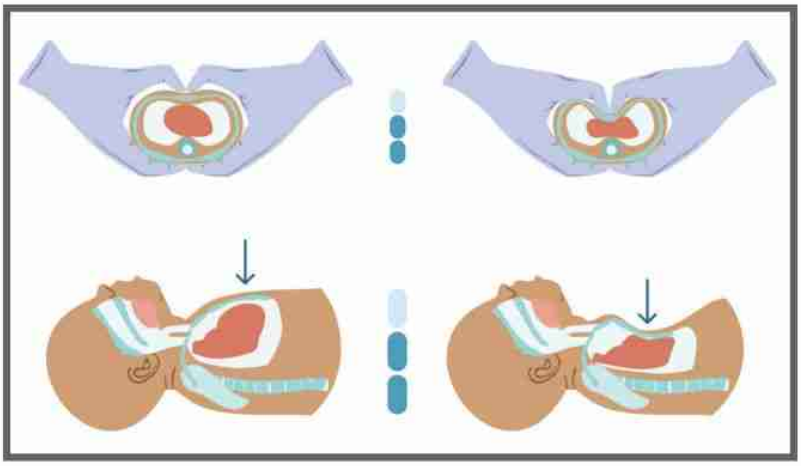


Figure 6.4. Compression depth is approximately one-third of the anterior-posterior diameter of the chest.

the pressure to allow the heart to refill. One compression consists of the downward stroke plus the release. The actual distance compressed will depend on the size of the infant.

Your thumbs should remain in contact with the chest during both compression and release. Allow the chest to fully expand by lifting your thumbs sufficiently during the release phase to permit the chest to expand; however, do not lift your thumbs completely off the chest between compressions. If your thumbs are lifted completely off the chest during the release phase, they may become accidentally positioned in an incorrect location during the next phase of compressions.

Compression rate

The compression rate is 90 compressions per minute, and the ventilation rate is 30 breaths per minute. To achieve this rate, you will give 3 rapid compressions and 1 ventilation during each 2-second cycle.

Coordinate chest compressions and ventilation

During neonatal cardiopulmonary resuscitation, chest compressions are always accompanied by coordinated ventilation. **Give 3 rapid compressions followed by 1 ventilation.**

Coordinated Compressions and Ventilations
3 compressions + 1 ventilation every 2 seconds

To assist coordination, the person doing compressions should count the rhythm out loud. Speak loudly enough for the person ventilating to hear the rhythm, but not so loud that the rest of the team members cannot hear each other as they share information. The goal is to give 90 compressions per minute and 30 ventilations per minute (90 + 30 = 120 events per minute). This is a rapid rhythm. Achieving good coordination requires practice.

Learn the rhythm by counting out loud: "**One**-and-**Two**-and-**Three**-and-*Breathe*; **One**-and-**Two**-and-**Three**-and-*Breathe*; **One**-and-**Two**-and-**Three**-and-*Breathe*."

- Compress the chest with each counted number ("**One, Two, Three**").
- Release the chest between each number ("-and-").
- Pause compressions and give a breath when the compressor calls out "*Breathe*."

Inhalation occurs during the "Breathe" portion of the rhythm, and exhalation occurs during the downward stroke of the next compression.

Oxygen concentration during chest compressions

When chest compressions are started, increase the F_{IO_2} to 100%. Once the heart rate is at least 60 bpm and a reliable pulse oximeter signal is achieved, adjust the F_{IO_2} to meet the target oxygen saturation guidelines.

The ideal F_{IO_2} to use during chest compressions is an area of active research, and this recommendation is based on expert opinion. Oxygen is essential for organ function. During chest compressions, blood flow to vital organs may be decreased, and using a higher F_{IO_2} may improve oxygen uptake and delivery. In addition, circulation may be so poor that the pulse oximeter will not give a reliable signal and oxygen saturation targeting may not be possible. However, once heart function has recovered, continuing to use 100% oxygen may increase the risk of tissue damage from excessive oxygen exposure.

Evaluate the newborn infant's response to chest compressions

Wait 60 seconds after starting coordinated chest compressions and ventilation before briefly pausing compressions to reassess the heart rate. If necessary, briefly pause ventilation.

A cardiac monitor is the preferred method for assessing heart rate during chest compressions. You may assess the infant's heart rate by listening with a stethoscope or using a pulse oximeter.

There are limitations to each of these methods.

- During resuscitation, auscultation can be difficult, prolonging the interruption in compressions, and potentially giving inaccurate results.
- If the infant's perfusion is very poor, a pulse oximeter may not reliably detect the infant's pulse.
- A cardiac monitor displays the heart's electrical activity and may shorten the interruption in compressions, but electrical activity may be present without the heart pumping blood. This unusual finding is called *pulseless electrical activity* (PEA), and is suspected when the cardiac monitor shows electrical activity but the infant's condition continues to deteriorate without palpable pulses, audible heart sounds, or a signal on the pulse oximeter. In the newborn, PEA is treated the same as absent electrical activity (heart rate = 0 or asystole).

Studies have shown that it may take 1 minute or more for the heart rate to increase after chest compressions are started. When compressions are stopped, coronary artery perfusion is decreased and requires time to recover once compressions are resumed. **Therefore, it is important to avoid unnecessary interruptions and delays in resuming chest compressions because each time you stop compressions, you may delay the heart's recovery.**

After administering chest compressions for 2 to 5 minutes, the compressor may experience fatigue, and the quality of chest compressions may deteriorate. If the compressor experiences fatigue; the quality of compressions deteriorates; or compressions continue for more than 5 minutes, consider changing roles to allow the compressor to recover and ensure administration of effective chest compressions.

Stopping chest compressions

Stop chest compressions when the heart rate is 60 bpm or greater.

Once compressions are stopped, return to ventilating at 30 to 60 breaths per minute. When a reliable pulse oximeter signal is achieved, adjust the FIO_2 to meet the target oxygen saturation guidelines.

Chest compression summary

Table 6-1 summarizes the recommended method of administering chest compressions during neonatal resuscitation.

Table 6-1. Neonatal Chest Compressions

Compressor position	Head of bed
Thumb position on the sternum	Two thumbs positioned in the midline just below the nipples. Avoid the ribs and xiphoid.
Depth	One-third anterior-posterior chest diameter
Rate	90 compressions per minute coordinated with 30 breaths per minute
Rhythm	**One**-and-**Two**-and-**Three**-and-***Breathe***
Oxygen concentration (FIO_2)	100% until heart rate ≥ 60 bpm and reliable signal on pulse oximeter
Response check	60 seconds after starting coordinated compressions and ventilations
Stop compressions	Heart rate ≥ 60 bpm

What do you do if the heart rate is *not* improving after 60 seconds of compressions?

While you continue to administer chest compressions and coordinated ventilation, your team needs to quickly assess the quality of your ventilation and compressions. In most circumstances, endotracheal intubation or laryngeal mask insertion should have been performed. If not, one of these procedures should be performed now.

Quickly ask each of the 5 questions in Table 6-2 out loud and confirm your assessment as a team.

Table 6-2. Questions to Ask When Heart Rate Is Not Improving With Compressions and Ventilation

1. Is the airway secured with a properly inserted endotracheal tube or laryngeal mask?
2. Is the chest moving with each breath?
3. Is 100% oxygen being administered through the ventilation device?
4. Are 3 compressions coordinated with 1 ventilation every 2 seconds?
5. Is the depth of compressions one-third of the anterior-posterior diameter of the chest?

If the infant's heart rate remains less than 60 bpm despite 60 seconds of effective ventilation and high-quality, coordinated chest compressions, epinephrine administration is indicated and emergency vascular access is needed.

Focus on Teamwork

Providing chest compressions highlights several opportunities for effective teams to use the Neonatal Resuscitation Program® (NRP®) Key Behavioral Skills.

Behavior	Example
Anticipate and plan.	Ensure that you have enough personnel present at the time of delivery based on the risk factors you identified. If there is evidence of severe fetal distress, be prepared for the possibility of a complex resuscitation, including chest compressions. If chest compressions are required, there is a high likelihood of also needing vascular access and epinephrine. Plan for this possibility during your team briefing. If compressions are started, a team member should immediately prepare the equipment necessary for emergency vascular access (umbilical vein catheter or intraosseous needle) and epinephrine.
Call for additional help when needed. Delegate workload optimally.	If chest compressions are required, you may need 4 or more health care providers. Performing all of the tasks quickly, including ventilation, auscultation, placing a pulse oximeter, intubating the airway, administering compressions, monitoring the quality of compressions and ventilations, monitoring the infant's response, preparing emergency vascular access, preparing epinephrine, documenting events as they occur, and supporting the infant's family, requires multiple team members.
Clearly identify a team leader. Allocate attention wisely.	The team leader needs to maintain situation awareness, paying attention to the entire situation and not becoming distracted by any single activity or procedure. This means that leadership may need to shift to another person if the team leader is performing a procedure that occupies their attention. It is important for someone to monitor the quality of ventilation and compressions while also monitoring the infant's heart rate.
Use available resources.	If the compressor becomes fatigued, have another team member take over compressions. A respiratory therapist can administer ventilation, enabling a nurse or physician to prepare for emergency vascular access and medication administration.

Continued

Behavior	Example
Communicate effectively. Maintain professional behavior.	During compressions, the compressor and ventilator need to coordinate their activity and maintain correct technique. They cannot perform other roles or have conversations while compressions are in progress. If a correction is required, make a clear, calm, and directed statement. Speak clearly, directly, and loudly enough for team members to hear you, but avoid extraneous conversation or unnecessarily loud communication that may be distracting. Share information with the individual documenting events so it can be accurately noted.

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own hospital setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. Who are the providers with chest compression skills in your birth setting?
2. Is someone with chest compression skills immediately accessible if needed?
3. How often do providers practice their chest compression and coordinated ventilation skills?
4. Is a cardiac monitor accessible in your birth setting for use when an infant requires intubation and chest compressions?

Process and outcome measures

1. How often do newborns receive chest compressions in your birth setting?
2. When compressions are required, how often is a skilled provider present at the time of birth?
3. How often is an endotracheal tube or a laryngeal mask inserted before chest compressions are started?
4. How often is the FiO_2 increased to 100% when compressions begin?

Frequently Asked Questions

What are the potential complications of chest compressions?

Chest compressions can cause trauma to the infant. Two vital organs lie within the rib cage—the heart and lungs. As you perform chest compressions, you must apply enough pressure to compress the heart between the sternum and spine without damaging underlying organs. The liver lies in the abdominal cavity partially under the ribs. Pressure applied directly over the xiphoid could cause laceration of the liver.

Chest compressions should be administered with the force directed straight down in the midline over the lower third of the sternum. Do not become distracted and allow your thumbs to push on the ribs connected to the sternum. By following the procedure outlined in this lesson, the risk of injuries can be minimized.

Why does the Neonatal Resuscitation Program Algorithm follow A-B-C (Airway-Breathing-Compressions) when other programs follow C-A-B (Compressions-Airway-Breathing)?

The NRP focuses on establishing effective ventilation, rather than starting chest compressions because the vast majority of newborn infants who require resuscitation have a healthy heart. The underlying problem is respiratory failure with impaired gas exchange; therefore, ventilation of the infant's lungs is the single most important and effective step during neonatal resuscitation. Very few infants will require chest compressions once effective ventilation has been established. Other programs focus on chest compressions because adults are more likely to have a primary cardiac problem causing cardiorespiratory collapse, and teaching a single approach for older children and adults simplifies the educational process.

Why does the Neonatal Resuscitation Program use a 3:1 compression-to-ventilation ratio instead of the 15:2 ratio used in other programs?

Neonatal animal studies have shown that the 3:1 ratio shortens the time to return of spontaneous circulation. Alternative ratios, as well as asynchronous (uncoordinated) ventilations after intubation, are routinely used outside the newborn period but have not been shown to improve recovery in newborn infants. Additional chest compression techniques and ratios are currently being studied, but there is insufficient evidence to recommend them at this time.

In the case at the beginning of the lesson, the CO_2 detector did not change color even though the endotracheal tube was correctly inserted. Why?

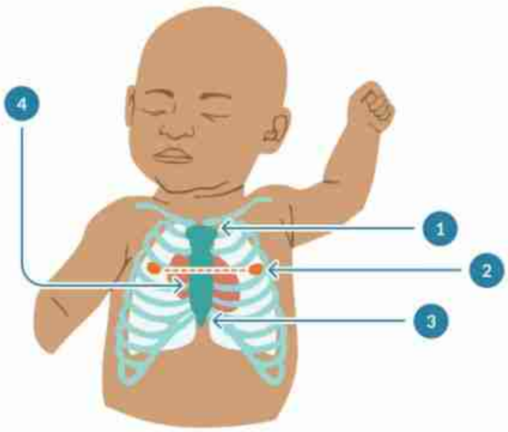
If an infant has a very low heart rate or very poor cardiac function, there may not be enough CO_2 carried to the lungs to change the detector's color. In this case, you will need to use other indicators (chest movement and breath sounds) to determine if the endotracheal tube is correctly inserted. If the CO_2 detector begins to change color during compressions, this may be an indication of improving cardiac function.

LESSON 6 REVIEW

1. A newborn infant is apneic at birth. The infant's condition does not improve with the initial steps, and ventilation is started. After 30 seconds, the heart rate has increased from 40 beats per minute (bpm) to 80 bpm. Chest compressions (should)/(should not) be started. Ventilation (should)/(should not) continue.

2. A newborn infant is apneic at birth. The infant's condition does not improve with the initial steps or ventilation. An endotracheal tube is inserted properly, the chest moves with ventilation, bilateral breath sounds are present, and ventilation has continued for another 30 seconds. The heart rate remains at 40 bpm. Chest compressions (should)/(should not) be started. Ventilation (should)/(should not) continue.

3. Which area on this infant would you apply chest compressions?



4. The correct depth of chest compressions is approximately

   a. One-fourth of the anterior-posterior diameter of the chest

   b. One-third of the anterior-posterior diameter of the chest

   c. One-half of the anterior-posterior diameter of the chest

   d. Two inches

5. The ratio of chest compressions to ventilation is (3 compressions to 1 ventilation)/(1 compression to 3 ventilations).

6. What phrase is used to achieve the correct rhythm for coordinating chest compressions and ventilation? ________________________________.

7. You should briefly stop compressions to check the infant's heart rate response after (30 seconds)/(60 seconds) of chest compressions with coordinated ventilations.

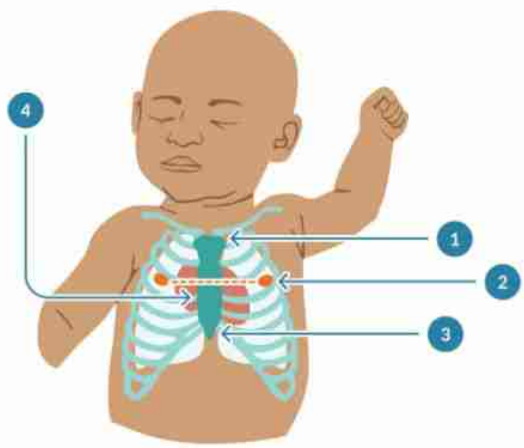
8. The threshold for discontinuing chest compressions is when the heart rate is at least (100 bpm)/(60 bpm).

Answers

1. Chest compressions should not be started. Ventilation should continue.

2. Chest compressions should be started. Ventilation should continue.

3. Compression area (4), in the midline, just below the nipples.



4. The correct depth of chest compressions is approximately one-third of the anterior-posterior diameter of the chest.

5. The ratio of chest compressions to ventilation is 3 compressions to 1 ventilation.

6. "**One**-and-**Two**-and-**Three**-and-***Breathe***. ..."

7. You should briefly stop compressions to check the infant's heart rate response after 60 seconds of chest compressions with coordinated ventilations.

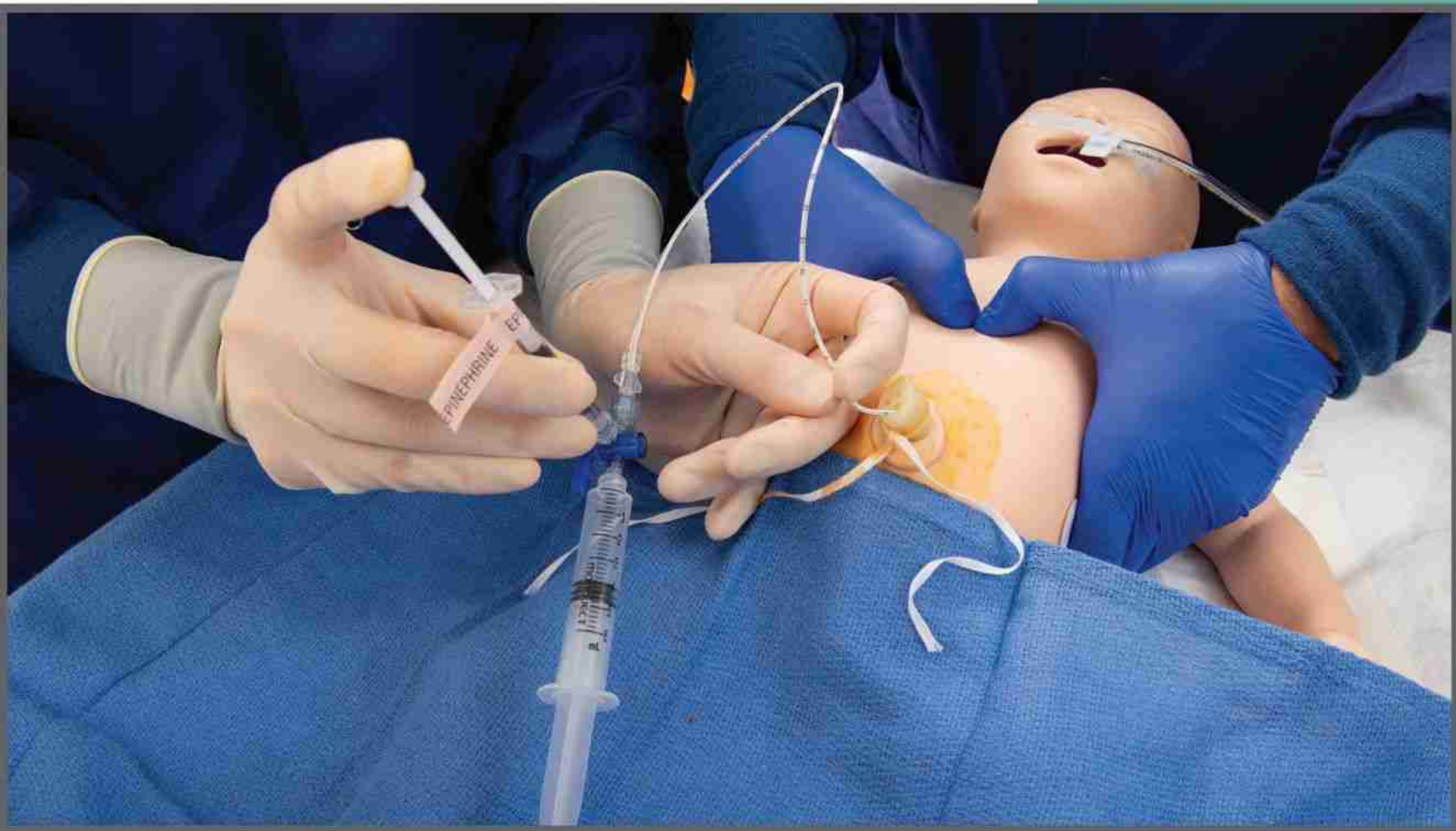
8. The threshold for discontinuing chest compressions is when the heart rate is at least 60 bpm.

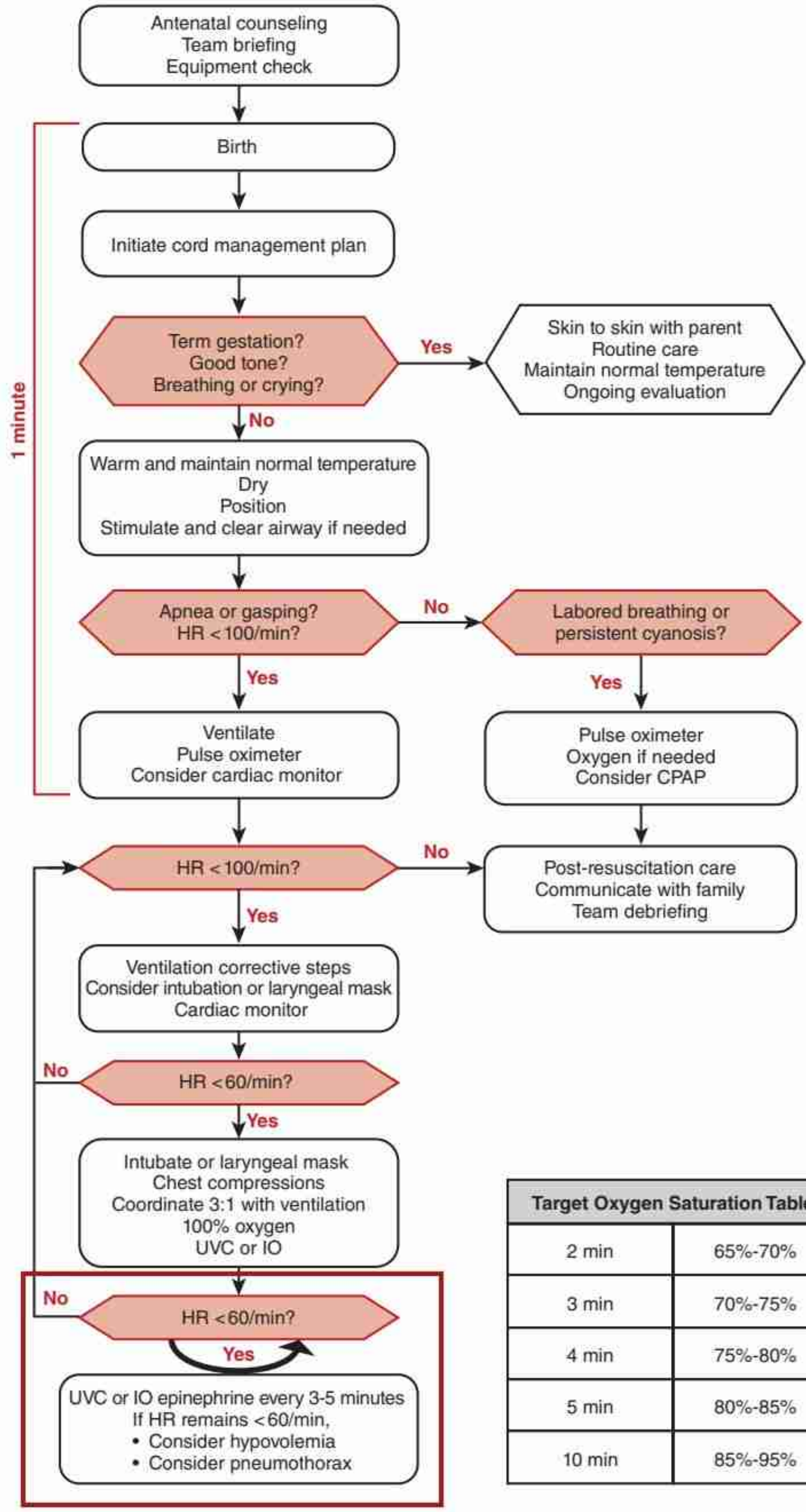
Lesson 7

Medications

What you will learn

- When to administer epinephrine during resuscitation
- How to administer epinephrine
- When to administer a volume expander during resuscitation
- How to administer a volume expander
- What to do if the infant is not improving after giving intravenous epinephrine and volume expander
- How to insert an emergency umbilical vein catheter
- How to insert an intraosseous needle





Target Oxygen Saturation Table	
2 min	65%-70%
3 min	70%-75%
4 min	75%-80%
5 min	80%-85%
10 min	85%-95%

Key Points

1. Epinephrine is indicated when the heart rate remains less than 60 beats per minute after:
   a. At least 30 seconds of ventilation that inflates the lungs as evidenced by chest movement, and
   b. Another 60 seconds of chest compressions coordinated with ventilation using 100% oxygen.

2. Epinephrine is not indicated before you have established ventilation that effectively inflates the lungs. Continue to focus on achieving effective ventilation.
   a. In most cases, ventilation should have been provided through a properly inserted endotracheal tube.
   b. If endotracheal intubation is not successful or not feasible, it is reasonable to administer ventilation during medication administration with a properly inserted laryngeal mask.

3. Epinephrine recommendations
   a. Concentration: 0.1 mg/mL = 1 mg/10 mL
   b. Route: Intravenous *(preferred)* or intraosseous
      i. The central venous circulation may be rapidly accessed using either an umbilical vein catheter or an intraosseous needle. For infants requiring vascular access immediately after birth, the umbilical vein is recommended.
      ii. Endotracheal epinephrine may be considered while vascular access is being established. Obtaining vascular access should not be delayed.
   c. Preparation:
      i. Intravenous or intraosseous: 1-mL syringe (labeled *Epinephrine-IV*)
      ii. Endotracheal: 3- to 5-mL syringe (labeled *Epinephrine-ET ONLY*)
   d. Dose:
      i. Intravenous or intraosseous = 0.02 mg/kg (equal to 0.2 mL/kg)
         a. May repeat every 3 to 5 minutes
         b. Acceptable range = 0.01 to 0.03 mg/kg (equal to 0.1 to 0.3 mL/kg)

c. Rate: *Rapidly*—as quickly as possible

d. Flush: Follow intravenous or intraosseous dose with a 3-mL saline flush

ii. Endotracheal = 0.1 mg/kg (equal to 1 mL/kg)

a. Acceptable range = 0.05 to 0.1 mg/kg (0.5 to 1 mL/kg)

b. If no response, recommend intravenous or intraosseous administration for subsequent doses

4 Administration of a volume expander is indicated if the infant is not responding to the steps of resuscitation and there are signs of shock or a history of acute blood loss.

5 Volume expansion recommendations

a. Solution: Normal saline (NS) or type O Rh-negative blood

b. Route: Intravenous or intraosseous

c. Preparation: 30- to 60-mL syringe (labeled NS or O- blood)

d. Dose: 10 mL/kg

e. Rate: Over 5 to 10 minutes

6 If there is a confirmed absence of heart rate after all appropriate steps of resuscitation have been performed, cessation of resuscitation efforts should be discussed with the team and family. A reasonable time frame for considering cessation of resuscitation efforts is around 20 minutes after birth; however, the decision to continue or discontinue should be individualized based on patient and contextual factors.

Case: Resuscitation with ventilation, chest compressions, and medications

Your team is called to attend a birth at 36 weeks' gestation complicated by a history of decreased fetal movement and vaginal bleeding. Fetal bradycardia is noted on the monitor. Your resuscitation team quickly assembles in the birth setting, completes a pre-resuscitation team briefing, and prepares supplies and equipment. An endotracheal tube, an umbilical vein catheter, epinephrine, and volume replacement are prepared because an extensive resuscitation is anticipated. An emergency cesarean birth is performed under general anesthesia and the obstetrician reports bloody amniotic fluid. The umbilical cord is clamped and cut, and a limp, pale infant is handed to the resuscitation team. A team member begins documenting the resuscitation events as they occur.

You perform the initial steps under a radiant warmer; however, the infant remains limp without spontaneous respirations. You begin assisted ventilation with 21% oxygen, a pulse oximeter sensor is placed on the infant's right hand, and cardiac monitor leads are placed on the chest. The infant's heart rate is 40 beats per minute (bpm) by cardiac monitor and auscultation, but the pulse oximeter does not display a reliable signal. Despite ventilation that moves the infant's chest, the heart rate does not improve. The newborn infant is successfully intubated and ventilation through the endotracheal tube continues for 30 seconds, but the heart rate remains 40 bpm. Chest compressions are performed with coordinated ventilation using 100% oxygen. A team member confirms the quality of compressions and ventilation, but, after 60 seconds, the infant's heart rate has not increased.

One team member quickly inserts an umbilical vein catheter and another administers epinephrine and a saline flush through the catheter. Ventilation and compressions are continued, and, 1 minute later, the infant's heart rate has increased to greater than 60 bpm. Chest compressions are stopped. As the heart rate continues to increase, the pulse oximeter begins to detect a reliable signal and shows oxygen saturation of 70% and rising. Assisted ventilation continues and the oxygen concentration is adjusted to maintain the infant's oxygen saturation within the target range. By 10 minutes after birth, the infant makes an initial gasp. The non-birthing parent arrives at the bedside and touches and comforts the infant. A member of your team gives the parent an interval update and explains the treatment plan. The infant is transferred to the special care nursery for post-resuscitation care. Shortly afterward, your team members conduct a debriefing to discuss their preparation, teamwork, and communication.

A very small number of newborn infants will require emergency medication

Most newborn infants requiring resuscitation will improve without emergency medications. Before administering medications, you should ensure the accuracy of your heart rate assessment and check the effectiveness of ventilation and compressions. In most cases, you should have inserted an endotracheal tube or a laryngeal mask to improve the efficacy of ventilation.

Despite inflating the lungs and augmenting cardiac output with chest compressions, a very small number of newborn infants (approximately 1 per 1,000 newborns) will still have a heart rate less than 60 bpm. This occurs when blood flow into the coronary arteries is severely decreased, resulting in such low oxygen delivery to the newborn infant's heart that it cannot contract effectively. These infants should receive epinephrine to improve coronary artery perfusion and oxygen delivery. Newborn infants with shock from acute blood loss (eg, bleeding vasa previa, fetal trauma, cord disruption, severe cord compression) may also require emergency volume expansion.

Epinephrine

Epinephrine is a cardiac and vascular stimulant. It causes constriction of blood vessels outside of the heart, which increases blood flow into the coronary arteries. Blood flowing into the coronary arteries carries the oxygen required to restore cardiac function. In addition, epinephrine increases the rate and strength of cardiac contractions.

Epinephrine administration

Indication

Epinephrine is indicated if the infant's **heart rate remains less than 60 bpm after**

- At least 30 seconds of ventilation that inflates the lungs as evidenced by chest movement, **and**
- Another 60 seconds of chest compressions coordinated with ventilation using 100% oxygen.

Epinephrine **is not** indicated before you have established ventilation that effectively inflates the lungs. Continue to focus on achieving effective ventilation.

- In most cases, ventilation should have been provided through a properly inserted endotracheal tube.
- If endotracheal intubation is not successful or not feasible, it is reasonable to administer ventilation during medication administration with a properly inserted laryngeal mask.

Concentration

Caution: Epinephrine is available in 2 concentrations.

The only concentration that should be used for neonatal resuscitation is **labeled either 0.1 mg/mL or 1 mg/10 mL**. It is usually supplied in a 10-mL glass vial that is packaged in a box with an injection device.

Do not use the higher-concentration epinephrine that may be stocked with emergency supplies for pediatric and adult resuscitation. This is often supplied in a small glass vial with a breakable top that does not have an injection device.

Route

Intravenous (*preferred*) or intraosseous: Epinephrine needs to rapidly reach the central venous circulation. Medications reach the central venous circulation quickly when administered via an umbilical vein catheter or an intraosseous needle. For newborn infants requiring vascular access after birth, the umbilical vein is recommended. When umbilical vein access is not feasible or successful, the intraosseous route is a reasonable alternative.

Attempting insertion of a peripheral intravenous catheter is not recommended for emergency medication administration in the setting of cardiovascular collapse. It is likely to be unsuccessful, result in epinephrine extravasation into the tissue, and delay the administration of potentially lifesaving therapy.

Endotracheal (*less effective*): Some clinicians may choose to administer epinephrine via the endotracheal tube while vascular access is established. Although it may be faster to administer endotracheal epinephrine than intravenous epinephrine, studies suggest that absorption is unreliable and the endotracheal route is less effective. For this reason, the intravenous and intraosseous routes are recommended.

Preparation

Use a sterile connector or stopcock to transfer epinephrine from the glass vial injector to a syringe (Figure 7.1).

Intravenous or intraosseous: Prepare intravenous or intraosseous epinephrine in a **1-mL syringe**. Clearly label the syringe: ***Epinephrine-IV***.

Endotracheal: Prepare endotracheal epinephrine in a **3- to 5-mL syringe**. Clearly label the syringe: ***Epinephrine-ET ONLY***. Be certain not to use this larger syringe for intravenous or intraosseous administration.

Enhanced Learning

https://bcove.video/3J9FiwO

QR 7.1 Scan here to see a 1.5-minute video of how to draw up epinephrine.

Figure 7.1. Use a connector or stopcock to transfer epinephrine.

Dose

Intravenous or intraosseous:

The suggested initial intravenous or intraosseous dose is 0.02 mg/kg (equal to 0.2 mL/kg).

You will need to estimate the infant's weight after birth.

- The acceptable dose range for intravenous or intraosseous administration is 0.01 to 0.03 mg/kg (equal to 0.1 to 0.3 mL/kg).

Endotracheal:

If you decide to administer an endotracheal dose while vascular access is being established, **the suggested initial endotracheal dose is 0.1 mg/kg (equal to 1 mL/kg)**.

- This higher dose is recommended *only* for endotracheal administration. ***Do not* administer the higher dose via the intravenous or intraosseous route.**
- The acceptable dose range for endotracheal administration is 0.05 to 0.1 mg/kg (equal to 0.5 to 1 mL/kg).

Administration

Intravenous or intraosseous:

- Rate: Infuse rapidly—administer epinephrine as quickly as possible.
- Flush: Follow intravenous or intraosseous doses with a **3-mL flush** of normal saline.

Endotracheal:

When administering endotracheal epinephrine, be sure to infuse the drug directly into the tube, being careful not to leave it deposited in the tube connector. Because you will be infusing a large fluid volume of epinephrine into the endotracheal tube, you should follow with several ventilating breaths to distribute the drug into the lungs. No flush is recommended.

Enhanced Learning

https://bcove.video/4lgi5ql

QR 7.2 Scan here to see a 1-minute video of closed-loop communication for ordering and administering epinephrine.

Use closed-loop communication

Use closed-loop communication when giving a medication order. State individual digits for numbers. Say the leading zero and the decimal point, but do not say trailing digits. Avoid using abbreviations during medication orders.

For example:

- The medical provider (Liz) and person administering medications (Taylor) first agree on an estimated weight.
  - *Liz*: "Taylor, I estimate the infant's weight is three kilograms."
  - *Taylor:* "Weight is three kilograms."
- The medical provider then states the medication name, concentration, dose, and route. The order is repeated back by the person administering the medication.
  - *Liz*: "Taylor, give epinephrine, one milligram in ten milliliters concentration, zero-point-zero-two milligrams per kilogram, rapidly through the umbilical vein catheter, then give three milliliters of saline flush."
  - *Taylor:* "I have epinephrine, one milligram in ten milliliters (show box). I'm giving zero-point-zero-two milligrams per kilogram, which is equal to zero-point-two milliliters per kilogram. The infant

weighs three kilograms, so I will give zero-point-six milliliters (show syringe). I'm giving it rapidly through the umbilical vein catheter. Then I will flush with three milliliters of saline (show syringe)."

- Once completed:
  - *Taylor:* "Liz, epinephrine has been given and the flush is completed."

Assess the infant's response to epinephrine

Assess the infant's heart rate response **1 minute after epinephrine administration**.

As you continue ventilation with 100% oxygen and chest compressions, the heart rate should increase to 60 bpm or higher within approximately 1 minute of intravenous or intraosseous epinephrine administration.

If the heart rate is less than 60 bpm after the first dose of intravenous or intraosseous epinephrine, continue coordinated ventilation and compressions. **You can repeat the epinephrine dose every 3 to 5 minutes.** If you started with the suggested initial dose of 0.02 mg/kg or lower, you should consider increasing subsequent doses. Do not exceed the maximum recommended dose. If there is not a satisfactory response after administering intravenous or intraosseous epinephrine, consider other problems such as hypovolemia and tension pneumothorax.

The response may take longer, or may not occur, if you administer endotracheal epinephrine. **If the first dose is administered by the endotracheal route and there is not a satisfactory response, a repeat dose should be administered as soon as an umbilical vein catheter or intraosseous needle is inserted.** Do not delay. If the heart rate is less than 60 bpm, you do not need to wait for 3 minutes after an endotracheal dose to administer the first intravenous or intraosseous dose. Once an umbilical vein catheter or intraosseous needle has been inserted, all subsequent doses should be administered by the intravenous or intraosseous route.

In addition, check to be certain that

- A cardiac monitor is being used for the most accurate assessment of heart rate.
- The lungs are being adequately ventilated as indicated by chest movement. Insertion of an endotracheal tube or a laryngeal mask should be strongly considered if not already done. If ventilation is provided through an endotracheal tube or a laryngeal mask, there should be equal breath sounds.
- The alternative airway is not displaced, bent, or obstructed by secretions.
- The oxygen concentration has been increased to 100%.
- Chest compressions are being performed at the correct depth (one-third of the anterior-posterior diameter of the chest) and correct rate (90/min).
- Interruptions in chest compressions are minimized because each interruption decreases coronary artery perfusion.

Epinephrine Summary

Concentration
0.1 mg/mL epinephrine = 1 mg/10 mL
Route
Intravenous *(preferred)* **or intraosseous**
Option: Endotracheal only while intravenous or intraosseous access is being established
Preparation
Intravenous or intraosseous: 1-mL syringe labeled *Epinephrine-IV*
• Prepare a 3-mL saline flush
Endotracheal: 3- to 5-mL syringe labeled *Epinephrine-ET ONLY*
Dose
Intravenous or intraosseous = 0.02 mg/kg (equal to 0.2 mL/kg)
• *Acceptable range = 0.01 to 0.03 mg/kg (equal to 0.1 to 0.3 mL/kg)*
Endotracheal = 0.1 mg/kg (equal to 1 mL/kg)
• *Acceptable range = 0.05 to 0.1 mg/kg (equal to 0.5 to 1 mL/kg)*
Administration
Intravenous or intraosseous **• Rapidly—as quickly as possible.** **• Flush with 3 mL normal saline.** **• Repeat every 3 to 5 minutes if heart rate remains less than 60 bpm.**
Endotracheal: Administer ventilating breaths to distribute into lungs. No flush.

Indications for a volume expander

If there has been an acute fetal-maternal hemorrhage, bleeding vasa previa, extensive vaginal bleeding, a placental laceration, fetal trauma, an umbilical cord prolapse, a tight nuchal cord, or blood loss from the umbilical cord, the newborn infant may be in hypovolemic shock. The infant may have a persistently low heart rate that does not respond to effective ventilation, chest compressions, and epinephrine.

Newborn infants with hypovolemic shock may appear pale, have delayed capillary refill, and/or have weak pulses. In some cases, there will be signs of shock with no obvious evidence of blood loss.

- **Administration of a volume expander is indicated if the infant is not responding to the steps of resuscitation and there are signs of shock or a history of acute blood loss.**
- **Volume expanders should not be administered routinely during resuscitation in the absence of shock or a history of acute blood loss.** Administering a large volume load to a heart that is already injured may actually worsen cardiac output and further compromise the infant.

Volume administration

Crystalloid fluid

The recommended crystalloid solution for acute treatment of hypovolemia is normal saline (0.9% NaCl). Lactated Ringer solution is an acceptable alternative but is not as commonly available. It contains sodium, potassium, calcium, and lactate. Because it contains calcium, it cannot be infused in the same intravenous line as red blood cells.

Packed red blood cells

Packed red blood cells should be considered for volume replacement when severe fetal anemia is suspected. If fetal anemia was diagnosed before birth, the donor unit can be cross-matched to the birthing parent to ensure compatibility with any maternal antibodies transferred to the infant. **If cross-matched blood is not immediately available, use emergency, non–cross-matched, type O Rh-negative packed red blood cells.**

Dose

The initial dose of the selected volume expander is 10 mL/kg. If the infant's condition does not improve after the first dose, you may need to administer an additional 10 mL/kg. In unusual cases of large blood loss, administration of additional volume may be considered.

Route

Options for emergency access to the vascular system during hypovolemic shock include an umbilical vein catheter or an intraosseous needle. Attempting insertion of a peripheral intravenous catheter is not recommended for emergency volume administration in the setting of cardiovascular collapse.

Preparation

Fill an appropriately sized syringe with the selected volume expander.

If using crystalloid fluid for volume expansion, label the syringe to identify its contents because it can be confused easily with other clear, colorless fluids.

Administration

In most cases, acute hypovolemia resulting in a need for resuscitation should be corrected quickly. No clinical trials have established a preferred infusion rate, but, in most cases, a steady infusion over 5 to 10 minutes is reasonable.

In preterm infants whose gestational age is less than 32 weeks, volume boluses administered during the first day after birth, volume boluses administered rapidly, and volume boluses greater than 10 mL/kg have been associated with an increased risk of intracranial hemorrhage.

Enhanced Learning

https://bcove.video/46OlclK

QR 7.3 Scan here to see a 1-minute video demonstration of how to administer volume expander.

Volume Expander Summary

Solution
Normal saline (0.9% NaCl)
Suspected severe anemia: Type O Rh-negative packed red blood cells
Route
Intravenous or intraosseous
Preparation
10- to 60-mL syringe (labeled NS or O- blood)
Dose
10 mL/kg
Administration
Over 5 to 10 minutes
(Use caution with preterm infants whose gestational age is less than 32 weeks.)

What do you do if the newborn infant is not improving after administering intravenous epinephrine and volume expander?

While continuing to administer chest compressions and ventilation, your team needs to quickly reassess the quality of ventilation and compressions. Intravenous administration of epinephrine may be repeated every 3 to 5 minutes.

If you have not inserted an alternative airway, this procedure should be performed now. If an alternative airway has been inserted, ensure it is positioned correctly and effectively inflating the lungs. A *stat* chest radiograph may provide valuable information. If necessary, call for additional help. If the resources and expertise are available, bedside point-of-care ultrasound (POCUS) may provide additional information.

Quickly ask each of the questions in Table 7-1 and confirm your assessment as a team.

Table 7-1. Questions to Ask When Heart Rate Is Not Improving With Ventilation, Compressions, Epinephrine, and Volume Expander

1. Is the chest moving with each breath?
2. Is the airway secured with an endotracheal tube or a laryngeal mask?
3. Are 3 compressions coordinated with 1 ventilation being administered every 2 seconds?
4. Is the depth of compressions one-third of the anterior-posterior diameter of the chest?
5. Is 100% oxygen being administered through the ventilation device?
6. Was the correct dose of epinephrine administered intravenously or intraosseously?
7. Is the umbilical vein catheter or intraosseous needle in place or has it been dislodged?
8. Is a pneumothorax or pericardial effusion present?

Discontinuing resuscitative efforts

Newborn infants with no detectable heart rate after 10 to 20 minutes of resuscitation frequently do not survive, and those who survive often have serious neurologic disabilities; however, survival without neurodevelopmental impairment is possible. There have been reports of a small number of newborn infants who experienced return of circulation and survived without severe disabilities despite an absent heart rate for 20 or more minutes after birth. The decision to discontinue resuscitative efforts must balance the possibility of stopping too early, when return of circulation and long-term survival may still be achievable, and continuing too long, when return of circulation is not possible and continued interventions offer no benefit or the infant may survive but with a significant burden of neurologic injury.

When making the decision to discontinue resuscitation, factors to be considered may include:

- Uncertainty about the duration of asystole
- An assessment of whether all appropriate interventions have been performed
- The infant's gestational age
- The presence of serious congenital anomalies
- The specific circumstances prior to birth such as the presumed etiology and timing of the perinatal events leading to cardiorespiratory arrest
- The family's stated preferences and values
- The availability of post-resuscitative resources such as neonatal intensive care and therapeutic hypothermia

Given these considerations, it is unlikely that a single time interval after birth or a uniform duration of cardiopulmonary resuscitation will be appropriate for all newborns.

- If there is a **confirmed absence of heart rate** after all appropriate steps of resuscitation have been performed, cessation of resuscitation efforts should be discussed with the team and family.
- **A reasonable time frame for considering cessation of resuscitation efforts is around 20 minutes after birth**; however, the decision to continue or discontinue should be individualized based on patient and contextual factors.

There are other situations, such as prolonged bradycardia without improvement, where, after complete and adequate resuscitation efforts have been made, discontinuation of resuscitation may be appropriate. However, there is not enough information on outcomes in these situations to make specific recommendations. Decisions on how to proceed in these circumstances must be made on a case-by-case basis. If possible, emergency consultation with a colleague or an individual with additional expertise may be helpful.

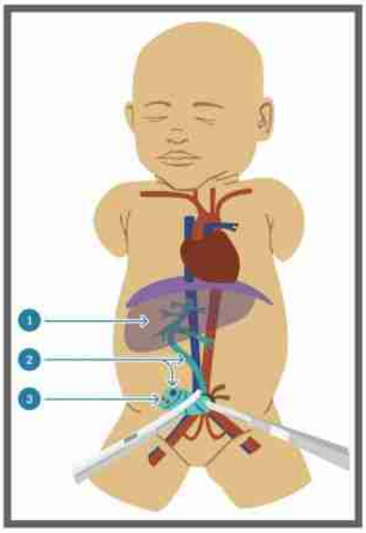


Figure 7.2. The umbilical vein travels through the liver to join the central venous circulation. 1. Liver, 2. Umbilical vein, 3. Umbilical arteries.

Enhanced Learning

https://bcove.video/4oRrQhD

QR 7.4 Scan here to see a 45-second review of emergency umbilical vein catheter insertion.

Enhanced Learning

https://bcove.video/4oQ2e4E

QR 7.5 Scan here to see a 3-minute video demonstration of emergency umbilical vein catheter insertion.

Establishing intravascular access

The umbilical vein

The umbilical vein is a rapidly accessible, direct intravenous route in the newborn infant (Figure 7.2). If the use of epinephrine can be anticipated because the infant is not responding to ventilation, a member of the resuscitation team should prepare to insert an umbilical vein catheter while others continue to provide ventilation and chest compressions.

Emergency umbilical vein catheter insertion

1. Put on gloves and quickly prepare an area for your equipment (Figure 7.3). Although you should attempt to use sterile technique, you must balance the need to rapidly secure emergency venous access with the risk of possibly introducing infection. If central venous access will be needed after stabilization, the emergency umbilical vein catheter will be removed and a new catheter will be inserted using full sterile technique.

Figure 7.3. Umbilical catheter (inside the plastic sleeve) prepared for emergency insertion.

2. Fill a 3.5F or 5F single-lumen umbilical catheter with normal saline using a syringe (3-10 mL) connected to a stopcock. Once the catheter and stopcock are filled, close the stopcock to the catheter to prevent fluid loss and air entry (Figure 7.4). Be certain that you know which direction is "off" on the stopcock used in your practice setting.

3. An assistant holds the cord taut with a clamp while you quickly clean the lower portion of the umbilical cord with an antiseptic solution. Place a loose, overhand tie at the base of the umbilical cord around Wharton's jelly near the skin margin. This tie can be tightened if there is excessive bleeding after you cut the cord. If the tie is placed around the skin, be sure that it does not compromise skin perfusion.

Figure 7.4. Close the stopcock to the catheter to prevent fluid loss and air entry.

4. Briefly stop chest compressions and caution the team that a scalpel is entering the field. Cut the cord with a scalpel below the umbilical clamp and about 2 cm above the skin line (Figure 7.5). If provided with your supplies, use a sterile wooden tongue depressor as a base to prevent the scapel from moving across the field in an uncontrolled manner. Attempt to cut straight across the cord rather than at an angle.

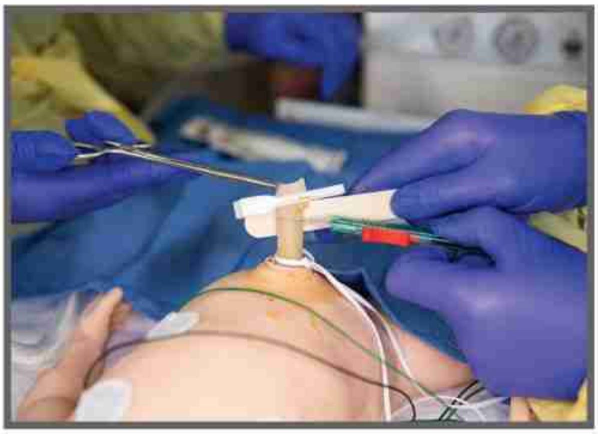


Figure 7.5. Cut the cord with a scalpel below the umbilical clamp and about 2 cm above the skin line.

5. The umbilical vein will be seen as a larger, thin-walled structure, often near the 12-o'clock position. The 2 umbilical arteries are smaller, have thicker walls, and frequently lie close together (Figure 7.6). The arteries coil within the cord and their position varies depending on where you cut the cord.

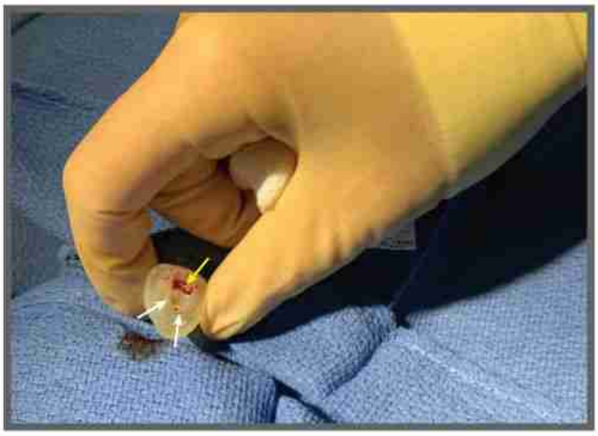


Figure 7.6 The umbilical cord ready for catheter insertion. The umbilical vein is shown by the yellow arrow. The 2 umbilical arteries are shown by the white arrows.

6. Insert the catheter into the umbilical vein (Figure 7.7).

   a. Continue inserting the catheter 3 to 4 cm beyond the abdominal wall until there is free flow of blood entering the catheter when the stopcock between the infant and the syringe is opened and the syringe is gently aspirated (Figure 7.8). The insertion depth may be less for extremely preterm infants.

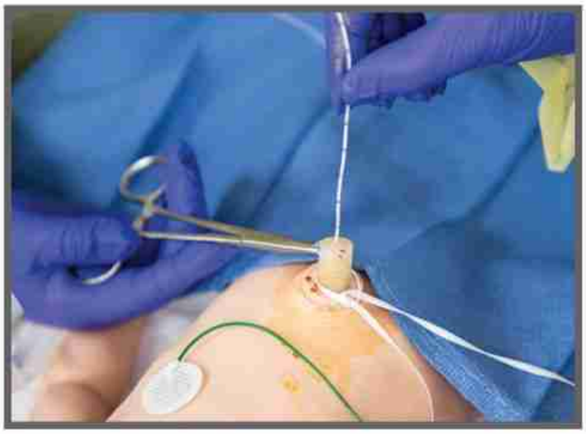


Figure 7.7. Saline-filled catheter inserted into the umbilical vein. Note the black centimeter markings on the catheter.

Figure 7.8. Advance the catheter until blood can be aspirated and the catheter can be easily flushed.

   b. For emergency use, the tip of the catheter should be located only a short distance into the vein—only to the point at which blood can be aspirated. If the catheter is inserted farther, there is risk of infusing medications directly into the liver, which may cause hepatic injury (Figure 7.9).

   c. Continue to hold the catheter securely in place with 1 hand until it is either secured or removed.

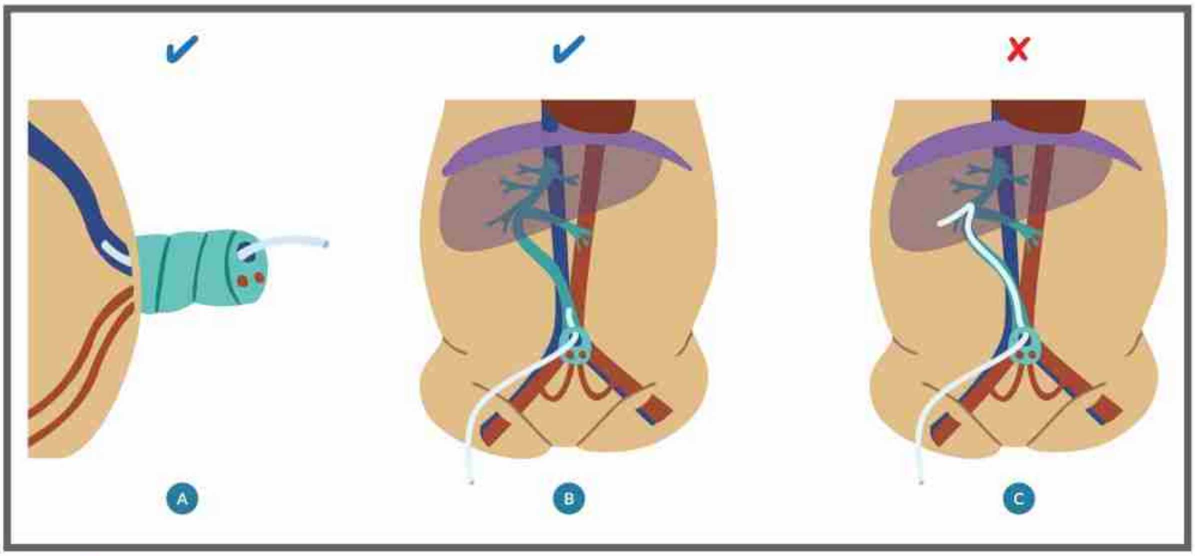


Figure 7.9. Correct (A and B) and incorrect (C) umbilical vein catheter insertion.

7. Attach the syringe containing either epinephrine or volume expander to the available stopcock port, turn the stopcock so that it is open between the medication or volume expander syringe and the catheter, ensure that there are no air bubbles in the syringe or catheter, and administer the appropriate dose (Figure 7.10). Flush the catheter using the saline flush syringe following administration of either epinephrine or blood.
   a. Avoid dislodging the catheter by asking an assistant to infuse the medication while the operator holds the catheter in place.

Figure 7.10. Open the stopcock toward the infant and infuse the medication.

b. Once the medication has been administered, temporarily secure the line in place to maintain vascular access until the infant's condition is stabilized. A clear adhesive dressing or an adhesive umbilical catheter holder can be used to rapidly secure the line to the infant's abdomen (Figure 7.11).

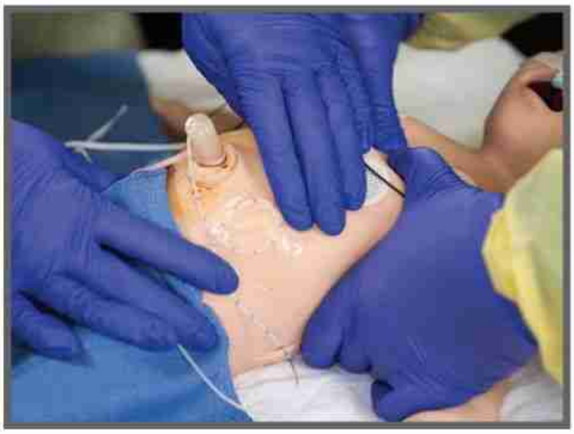


Figure 7.11. Temporarily secure the umbilical catheter with a clear adhesive dressing or catheter holder.

8. After the infant's condition is stabilized, either remove the catheter or ensure that the catheter has been secured before the infant is transported to the nursery. If you remove the catheter, do it slowly and be prepared to control bleeding by tightening the cord tie, squeezing the umbilical stump, or applying pressure above the umbilicus. If the umbilical vein catheter is not removed, the insertion site should remain visible to monitor for bleeding.

The intraosseous needle

Although an umbilical vein catheter is typically the preferred method of obtaining emergency vascular access immediately after birth, an intraosseous needle is a reasonable alternative if umbilical vein access is unsuccessful or not feasible. Intraosseous needles are frequently used for emergency access in prehospital settings and emergency departments. An intraosseous needle (Figure 7.12) is inserted through the skin into the flat portion of a large bone and advanced into the bone marrow cavity (Figure 7.13). When medications and fluids are infused, they quickly reach the central venous circulation and have the same hemodynamic effect as intravenous administration. All medications and fluids that can be infused into an umbilical vein catheter can be infused into an intraosseous needle. Small case series have shown that intraosseous needles are feasible to insert in term and preterm infants, have similar efficacy to that of intravenous routes, and can be inserted quickly. However, there is a risk of severe complications, including extravasation of fluid into the soft tissue, infection, bone fracture, and limb ischemia. The rate of successful insertion in very preterm infants is unknown.

Figure 7.12. Examples of intraosseous needles.

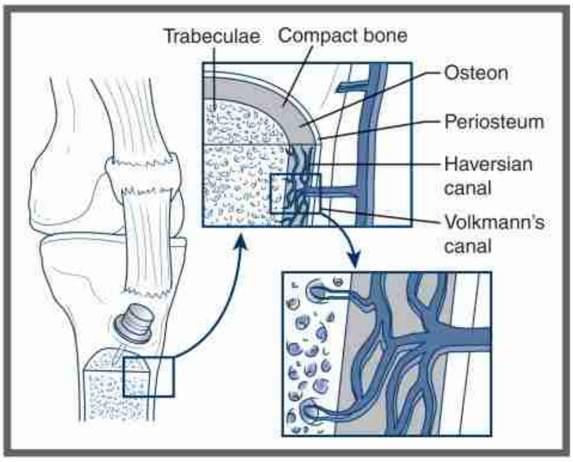


Figure 7.13. Intraosseous needle in the bone marrow cavity. Infused medications and fluids reach the central venous circulation quickly. (Adapted from Teleflex Incorporated. ©2016 Teleflex Incorporated. All rights reserved.)

Several types of intraosseous needles are commercially available. Some are intended to be manually inserted using a twisting motion to penetrate the skin and bone. Other needles are inserted using a battery-operated drill. Consult the manufacturer's literature to identify the correct-sized needle for your patient. The intraosseous needle has a stylet that is used during insertion and must be removed before infusion.

Intraosseous needle insertion

1. Identify the insertion site. For term infants, the preferred site is the flat surface of the lower leg, approximately 2 cm below and 1 to 2 cm medial to the tibial tuberosity (the bony bulge below the kneecap) (Figure 7.14).

Figure 7.14. Needle insertion site along the flat anteromedial surface of the tibia.

Enhanced Learning

https://bcove.video/4frmqFE

QR 7.6 Scan here to see a 1-minute video demonstration of intraosseous needle insertion.

2. Quickly clean the insertion site with antiseptic solution (Figure 7.15).

Figure 7.15. Quickly clean the insertion site.

3. Hold the intraosseous needle perpendicular to the skin and advance the needle through the skin to the surface of the bone (periosteum) (Figure 7.16).

Figure 7.16. Insertion using an intraosseous drill.

4. Direct the needle perpendicular to the bone and advance the needle through the bone cortex into the marrow space. If advancing the needle by hand, use strong downward pressure with a twisting motion. If advancing the needle with an electric drill, press the trigger while maintaining downward pressure, as described in the manufacturer's instructions. When the needle enters the marrow space, a distinct change in resistance ("pop") is noticeable.

5. Follow the manufacturer's instructions for removing the stylet and securing the needle (Figure 7.17).

Figure 7.17. Remove the intraosseous needle stylet.

6. Connect an infusion set (prefilled with normal saline) to the needle's hub, open the stopcock toward the needle, flush the needle with 3 to 5 mL of normal saline to open the bone marrow space, and administer the medication and saline flush (Figure 7.18).

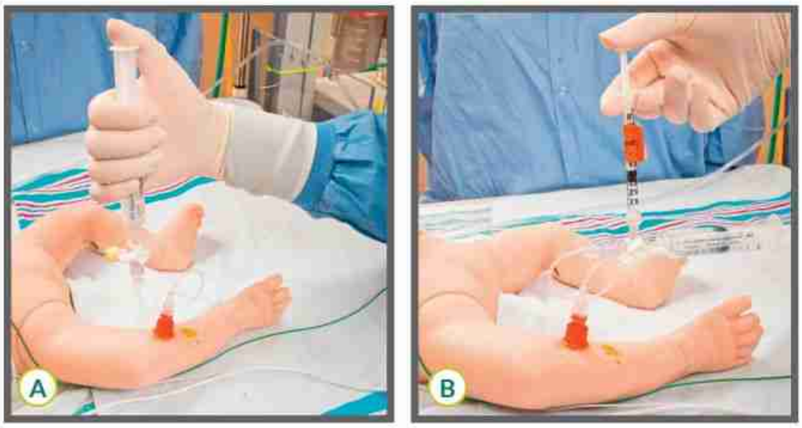


Figure 7.18. Connect a fluid-filled infusion set to the intraosseous needle, open the stopcock toward the needle, flush the needle (A), and infuse the medication or fluid (B).

7. Monitor the insertion site for evidence of swelling or fluid extravasation.

Focus on Teamwork

The administration of epinephrine and a volume expander during resuscitation highlights several opportunities for effective teams to use the Neonatal Resuscitation Program® (NRP®) Key Behavioral Skills.

Behavior	Example
Anticipate and plan. Use available information.	If perinatal risk factors suggest that the fetus may have experienced acute blood loss or have severe cardiorespiratory compromise (eg, prolonged fetal bradycardia), prepare an umbilical vein catheter or an intraosseous needle, epinephrine, and fluid for volume expansion before the birth. Emergency insertion of an umbilical vein catheter or intraosseous needle and blood administration are infrequently used skills, and teams must practice them frequently to be certain that they can be performed correctly and efficiently during an emergency. If an infant requires chest compressions, it is likely that epinephrine also will be required. Once compressions are started, a team member should prepare epinephrine and an umbilical vein catheter or an intraosseous needle so that intravascular epinephrine can be administered without delay.
Know your environment.	Your team needs to know where emergency type O Rh-negative blood is stored, how it will be obtained when needed, and what additional equipment will be needed to prepare and infuse it without delay. Your team needs to know where the emergency vascular access equipment is stored.
Call for additional help when needed.	If epinephrine or volume expansion is required, you will need additional help. It will likely take more than 4 team members to continue effective ventilation and compressions, quickly insert and secure emergency vascular access, prepare and administer epinephrine or fluid, monitor the passage of time, monitor the quality of compressions and ventilations, document events as they occur, and provide support for the infant's family.
Allocate attention wisely. Clearly identify a team leader.	If the team leader becomes involved in umbilical catheter insertion, their attention is focused primarily on that task, and they may not be able to pay full attention to the infant's condition, the passage of time, or the adequacy of ventilation and compressions. Any team member who has mastered the NRP Algorithm and has strong leadership skills can become the team leader. Clearly announce the change in leadership when it occurs.
Use available resources.	If you have difficulty inserting an emergency umbilical vein catheter, use an intraosseous needle.
Communicate effectively. Maintain professional behavior.	Use efficient, directed, closed-loop communication when epinephrine or volume expanders are requested. When you give an instruction, direct the request to a specific individual, call the team member by name, make eye contact, and speak clearly. After giving an instruction, ask the receiver to report back as soon as the task is completed. After receiving an instruction, repeat the instruction back to the sender. During a complex resuscitation, it is easy for the quality of communication to deteriorate. It is critically important for the leader to establish and maintain calm and professional behavior.

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own hospital setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. Which providers can insert an umbilical vein catheter and intraosseous needle in your birth setting?
2. Is someone with these skills immediately accessible if needed?
3. Is a kit with all necessary supplies for emergency vascular access immediately accessible if needed?
4. Do providers know where to obtain an intraosseous needle?
5. Does your emergency medication cart/box only include the dilute (0.1 mg/mL) solution of epinephrine for newborn resuscitation, or does it also have the concentrated (1 mg/mL) solution?
6. How often do NRP providers practice how to calculate and prepare a dose of epinephrine for neonatal resuscitation?
7. Do you have a weight-based emergency medication chart/table near each radiant warmer?
8. Do NRP providers know how to access emergency type O Rh-negative blood in your birth setting? Do they know the procedure for blood administration?

Process and outcome measures

1. How often do newborn infants receive epinephrine in your birth setting?
2. How often do newborn infants receive volume expanders in your birth setting?
3. When emergency medications are required, how often is a skilled provider present at the time of birth?
4. How often is the first dose of epinephrine administered by the intravascular route?
5. What percentage of resuscitation team members have demonstrated that they can properly calculate and prepare emergency epinephrine in a simulation setting each year?

Frequently Asked Questions

When ordering emergency epinephrine, is it safer to express the dose as a mass (mg/kg) or a volume (mL/kg)?

Because this question has not been fully resolved, this program describes the dose using both mass (mg/kg) and volume (mL/kg) expressions. Each method has risks and benefits. If the dose is expressed using the mass method, the team member preparing the dose will need to convert milligrams to milliliters, and there is a risk of making a decimal point error. If the dose is expressed using the volume method, the provider preparing the dose does not have to convert between units, but there is a risk of giving a 10-times overdose if the provider accidently uses the concentrated (1 mg/mL) epinephrine solution. This medication error is preventable by ensuring that the dilute (0.1 mg/mL) solution of epinephrine is the *only* concentration included in neonatal emergency supplies.

Whichever dosing method is used, the providers should use closed-loop communication, repeat back the intended dose, include the desired units and the infant's estimated weight when ordering and preparing the dose, confirm the concentration of the epinephrine solution used by showing the box to another team member, and compare the prepared dose with a weight-based chart or table to ensure accuracy.

Why is the intravenous route for epinephrine administration preferred over the endotracheal route? Isn't the endotracheal route easier and faster?

Epinephrine administered through the endotracheal tube may be absorbed by the lungs and enter blood that drains directly into the heart. Although it may be faster to administer epinephrine to an intubated infant through the endotracheal tube, the process of absorption by the lungs makes the response time slower and more unpredictable than if epinephrine is administered directly into the blood. Data from both animal models and clinical studies suggest that the standard intravenous dose is ineffective if administered via the endotracheal tube. There is some evidence in animal models that administering a higher dose can compensate for the delayed absorption from the lungs; however, no studies have confirmed the efficacy or safety of this practice in newborn infants. If the need for medications is anticipated, preparation of an umbilical vein catheter before delivery allows rapid administration of intravenous epinephrine without delay.

After intraosseous needle insertion, is it necessary to aspirate the syringe before infusing fluid?

No. In the newborn infant, aspiration of the intraosseous needle is not a reliable indicator of correct needle insertion and is not necessary. If the needle is correctly inserted, it should feel firmly secured in the bone and not "wiggle." When fluid is infused, the soft tissue surrounding the bone should not swell.

LESSON 7 REVIEW

1. Ventilation that moves the chest has been performed through an endotracheal tube for 30 seconds, followed by coordinated chest compressions and 100% oxygen for an additional 60 seconds. Epinephrine is indicated if the infant's heart rate remains less than (60 beats per minute [bpm])/(80 bpm).
2. The preferred route for epinephrine is (intravenous)/(endotracheal).
3. Your team is resuscitating an infant born at term. The infant's heart rate is 40 bpm after 30 seconds of ventilation through an endotracheal tube and an additional 60 seconds of coordinated chest compressions and ventilation using 100% oxygen. You determine that epinephrine is indicated. Your team should (quickly attempt to insert a peripheral intravenous catheter in the infant's right hand)/(insert an umbilical vein catheter).
4. The recommended concentration of epinephrine for newborn infants is (0.1 mg/mL)/(1 mg/mL).
5. The suggested initial intravenous dose of epinephrine is (0.02 mg/kg)/(0.1 mg/kg).
6. Intravenous epinephrine should be administered (slowly)/(as quickly as possible), followed by a (3-mL)/(1-mL) normal saline flush.
7. If the infant's heart rate remains less than 60 bpm, you can repeat the dose of epinephrine every (3 to 5 minutes)/(8 to 10 minutes).
8. If an emergency volume expander is indicated, the initial dose is (1 mL/kg)/(10 mL/kg).

Answers

1. Epinephrine is indicated if the infant's heart rate remains less than 60 bpm.
2. The preferred route for epinephrine is intravenous.
3. Your team should insert an umbilical vein catheter or an intraosseous needle. During cardiopulmonary collapse, a peripheral intravenous catheter is unlikely to be successful and attempts at insertion may delay appropriate therapy.
4. The recommended concentration of epinephrine for newborn infants is 0.1 mg/mL.
5. The suggested initial intravenous dose of epinephrine is 0.02 mg/kg.

6. Intravenous epinephrine should be administered as quickly as possible, followed by a 3-mL normal saline flush.
7. If the infant's heart rate remains less than 60 bpm, you can repeat the dose of epinephrine every 3 to 5 minutes.
8. The initial dose is 10 mL/kg.

Lesson 8

Resuscitation and Stabilization of Infants Born Preterm

What you will learn

- Why preterm infants are at higher risk of medical complications
- The additional resources needed to prepare for a preterm birth
- Additional strategies to maintain the preterm infant's body temperature

- How to assist ventilation when a preterm infant has difficulty breathing
- Additional considerations for oxygen management in a preterm infant
- Ways to decrease the chances of lung and brain injury in preterm infants
- Special precautions to take after the initial stabilization period
- How to present information to parents before the birth of an extremely preterm infant

Key Points

1. Preterm infants are at increased risk of requiring resuscitation and assistance with transition after birth.
2. Preterm infants are at increased risk of complications because of rapid heat loss, immature organ systems, small blood volume, and vulnerability to hypoglycemia.
3. Additional resources (including skilled personnel, a ventilation device that can provide positive end-expiratory pressure [PEEP] and continuous positive airway pressure [CPAP], and surfactant) should be available.
4. The temperature in the room where resuscitation takes place should be 23°C to 25°C (74°F to 77°F).
5. If the newborn infant's gestational age is less than 32 weeks, a polyethylene plastic bag or wrap and a thermal mattress should be prepared.
6. If assisted ventilation is required, use the lowest inflation pressure necessary to achieve and maintain an adequate heart rate response. It is preferable to use a device that can provide PEEP.
7. Consider using CPAP if the newborn infant is breathing spontaneously with a heart rate of at least 100 beats per minute (bpm) but has labored respirations or low oxygen saturation.
8. Initiate resuscitation of newborn infants whose gestational age is 32 to 34 weeks with 21% to 30% oxygen, and use a pulse

oximeter and an oxygen blender to guide the administration of oxygen to maintain oxygen saturation within the same target range described for healthy term newborn infants. For newborn infants whose gestational age is < 32 weeks, an initial oxygen concentration of 30% or greater may be considered based on institutional guidelines.

9. To decrease the risk of neurologic injury, handle the newborn infant gently, avoid positioning the infant's legs higher than the head, avoid high ventilation or CPAP pressures, use a pulse oximeter and blood gases to adjust ventilation and oxygen concentration, and avoid rapid intravenous fluid infusions.

The following 2 cases describe the birth and resuscitation of preterm infants. As you read the cases, imagine yourself as part of the team from the anticipation of the delivery through the resuscitation, stabilization, and transfer to an intensive care nursery.

Case 1: Stabilization of an infant born very preterm

A pregnant person arrives in preterm labor at 29 weeks' gestation with ruptured membranes and clear amniotic fluid. A vaginal birth is anticipated. The resuscitation team leader meets with the obstetrician and parents to discuss the care plan. Anticipating the possibility of a complex resuscitation, your resuscitation team is assembled and reviews each team member's role. Using a written checklist, your team ensures that all supplies and equipment needed to resuscitate and stabilize a preterm infant are ready for use. One team member attaches a preterm-sized mask to the T-piece resuscitator. The peak inflation pressure (PIP) is adjusted to 25 cm H_2O, and positive end-expiratory pressure (PEEP) is set to 5 cm H_2O. Next, a laryngoscope with a size 0 blade and both 3.0-mm and 2.5-mm endotracheal tubes are prepared. The oxygen blender is adjusted to provide the initial oxygen concentration (FIO_2) suggested by institutional guidelines. Additional team members increase the delivery room temperature, turn on the radiant warmer, obtain polyethylene plastic wrap and a hat, activate a thermal mattress, and cover the mattress with a cotton blanket.

At the time of birth, the newborn infant has flexed extremities but does not cry. The obstetrician and an assistant wrap the infant in a plastic sheet, place a hat on the infant's head, and provide gentle tactile stimulation. After 15 seconds, the infant begins to take spontaneous breaths. By 30 seconds, the infant has sustained respirations and is actively moving. An assistant clamps and cuts the umbilical cord after 60 seconds, and the infant is handed to your resuscitation team. The infant is carried to the radiant warmer and placed on the blanket-covered thermal mattress. The infant is breathing and auscultation demonstrates a heart rate greater than 100 beats per minute (bpm), but breathing is labored and breath sounds are decreased. A team member attaches a pulse oximeter sensor to the infant's right hand and cardiac monitor leads to the infant's chest. Continuous positive airway pressure (CPAP) is administered using the face mask and T-piece resuscitator. The infant's breath sounds and work of breathing improve, but the oxygen saturation (SpO_2) is below the target range. The FiO_2 is adjusted and the SpO_2 begins to rise. Nasal CPAP prongs are placed while your team continues to monitor the infant's breathing effort and SpO_2.

The parents are updated by the team leader, they have an opportunity to see and touch their infant, and the infant is moved to the intensive care nursery in a prewarmed transport incubator with blended oxygen and continuous monitoring. Shortly afterward, team members conduct a debriefing to review their preparation, teamwork, and communication.

Case 2: Resuscitation and stabilization of an infant born extremely preterm

A pregnant person arrives in labor at 23 weeks' gestation with ruptured membranes and clear amniotic fluid. Your resuscitation team leader meets with the obstetrician and parents to discuss current outcome data and the procedures that may be required to resuscitate and stabilize an extremely preterm newborn infant. After the discussion, they develop a care plan based on the parents' assessment of their infant's best interests. The parents and health care providers agree to provide intensive medical care, including endotracheal intubation, chest compressions, and emergency medication, if necessary. Despite tocolysis, labor progresses and a vaginal birth is anticipated. Your resuscitation team is assembled for a pre-resuscitation briefing to review each member's roles and responsibilities. Using a written checklist, the team prepares the necessary supplies and equipment. The oxygen blender is adjusted to provide the initial FiO_2 suggested by institutional guidelines. Additional team members increase the delivery room temperature, turn on the radiant warmer, obtain polyethylene plastic wrap and a hat, activate a thermal mattress, and cover the mattress with a cotton blanket.

At the time of birth, the newborn infant is flaccid and does not cry. The obstetrician and an assistant wrap the infant in a plastic sheet, place a hat on the infant's head, and provide gentle tactile stimulation, but the infant's tone remains poor and the infant is not breathing. The umbilical cord is clamped and cut and the infant is handed to your resuscitation team. The infant is carried to the radiant warmer and placed on the blanket-covered thermal mattress. The infant remains limp without respiratory effort. You provide assisted ventilation using the T-piece resuscitator. A team member attaches a pulse oximeter sensor to the infant's right wrist and cardiac monitor leads to the chest. The infant's heart rate is 70 bpm and the chest is not moving. The ventilation corrective steps are performed, including incrementally increasing the inflation pressure from 25 cm H_2O to 30 cm H_2O, but the heart rate still does not improve. A 2.5-mm endotracheal tube is inserted, and placement is confirmed with a carbon dioxide (CO_2) detector. Ventilation is continued with the T-piece resuscitator, breath sounds are equal bilaterally, and the heart rate promptly increases. The nasal-tragus length is 4.5 cm and the endotracheal tube is secured with the 5.5-cm mark adjacent to the infant's gum. The FIO_2 is adjusted to meet the SPO_2 target, and the T-piece PIP is adjusted to maintain gentle chest movement with each breath. A short time later, surfactant is administered through the endotracheal tube. By 20 minutes, the FIO_2 has been decreased to 25%.

The parents are updated by the team leader, they have an opportunity to see and touch their infant, and the infant is moved to the intensive care nursery in a prewarmed transport incubator with blended oxygen and continuous monitoring. Shortly afterward, team members conduct a debriefing to review their preparation, teamwork, and communication.

Preterm birth

In the previous lessons, you learned a systematic approach to neonatal resuscitation. When birth occurs before term gestation (less than 37 weeks' gestation), additional challenges make the transition to extrauterine life more difficult. The likelihood that a preterm infant will need help making this transition is related to gestational age. Infants born at lower gestational ages are more likely to require additional interventions. Because preterm infants are also more vulnerable to injury from resuscitation procedures, it is important to find the correct balance between initiating resuscitation without delay and avoiding unnecessarily invasive procedures. Your management during these first minutes may decrease the risk of both short- and long-term complications. This lesson focuses on the additional problems associated with preterm birth and the actions you can take to prevent or manage them.

Preterm infants have a higher risk of complications

Some complications result from the underlying problem that caused the preterm birth while others reflect the newborn infant's anatomic and physiologic immaturity.

- Thin skin, decreased subcutaneous fat, a large surface area relative to body mass, and a limited metabolic response lead to rapid heat loss.
- Weak chest muscles, poorly compliant (stiff) lungs, and flexible ribs decrease the efficiency of spontaneous breathing efforts.

- Immature lungs that lack surfactant are more difficult to inflate, tend to collapse during exhalation (losing functional residual capacity), and are at greater risk of injury from ventilation.
- Immature tissues are more easily damaged by oxygen.
- Infection of the amniotic fluid and placenta (chorioamnionitis) may initiate preterm labor, and the immature immune system increases the infant's risk of developing severe infections such as pneumonia, sepsis, and meningitis.
- A smaller blood volume increases the risk of hypovolemia from blood loss.
- Immature blood vessels in the brain cannot adjust to rapid changes in blood flow, which may cause bleeding or damage from insufficient blood supply.
- Limited metabolic reserves and immature compensatory mechanisms increase the risk of hypoglycemia after birth.

Additional resources are needed for resuscitating a preterm infant

The chance that a preterm infant will require resuscitation is significantly higher than that for an infant born at full term. This is true even for late-preterm infants born at 34 through 36 weeks' gestation.

- If the infant is expected to be born at less than 32 weeks' gestation, prepare a polyethylene bag or wrap and a thermal mattress, as described in the next section.
- A resuscitation device capable of providing PEEP and CPAP, such as a T-piece resuscitator or flow-inflating bag, is preferred.
- Consider having surfactant available if the infant is expected to be born at less than 30 weeks' gestation.
- If the infant will be moved after the initial stabilization, a prewarmed transport incubator with blended oxygen and a pulse oximeter is important for maintaining the infant's temperature and oxygenation within the target range.

Additional measures to keep the preterm newborn infant warm

Preterm newborn infants have a high risk of developing hypothermia (body temperature below 36.5°C [97.7°F]) and complications from cold stress. Although drying with warm towels, skin-to-skin contact, and early breastfeeding may be sufficient to maintain normal temperature in term newborn infants and some vigorous late-preterm infants, additional measures are required for very preterm infants and those requiring assistance after birth. When a preterm birth is expected, anticipate that temperature regulation will be challenging and prepare for it.

- **Set the temperature in the room where the infant will be resuscitated and receive initial care to approximately 23°C to 25°C (74°F to 77°F).**
- Preheat the radiant warmer well before the time of birth.
- After delivery, quickly place a hat on the infant's head.
- Use a prewarmed transport incubator if the infant will be moved after initial care is completed.
- **Maintain the infant's axillary temperature between 36.5°C and 37.5°C.**

Additional steps for thermoregulation of infants born at less than 32 weeks' gestation*

- Use a thermal mattress as an additional heat source.

  Portable thermal mattresses release heat when a chemical gel inside the mattress is activated to form crystals.

  - **The thermal mattress should be stored and activated at room temperature (19°C to 28°C [66°F to 82°F]).** If the mattress is stored or activated at a warmer temperature, it may exceed the target surface temperature.
  - Following the manufacturer's recommendations, squeeze the pad to activate the gel approximately 5 minutes before the infant is born. Once activated, it will reach the target surface temperature within 5 minutes and maintain that temperature for 1 hour after activation.
  - Once the thermal mattress is activated, place it on the radiant warmer and cover it with a blanket (Figure 8.1) so the mattress is not directly exposed to radiant heat and the heated surface is not in direct contact with the newborn infant's skin.
- Wrap the newborn infant in a polyethylene plastic bag or wrap.
  - Drying the body is not necessary. Instead of being dried with towels, very preterm infants should be wrapped up to their neck in polyethylene plastic immediately after birth. This can be done by the obstetric provider, with assistance as needed, before the umbilical cord is clamped as part of the rapid evaluation and initial steps of care.
  - You may use a food-grade reclosable 1-gallon plastic bag, a large plastic surgical bag, food wrap, a commercially available

Figure 8.1. Thermal mattress placed under a blanket on the resuscitation table.

*Note: Depending on the birth weight and environmental conditions, some newborn infants born at up to 35 weeks' gestation may benefit from the use of a thermal mattress and plastic bag/wrap.

Figure 8.2. Polyethylene plastic bag for reducing heat loss.

plastic poncho, or sheets of commercially available polyethylene plastic (Figure 8.2).

- If using a reclosable bag, you may cut the bottom open, slide the infant into the bag through the cut side, and close the bag below the infant's feet.
- If using a plastic sheet or food wrap, you may either wrap the infant in a single sheet or use 2 sheets and place the infant between the sheets.
- It is important to keep the newborn infant fully covered during resuscitation and stabilization. If an umbilical catheter will be inserted, cut a small hole in the plastic and pull the umbilical cord through the hole rather than uncovering the infant.

- Monitor the newborn infant's temperature frequently because overheating has been described while using a combination of warming methods.

Assisting ventilation for preterm newborn infants

Most preterm infants will initiate spontaneous respiratory effort without intervention. Gentle repetitive stimulation, such as stroking the infant's back, may help establish regular respirations and improve SpO_2 during the first minutes after birth. However, tactile stimulation should not delay the initiation of ventilation for newborn infants who remain apneic or have insufficient respiratory effort. Use the same criteria for initiating ventilation that you have learned for a term infant (apnea, or gasping, or heart rate less than 100 bpm within 60 seconds of birth despite the initial steps).

Preterm infants have immature lungs that may be difficult to ventilate and are more susceptible to injury from ventilation. The following are special considerations for assisting ventilation of preterm newborn infants:

- **If the infant is breathing spontaneously, consider using CPAP rather than intubating.**

  Initiating CPAP (5-6 cm H_2O) may be helpful if the infant is breathing spontaneously and has a heart rate of at least 100 bpm but has labored respirations or an SPO_2 below the target range. Using early CPAP, you may be able to avoid intubation and mechanical ventilation. **CPAP alone is *not* appropriate therapy for an infant who is not breathing or whose heart rate is less than 100 bpm.** After starting CPAP, monitor the infant's respiratory effort, heart rate, and SPO_2. Application of a face mask for CPAP may induce the trigemino-cardiac reflex, a reflex triggered by nerves on the infant's face, resulting in apnea and bradycardia.

- **If ventilation is required, use the lowest inflation pressure necessary to achieve and maintain a heart rate greater than 100 bpm.**

  The infant's heart rate response is the best indicator of effective ventilation. An initial inflation pressure of 20 to 25 cm H_2O is adequate for most preterm newborn infants. The volume of air required to ventilate a preterm infant's lungs is very small and may not result in perceptible chest movement.

  Use the lowest inflation pressure necessary to maintain a heart rate of at least 100 bpm and gradually improve SPO_2. The maximum inflation pressure used for an infant born at term may be too high for a preterm newborn. **Use your judgment when increasing ventilation pressure; however, it is reasonable to limit face mask ventilation to a maximum inflation pressure of 30 cm H_2O**. If face mask ventilation at this pressure does not result in clinical improvement, providing ventilation through an endotracheal tube or a laryngeal mask may improve the efficacy of ventilation and allow you to decrease the ventilating pressure.

  Airway obstruction and face mask leak are common problems during face mask ventilation with preterm infants, and very small changes in the head and neck position may lead to significant changes in ventilation. A CO_2 detector placed between the mask and ventilation device may provide a visual cue to help determine when you have achieved the correct mask and neck position. The CO_2 detector will change color when ventilation successfully exchanges gas within the infant's lungs, and CO_2 is exhaled through the mask.

- **If ventilation is required, it is preferable to use a device that can provide PEEP.**

  Initiating ventilation with PEEP (5 cm H_2O) helps the infant's lungs remain inflated between breaths. This is particularly important if you are using an endotracheal tube for ventilation. Both the T-piece resuscitator and flow-inflating bag can provide PEEP during ventilation through either a face mask or an endotracheal tube. If a

PEEP valve is attached, a self-inflating bag may provide PEEP during endotracheal tube ventilation. It is difficult to maintain PEEP during face mask ventilation with most self-inflating bags.

- **Consider administering surfactant if the infant requires intubation for respiratory distress or is extremely preterm.**

  After initial stabilization, preterm infants who need intubation and mechanical ventilation because of respiratory distress syndrome should be given surfactant.

  Studies completed prior to the common use of antenatal steroids and early CPAP concluded that infants born at less than approximately 30 weeks' gestation would benefit from intubation and prophylactic surfactant treatment before they developed respiratory distress. Subsequent studies indicate that CPAP initiated shortly after birth should be considered as an alternative to routine intubation and prophylactic surfactant administration. Many preterm infants can be stabilized with early CPAP and avoid the risks of intubation and mechanical ventilation.

  Surfactant can be selectively administered to newborns who fail a trial of CPAP. In some cases, you may be able to administer surfactant through a thin tube or supraglottic airway device while the infant remains on CPAP (Less Invasive Surfactant Administration [LISA], Minimally Invasive Surfactant Treatment [MIST], or Surfactant Administration Through a Laryngeal or Supraglottic Airway [SALSA]) or remove the endotracheal tube immediately after surfactant administration and return to CPAP for ongoing respiratory support (INtubate-SURfactant-Extubate [INSURE]). Some experts still recommend prophylactic surfactant for a subset of extremely preterm newborns because the likelihood of CPAP failure in this subgroup is very high. Criteria for CPAP failure and the administration of surfactant should be developed in coordination with local experts.

  If the resuscitation team does not have expertise in surfactant administration, it may be preferable to wait for the arrival of more experienced providers.

Oxygen supplementation for preterm newborn infants

You have learned in previous lessons that injury during transition may result from inadequate blood flow and oxygen delivery and that restoring these factors is an important goal during the resuscitation of newborn infants. However, research indicates that administering excessive oxygen after perfusion has been restored can result in additional injury. Preterm infants may be at higher risk for this reperfusion injury because fetal tissues normally develop in a low-oxygen environment and the mechanisms that protect the body from oxygen-associated injury have not yet fully developed.

Nevertheless, many preterm infants will require supplemental oxygen to achieve the anticipated gradual increase in SpO_2. Among preterm infants born at less than 32 weeks' gestation, both prolonged bradycardia and low oxygen saturations have been associated with worse outcomes. Evidence suggests that preterm infants who reach an SpO_2 of 80% to 85% within the first 5 minutes experience improved survival and neurologic outcomes. To achieve this target, they may require a higher initial FiO_2 or more rapid titration.

For newborn infants whose gestational age is 32 to 34 weeks, the current recommendation is to initiate resuscitation with 21% to 30% oxygen and use a pulse oximeter and an oxygen blender to guide the administration of oxygen in order to maintain SpO_2 within the same target range described for healthy term newborn infants. For newborn infants whose gestational age is < 32 weeks, an initial FiO_2 of 30% or greater may be considered based on institutional guidelines. As long as pulse oximetry is used to guide therapy to avoid the extremes of oxygenation, it may be reasonable to initiate ventilation across a wide range of oxygen concentrations.

An assistant should place a pulse oximeter sensor on the right hand or wrist as soon as possible after ventilation is started. Once the pulse oximeter is reading reliably, compare the newborn infant's pre-ductal SpO_2 with the range of target values summarized in Table 8-1, and use the blender to increase or decrease the FiO_2 as needed. There is insufficient evidence to recommend a specific approach to adjusting the FiO_2. A reasonable approach is to adjust the FiO_2 in increments of 20% to 30% every 30 seconds until the SpO_2 target is achieved.

Table 8-1. Target Pre-Ductal Oxygen Saturation

Target Oxygen Saturation Table	
2 min	65%-70%
3 min	70%-75%
4 min	75%-80%
5 min	80%-85%
10 min	85%-95%

Decreasing the risk of neurologic injury in preterm newborn infants

Before approximately 32 weeks' gestation, a preterm newborn infant has a fragile network of capillaries in their brain that are prone to rupture and bleeding. Obstruction of venous drainage from the head or rapid changes in blood CO_2 levels, blood pressure, or blood volume may increase the risk of rupturing these capillaries. Bleeding in the brain may cause tissue damage and lead to lifelong disability. Inadequate blood flow and oxygen delivery may cause damage to other areas of the brain, even in the absence of hemorrhage, while excessive oxygen administration may cause damage to the developing retina, leading to vision loss.

An organized care plan that is practiced during simulation can help you cluster interventions and complete them efficiently while minimizing disturbances to the preterm newborn infant.

Consider the following precautions when resuscitating a preterm newborn:

- **Handle the newborn infant gently.**

  While this may seem obvious, this aspect of care may be forgotten when members of the resuscitation team are trying to perform many steps quickly. If possible, avoid multiple intubation attempts, frequent suctioning, and other painful, noisy, or irritating stimuli.

- **Do not position the newborn infant's legs higher than the head (Trendelenburg position).**

  Placing the legs higher than the head may increase cerebral venous pressure and the risk of bleeding. It may be helpful to place the infant in a midline, supine (on the back) position with the head slightly elevated to avoid obstruction of venous drainage.
- **Avoid using high pressure during ventilation or CPAP.**

  Excessive pressure can create a pneumothorax or interfere with venous return from the head. Both of these complications have been associated with an increased risk of brain hemorrhage.
- **Use a pulse oximeter and blood gases to monitor and adjust ventilation and F_{IO_2}.**

  Continuously monitor S_{PO_2} until you are confident that the newborn infant can maintain normal oxygenation while breathing room air. If the infant requires continued assistance with ventilation, a blood gas test should be obtained to guide therapy. Rapid changes in CO_2 levels can increase the risk of bleeding. If your hospital does not have the resources to manage preterm infants who require ongoing assisted ventilation, arrange transfer to an appropriate facility.
- **Do not rapidly infuse intravenous fluids.**

  If emergent volume expansion is needed during resuscitation, infuse the fluid over at least 5 to 10 minutes. Hypertonic intravenous solutions, such as sodium bicarbonate, should be avoided.

Precautions that should be taken after the initial stabilization period

During the last trimester of pregnancy, the fetus undergoes physiologic changes in preparation for extrauterine survival. After preterm birth, many of these adaptations have not occurred. Consider the following:

- **Monitor the newborn infant's temperature.**

  Continue to carefully monitor the infant's temperature after the initial resuscitation and stabilization period. Very preterm infants should remain wrapped in polyethylene plastic until they have been moved to a warmed and humidified incubator. Even moderately and late preterm infants remain at risk for hypothermia and should be carefully monitored.
- **Monitor blood glucose levels.**

  Very preterm infants have lower amounts of stored glucose than infants born at term. If resuscitation is required, it is more likely that these stores will be depleted quickly and the infant may become hypoglycemic. Promptly secure intravenous access, initiate a dextrose infusion, and monitor the blood glucose concentration.

- **Monitor the newborn infant for apnea and bradycardia.**
  Preterm newborn infants often have unstable respiratory control. Significant apnea and bradycardia during the stabilization period may be the first clinical signs of an abnormality in body temperature, oxygenation, CO_2, electrolytes, blood glucose, or blood acid levels.

Focus on Teamwork

The resuscitation and stabilization of preterm newborn infants highlights several opportunities for effective teams to use the Neonatal Resuscitation Program® (NRP®) Key Behavioral Skills.

Behavior	Example
Anticipate and plan. Delegate workload optimally.	Multiple procedures may be performed in a brief period of time. Work with a multidisciplinary team to develop and practice a systematic approach to the first hours of care by defining roles and responsibilities in advance.
Use available information. Clearly identify a team leader.	Complete a pre-resuscitation team briefing to review the prenatal and intrapartum history, identify a team leader, review roles and responsibilities of each team member, and plan the approach to respiratory support.
Know your environment.	Know where polyethylene plastic bags/wraps and thermal mattresses are stored. Know how to use the temperature sensor on your radiant warmer. Know how to set up a device to administer CPAP.
Allocate attention wisely.	If the team leader becomes involved in endotracheal intubation, their attention is focused primarily on that task and they may not be able to pay full attention to the infant's condition or the passage of time. A different team leader who can maintain situation awareness may need to be identified.
Communicate effectively. Maintain professional behavior.	Share your assessments aloud so that all members of the team are aware of the infant's condition and response to treatment. The importance of effective communication continues after the resuscitation is completed. A post-resuscitation team debriefing is an important opportunity to review the team's performance, identify areas for improvement, practice effective communication skills, and improve teamwork. If the newborn infant will be transferred to another hospital after birth, develop a plan for efficiently communicating the birth parent's and newborn's history. Designate a team member to share progress updates and plans with parents.

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own delivery setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. Where are polyethylene plastic bags/wraps stored in your birth setting?
2. Can you increase the room temperature in your birth setting?
3. Do you have a protocol or checklist for organizing the first hour of post-resuscitation care for preterm newborn infants?
4. Has your team simulated the resuscitation and stabilization of a very preterm newborn infant to assess your preparedness?

Process and outcome measures

1. How often are preterm infants hypothermic (temperature $<36.5°C$) at 1 hour of age?
2. How often are preterm infants hypoglycemic at 1 hour of age?
3. How often do parents receive an update on their infant's condition and have the opportunity to see and touch their infant within the first 30 to 60 minutes after birth?
4. How often does your team complete a debriefing after the resuscitation and initial stabilization period?
5. How soon after the infant is born are parents instructed in how to express or pump breast milk?

Frequently Asked Questions

Should deferred umbilical cord clamping be considered for preterm newborn infants?

Early cord clamping (<60 seconds after birth) may interfere with healthy transition from fetal to neonatal circulation, as it leaves fetal blood in the placenta rather than filling the newborn infant's circulating blood volume. Preterm infants who have deferred umbilical cord clamping are more likely to survive their hospital stay, less likely to receive medications for hypotension, and less likely to receive a blood transfusion.

Before birth, establish a plan for the timing of umbilical cord clamping with the obstetric care providers. For most vigorous preterm infants, clamping the umbilical cord should be deferred for at least 60 seconds. By carefully coordinating care with the obstetric providers, the rapid evaluation and initial steps of newborn care, including thermal management, can be performed with the umbilical cord intact.

For preterm infants born at between 28 and 34 weeks' gestation who do not require resuscitation and in whom delayed cord clamping cannot be performed, it may be reasonable to milk the intact umbilical cord toward the infant prior to clamping the umbilical cord. **For preterm infants born at less than 28 weeks' gestation, umbilical cord milking is not recommended because it has been associated with an increased risk of intraventricular hemorrhage.**

If the birth parent's condition is hemodynamically unstable or the placental circulation is not intact, such as after a placental abruption, bleeding placenta previa, bleeding vasa previa, or cord avulsion, the cord should be clamped and cut immediately after birth.

Not enough evidence exists to make a definitive recommendation regarding whether umbilical cord clamping should be deferred in preterm newborns who are not vigorous after birth. If the placental circulation is intact, it may be reasonable to briefly defer umbilical cord clamping while the obstetric provider gently stimulates the infant to breathe. If the infant does not begin to breathe during this time, additional treatment is required. The umbilical cord should be clamped and the infant should be brought to the radiant warmer. Research studies are investigating whether it is feasible and beneficial in this situation to initiate resuscitation adjacent to the birth parent with the umbilical cord intact.

How do you counsel parents before the birth of an extremely preterm infant?

Meeting with parents before the birth of an extremely preterm infant is important for both the parents and the neonatal care providers. Prenatal discussions are an opportunity to provide parents with important information, discuss goals of care, and establish a trusting relationship that will support shared decision-making for their infant.

These discussions can be difficult because of the challenges inherent in communicating a large amount of complex information during a stressful time. You should be prepared with accurate information about available treatment options and the anticipated short- and long-term outcomes for the specific situation. You should be familiar with both national and local outcome data and understand their limitations. If necessary, consult with specialists at your regional referral center to obtain up-to-date information. Ideally, both the obstetric provider and the neonatal provider should be present to talk with the parents. The obstetric and neonatal perspectives may be different. These differences should be discussed before meeting with the parents so that the information presented is consistent.

If possible, meet with both parents (or the birthing parent and chosen support person) at the same time and allow enough time for them to consider the content of your discussion and ask questions. Try to meet with the parents before the birthing parent has received medications that might make it difficult to understand or remember your conversation and before the final stages of labor. If you are called to consult during active labor, there may not be time for an extended discussion, but it is still helpful to introduce yourself and briefly describe potential issues and your preliminary treatment plan. Use clear language without medical abbreviations or jargon. Be cautious about describing outcomes in terms of risk ratios, proportions, or percentages because parents may have limited understanding of these mathematical concepts. In addition, quoting these data may give the impression that your estimates are more precise than they actually are. It is important to present a balanced, accurate, and objective picture of the range of possible outcomes while avoiding excessively negative or unrealistically positive descriptions. Use an appropriately trained medical interpreter, not a friend or family member, if the family is not proficient in the language spoken by the health care team or includes someone with a hearing disability. Visual aids and written materials, including pictures and graphs, can supplement your discussion and help the parents remember the topics you discussed. Offer to give the parents time alone to discuss what you have told them. Some parents may want to consult with other family members or clergy. If time allows, offer to make a return visit to confirm both their understanding of what may occur and your understanding of their wishes.

After you meet with the parents, document a summary of your conversation in the medical record. Review what you discussed with the obstetric care providers and the other members of your delivery room resuscitation team. For preterm infants born at the edge of viability, if it was decided that resuscitation would not be initiated, ensure that all members of your team, including on-call personnel and the obstetric care providers, are informed and in agreement with this decision. If disagreements occur, discuss them in advance and consult additional professionals, including legal and ethics consultants, if necessary.

LESSON 8 REVIEW

1. You have turned on the radiant warmer in anticipation of the birth of a preterm infant at 27 weeks' gestation. List 4 additional steps that will help maintain this infant's temperature.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

2. An infant is born at 26 weeks' gestation. The initial steps of care, including gentle stimulation, have been completed and the infant is nearly 1 minute old. The infant is not breathing and the heart rate is 80 beats per minute. You should (start continuous positive airway pressure [CPAP] with a face mask)/(start ventilation).

3. An infant is delivered at 30 weeks' gestation. At 5 minutes of age, the infant is breathing, has a heart rate of 140 beats per minute, and is receiving CPAP with 30% oxygen. A pulse oximeter on the right hand is reading 95% and is increasing. You should (decrease the oxygen concentration)/(begin ventilation).

4. A (self-inflating bag)/(T-piece resuscitator) can provide CPAP for a spontaneously breathing infant.

5. You are preparing for the birth of an infant at 34 weeks' gestation. You set the ventilation device so that the peak inflation pressure is (25 cm H_2O)/(35 cm H_2O) and positive end-expiratory pressure (PEEP) is (5 cm H_2O)/(10 cm H_2O).

6. Initiate resuscitation of a preterm infant born at 34 weeks' gestation with (21% to 30% oxygen)/(60% to 100% oxygen).

7. You may *decrease* the risk of neurologic injury in a preterm newborn infant during and after resuscitation by (tilting the bed so the infant's legs are higher than the head)/(adjusting the bed so that the infant's legs are even with or lower than the head).

8. Compared with term newborn infants, preterm infants have a (higher)/(lower) risk of developing hypoglycemia shortly after resuscitation.

Answers

1. You can increase the room temperature to 23°C to 25°C (74°F to 77°F), prepare a thermal mattress, prepare a polyethylene plastic bag or wrap, and prewarm a transport incubator if the infant will be moved after birth.

2. You should start ventilation.

3. You should decrease the FIO_2.

4. A T-piece resuscitator can provide CPAP for a spontaneously breathing infant. A self-inflating bag *cannot* be used to provide CPAP.

5. Set the peak inflation pressure to 25 cm H_2O and PEEP to 5 cm H_2O.

6. Initiate resuscitation of this preterm newborn infant with 21% to 30% oxygen.

7. You may *decrease* the risk of neurologic injury in a preterm newborn infant during and after resuscitation by adjusting the bed so that the infant's legs are even with or lower than the head.

8. Preterm newborn infants have a higher risk of developing hypoglycemia shortly after resuscitation.

Lesson 9

Post-resuscitation Care

What you will learn

- What to do after neonatal resuscitation
- Medical conditions that may occur following neonatal resuscitation
- Management considerations following neonatal resuscitation
- The role of therapeutic hypothermia in post-resuscitation care

Key Points

1. An infant who requires resuscitation must be closely observed and frequently assessed during the immediate neonatal period to ensure normal transition. Some will require laboratory evaluations such as a blood gas test and measurement of blood glucose and electrolytes.

2. Be careful to avoid overheating the infant during or after resuscitation.

3. If indicated, therapeutic hypothermia must be initiated promptly; therefore, every birth unit should have a system for identifying potential candidates and contacting appropriate resources.

Case: An early term pregnancy with fetal distress

An infant was born at 37 weeks' gestation by emergency cesarean delivery because of intrapartum fever with signs of fetal distress during labor. After birth, the infant was limp and apneic and did not respond to the initial steps of newborn care. Assisted ventilation was started and continued for 3 minutes until effective spontaneous respiratory effort was established. During the next several minutes, the infant developed labored breathing and required supplemental oxygen to maintain oxygen saturation within the target range. The team leader updated the parents, explained the infant's condition, and described the post-resuscitation care plan.

The newborn infant arrives in the nursery where vital signs, including temperature, oxygen saturation, and blood pressure, are recorded. A complete physical examination, including a standardized neurologic assessment, is performed. The infant continues to require supplemental oxygen and continues to have labored breathing; a chest radiograph is requested. A team member obtains a blood sample for glucose concentration, bacterial culture, and blood gas testing. An intravenous catheter is inserted, and the infant receives fluids and parenteral antibiotics. The health care providers discuss their plan for close monitoring and frequent assessment. A parent arrives at the bedside, receives an interval update from the nursery staff, and touches and comforts their infant. Shortly afterward, the team members conduct a debriefing to review their preparation, teamwork, and communication.

Postnatal care

The physiologic transition to extrauterine life continues for several hours after birth. Newborn infants who require resuscitation may have problems making this transition even after their vital signs appear to return to normal. Medical complications after resuscitation may involve multiple organ systems. Many of these complications can be anticipated and promptly addressed by appropriate monitoring.

This program refers to 2 broad categories of postnatal care. The intensity of monitoring and the interventions required for individual newborns will vary within these categories.

Routine postnatal care

Nearly 90% of newborn infants are vigorous term infants with no risk factors, and they should remain with their parents to promote bonding, initiate breastfeeding, and receive routine newborn care (Figure 9.1). Similarly, an infant with certain prenatal or intrapartum risk factors who responded well to the initial steps of newborn care may need only close observation and does not need to be separated from the parents. Ongoing observation of breathing, thermoregulation, feeding, and activity is important to determine if additional interventions are required. The location and frequency of these evaluations will be determined by the specific perinatal risk factors and the infant's condition.

Figure 9.1. Routine postnatal care.

Post-resuscitation care

Infants who required supplemental oxygen, assisted ventilation, or continuous positive airway pressure (CPAP) after delivery will need closer assessment. They may develop problems associated with abnormal transition and should be evaluated frequently during the immediate newborn period. In addition to routine newborn care, they often require ongoing respiratory support, such as supplemental oxygen, nasal CPAP, or mechanical ventilation. Many will require admission to a nursery environment where continuous cardiorespiratory monitoring is available and vital signs can be measured frequently (Figure 9.2). Some will require transfer to a neonatal intensive care unit. If a newborn infant requires post-resuscitation care in a location outside of the parent's room, the parents should be encouraged to see and touch their infant as soon as it is feasible. The location and period of time needed for close observation depend on the newborn infant's condition, progress toward normal transition, and the presence of identifiable risk factors.

Figure 9.2. Post-resuscitation care in a setting where continuous cardiorespiratory monitoring is available and vital signs can be measured frequently.

Medical conditions that may occur in infants who required resuscitation

Abnormalities in multiple organ systems may occur following neonatal resuscitation. Anticipated clinical signs, laboratory findings, and management considerations are summarized in Table 9-1. Individual circumstances will determine which of these management considerations are appropriate.

Table 9-1. **Clinical Signs, Laboratory Findings, and Management Considerations**

Organ System	Clinical Signs and Laboratory Findings	Management Considerations
Constitutional	Hypothermia, hyperthermia	Delay bathing. Monitor temperature.
Respiratory	Tachypnea, grunting, retractions, nasal flaring, low oxygen saturation, pneumothorax	Maintain adequate oxygenation and ventilation. Monitor for signs of pulmonary hypertension. Avoid unnecessary suctioning. Cluster care to allow periods of rest. Consider radiograph and blood gas test. Consider surfactant therapy. Consider delayed initiation of feedings with use of intravenous fluids.
Cardiovascular	Hypotension, tachycardia, metabolic acidosis, poor perfusion	Monitor blood pressure, perfusion, urine output, and heart rate. Consider volume replacement or inotrope administration if infant is hypotensive or has signs of poor cardiac output.
Immunologic	Tachypnea, tachycardia, hypotension, hypothermia, hyperthermia	Consider blood culture. Consider antibiotics.
Endocrine-metabolic	Metabolic acidosis, hypoglycemia (low glucose), hyperglycemia (high glucose), hypocalcemia (low calcium), hyponatremia (low sodium), hyperkalemia (high potassium)	Consider measuring blood glucose and serum electrolytes. Consider intravenous fluids. Replace electrolytes as indicated.
Gastrointestinal	Feeding intolerance, vomiting, abdominal distention, abnormal liver function test results, gastrointestinal bleeding	Consider abdominal radiograph. Consider liver function tests. Consider delayed initiation of feedings. Consider use of intravenous fluids. Consider parenteral nutrition. Consider gastric decompression.
Renal	Decreased urine output, edema, electrolyte abnormalities	Monitor urine output. Consider measuring serum electrolytes. Monitor weight. Consider restricting fluids if there are signs of renal failure and intravascular volume is adequate.

Table 9-1. **Clinical Signs, Laboratory Findings, and Management Considerations—cont'd**

Organ System	Clinical Signs and Laboratory Findings	Management Considerations
Neurologic	Apnea, seizures, irritability, poor tone, altered neurologic examination, poor feeding coordination	Monitor for apnea. Support ventilation as needed. Consider measuring glucose and electrolytes. Avoid hyperthermia. Consider anticonvulsant therapy. Consider therapeutic hypothermia. Consider delayed initiation of feedings. Consider use of intravenous fluids.
Hematologic	Anemia, thrombocytopenia, delayed clotting, pallor, bruising, jaundice, petechiae	Consider measuring complete blood count and bilirubin and performing coagulation studies.

The following is a brief overview of selected common conditions.

Temperature instability

After resuscitation, infants may become too cold (hypothermic) or too warm (hyperthermic). Preterm newborns are at high risk of experiencing hypothermia, and this has been associated with increased mortality. Special techniques for maintaining body temperature in preterm infants are addressed in Lesson 8. Infants may become hyperthermic if their birth parent has a fever or chorioamnionitis, if the infant has an infection, or if the radiant warmer is not used properly. Hyperthermia has been associated with worse outcomes and should be avoided.

Pneumothorax and pneumonia

If acute respiratory deterioration occurs during or after resuscitation, consider the possibility that the infant has a pneumothorax (Figure 9.3). Lesson 10 includes details about managing a pneumothorax. If the infant is intubated and develops acute respiratory deterioration, ensure that the endotracheal tube has not become dislodged or obstructed by secretions.

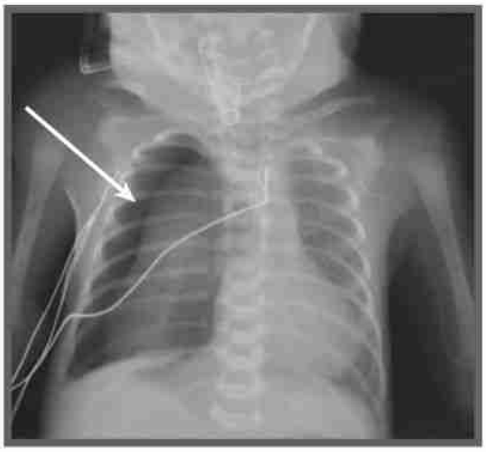


Figure 9.3. Right pneumothorax (arrow).

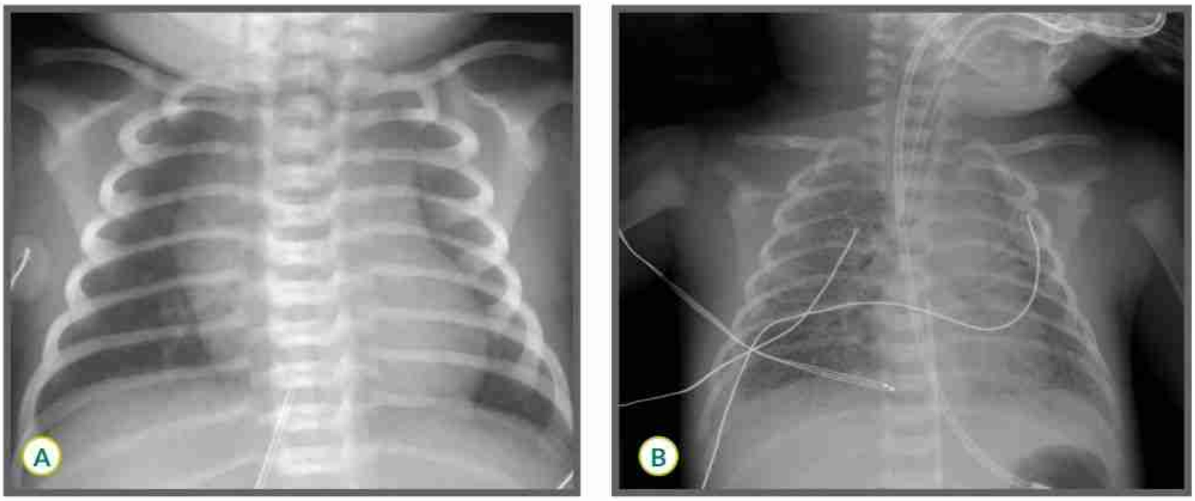


Figure 9.4. Neonatal chest radiographs: (A) normal, (B) pneumonia.

The need for resuscitation may be an early sign that a newborn has pneumonia, a perinatal infection, or an aspiration event. Neonatal pneumonia (Figure 9.4) may present with tachypnea and other signs of respiratory distress such as grunting, nasal flaring, and chest retractions. It can be difficult to differentiate between respiratory distress syndrome, retained fetal lung fluid, and neonatal pneumonia by chest radiography. If an infant who required resuscitation continues to show signs of respiratory distress or requires supplemental oxygen, consider evaluating for pneumonia and perinatal infection, obtaining appropriate laboratory tests, and beginning parenteral antibiotic treatment.

Pulmonary hypertension

As described in Lesson 1, blood vessels in the fetal lungs are tightly constricted. After birth, the pulmonary vessels relax and blood flows into the lungs where hemoglobin can be saturated with oxygen for delivery to the tissues and organs.

The pulmonary blood vessels may remain constricted after birth. This condition is called *persistent pulmonary hypertension of the newborn* (PPHN) and is most often seen in infants with a gestational age of 34 weeks or greater. PPHN usually is managed with supplemental oxygen and, in some cases, mechanical ventilation. Severe PPHN may require special therapies such as high-frequency mechanical ventilation, inhaled nitric oxide, and extracorporeal membrane oxygenation (ECMO).

After resuscitation, the infant's pulmonary vascular tone can be labile and may increase in response to sudden decreases in oxygen saturation or unintentional hypothermia; therefore, avoid unnecessary suction, excessive stimulation, and immediate bathing. Although avoiding sudden decreases in saturation may be beneficial, intentionally maintaining very high blood levels of oxygen is not likely to be helpful and may cause additional complications. A pulse oximeter should be used to guide oxygen therapy. In the setting of suspected PPHN, an arterial blood gas test provides additional useful information that cannot be obtained from pulse oximetry alone. Additional diagnostic tests, including measurement of oxygen saturation with pulse oximetry in the right upper extremity and a lower extremity (pre- and post-ductal) and an echocardiogram, may be helpful and should be guided by consultation with local experts. Depending on local resources, early transfer to a referral center may be indicated.

Hypotension

Hypotension during the post-resuscitation phase may occur for multiple reasons. Low oxygen levels around the time of birth can decrease both cardiac function and blood vessel tone. If the infant had significant blood loss, the circulating blood volume may be low and therefore contribute to hypotension. Infants with sepsis may have normal or high cardiac output, but they may become hypotensive because of dilation of peripheral blood vessels.

Newborn infants who require significant resuscitation should undergo blood pressure monitoring until the blood pressure is stable and within an acceptable range. If there is evidence of hypovolemia, volume expansion with a crystalloid solution, or blood transfusion, may be indicated. Routine volume expansion without evidence of hypovolemia is not recommended. Some infants may require medication to improve cardiac output, increase systemic blood flow, or increase vasomotor tone. If these medications are required, consultation with local experts should be considered.

Hypoglycemia

Glucose consumption is increased when metabolism occurs without adequate oxygen (anaerobic metabolism). Low blood glucose (hypoglycemia) levels may occur in newborn infants because glucose stores are depleted rapidly during perinatal stress. A transiently high glucose level (hyperglycemia) may occur before the blood glucose level begins to fall.

In newborn infants, glucose is an essential fuel for brain function, and prolonged hypoglycemia may contribute to brain injury. Some infants who require resuscitation, including those believed to be at risk of developing hypoxic-ischemic encephalopathy (HIE), need to have their blood glucose level checked soon after birth and then at regular intervals until it remains stable and within normal limits. Intravenous dextrose may be necessary to maintain normal blood glucose levels until oral feedings are established.

Feeding problems

The newborn infant's gastrointestinal tract is very sensitive to decreased oxygen and blood flow. Feeding intolerance, poor motility, inflammation, bleeding, and perforation of the intestinal wall can occur after resuscitation. In addition, sucking patterns and oral feeding coordination may be affected for several days because of neurologic dysfunction. Alternative methods for providing nutrition may be required during this period.

Ideally, feeding should be initiated with breast milk. If the infant is born very preterm or is unable to start breastfeeding, work with the obstetric care providers to develop a plan that supports expressing and storing breast milk as soon as possible after birth.

Renal failure

Hypotension, hypoxia, and acidosis can decrease blood flow to the kidneys and cause either temporary or permanent renal failure. Acute tubular necrosis is usually a temporary form of renal failure that may occur after resuscitation. It can cause fluid retention and significant electrolyte abnormalities. Newborn infants initially may have low urine output and require fluid restriction for several days. During the recovery phase, they may develop very high urine output and require additional fluid.

Urine output, body weight, and serum electrolyte levels should be checked frequently in infants who require significant resuscitation. Adjust fluid and electrolyte intake based on the infant's urine output, body weight changes, and laboratory results.

Metabolic acidosis

Metabolic acidosis is a common finding after resuscitation because acids are produced when tissues receive insufficient oxygen and blood flow. Severe acidosis may interfere with heart function and worsen pulmonary hypertension. In most cases, the acidosis will gradually resolve as the infant's respiratory and circulatory systems recover. The most important intervention is to identify and correct the underlying cause of metabolic acidosis.

Altered neurologic examination findings

Infants may demonstrate acute disturbances of neurologic function in the first hours after birth. Findings may include a decreased level of consciousness, lethargy, irritability, apnea, abnormal muscle tone, depressed or asymmetric reflexes, or seizures. *Neonatal encephalopathy* is the general term used to describe an acute alteration in neurologic function after birth. The use of this term does not indicate a specific cause of the altered neurologic function. Neonatal encephalopathy may be caused by exposure to narcotics or anesthetics administered to the birthing parent, infection, structural brain anomalies, intracranial hemorrhage, neonatal stroke, genetic conditions, electrolyte disturbances, or metabolic abnormalities.

One cause of neonatal encephalopathy that is important to recognize, because it has a limited window for treatment, is related to perinatal asphyxia.

Hypoxic-ischemic encephalopathy (HIE)

Newborn infants who experience a period of insufficient oxygen and blood flow to their brain and other organs before, during, or immediately after birth (perinatal asphyxia) are at risk of experiencing HIE. Initially, the newborn infant may have lethargy, decreased muscle tone, poor respiratory effort, or apnea. Seizures may appear after several hours. Infants who required extensive resuscitation should be carefully examined for signs of HIE. A standardized neurologic assessment is a useful tool. Consultation with a specialist should be considered.

Among late preterm and term infants (≥ 36 weeks' gestation) with moderate to severe HIE, studies have shown that controlled cooling of the infant's head or body (therapeutic hypothermia) for 3 days reduces the risk of death and improves neurologic outcomes. Cooling slows cellular metabolism and allows the infant's brain cells to avoid further injury. Typically, eligible newborn infants have experienced an acute perinatal event, such as a placental abruption or cord prolapse, with fetal distress. There is clinical and laboratory evidence of perinatal hypoxia and ischemia, including birth depression, requiring resuscitation and blood gas tests demonstrating metabolic acidosis. A standardized neurologic examination will show seizures or multiple moderate-to-severe abnormalities such as lethargy, hypotonia, abnormal posture, abnormal vital signs, and absent or abnormal suck and Moro reflexes. For eligible infants, cooling should be started within 6 hours of birth. Additional details regarding the selection of eligible infants and clinical management during hypothermia are available in the Clinical Report published by the American Academy of Pediatrics Committee on Fetus and Newborn and the Position Statement published by the Canadian Paediatric Society.

If your hospital does not have a therapeutic hypothermia program, contact the closest referral center that provides this therapy as soon as you suspect that an infant may be a candidate. Work with your referral center to develop an organized plan to identify candidates for therapy and quickly arrange for transport. Delay in the recognition or referral of a newborn infant who qualifies for cooling could mean that treatment cannot be initiated because the infant is outside of the therapeutic window of 6 hours after birth. If the decision is made to transport the infant to another center, follow instructions from the referral center to avoid hyperthermia or unintentional excessive hypothermia while awaiting transport.

Focus on Teamwork

Post-resuscitation care highlights several opportunities for effective teams to use the Neonatal Resuscitation Program® (NRP®) Key Behavioral Skills.

Behavior	Example
Anticipate and plan.	Plan where post-resuscitation care will take place at your institution. Discuss what type of post-resuscitation care will be provided in the parent's room and when care should be transferred to a transitional area or an intensive care nursery. Plan who will be responsible for ongoing monitoring and who to contact if the infant's condition changes. Develop a plan to rapidly recognize infants who may qualify for therapeutic hypothermia and determine who to contact if this therapy may be indicated. Practice how to initiate therapeutic hypothermia or the process for promptly transferring the infant to a referral center with the required expertise.
Know your environment.	Know what equipment is available in your institution to measure blood gas, electrolyte, and glucose levels. Know how to monitor and adjust temperature with your radiant warmer.
Delegate workload optimally.	Many procedures need to be performed during the first hour after a successful resuscitation. Plan who will perform each task to avoid unnecessary delays.
Communicate effectively.	Bring the care team together for a post-resuscitation debriefing to reinforce good teamwork habits and identify areas for improvement. Identifying small changes may result in significant improvements in your team's performance and patient safety.

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own hospital setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. If a newborn infant has received oxygen, assisted ventilation, or continuous positive airway pressure (CPAP) during the initial stabilization, who will be responsible for post-resuscitation care and continued assessments?
2. What resources are available to care for an infant who requires advanced neonatal care?
3. What challenges does your team face when transporting a newborn from the birth setting to an environment where continuous cardiorespiratory monitoring is available and vital signs can be measured frequently?
4. Have neonatal care providers been trained to identify infants who may be candidates for therapeutic hypothermia?

5. Do you know whom to contact if you believe an infant is a candidate for therapeutic hypothermia?
6. Do you have a process to support the parents' preferred feeding plan when the newborn infant requires ongoing monitoring?

Process and outcome measures

1. How often does the resuscitation team complete a post-resuscitation debriefing?
2. How often are newborn infants hypoglycemic after resuscitation?
3. How often are newborn infants transferred from the birth setting to an advanced care nursery/unit?
4. How often does the receiving medical center conduct a collaborative review with the referring medical center of infants transported to its facility?

Frequently Asked Questions

Can post-resuscitation care and monitoring be performed in the parent's room?

The location of post-resuscitation care is less important than ensuring that appropriate monitoring occurs, medical conditions that require intervention are promptly recognized, and the necessary treatment is initiated. The most appropriate location for post-resuscitation care will depend on the newborn infant's condition, progress toward normal transition, and available resources. In some cases, appropriate monitoring may be possible in the parent's room, while in other cases transfer to a transitional nursery or an intensive care setting will be required.

Should sodium bicarbonate routinely be given to newborns with metabolic acidosis?

No. Infusing a chemical buffer, like sodium bicarbonate, may appear to be a helpful intervention; however, there is currently no evidence to support this as a routine practice. Sodium bicarbonate infusion has several potential side effects. When sodium bicarbonate mixes with acid, carbon dioxide (CO_2) is formed. If the infant's lungs cannot rapidly exhale the additional CO_2, the acidosis will worsen. Although the blood measurement of acid (pH) may appear to improve, sodium bicarbonate may interfere with other acid buffering systems and actually worsen the acidosis inside of cells. In addition, rapid administration of sodium bicarbonate may increase the risk of intraventricular hemorrhage in preterm infants.

LESSON 9 REVIEW

1. An infant born at 36 weeks' gestation received assisted ventilation and oxygen supplementation. This infant (does)/(does not) need frequent evaluation of respiratory effort and oxygenation during the immediate neonatal period.
2. If a newborn infant requires admission to a neonatal intensive care unit, the parent(s) (should)/(should not) be encouraged to see and touch their infant.
3. A full-term newborn infant had significant birth depression and required a complex resuscitation. The infant has continued respiratory failure with carbon dioxide retention and metabolic acidosis. Sodium bicarbonate (should)/(should not) be infused immediately after resuscitation.
4. Among newborn infants who required complex resuscitation and have signs of neurologic injury, aggressive warming and hyperthermia (improves)/(worsens) the outcome and should be (encouraged)/(avoided).

Answers

1. This infant does need frequent evaluation of respiratory effort and oxygenation during the immediate neonatal period.
2. The parent(s) should be encouraged to see and touch their infant.
3. Sodium bicarbonate should not be infused immediately after resuscitation.
4. Aggressive warming and hyperthermia worsens the outcome and should be avoided.

References

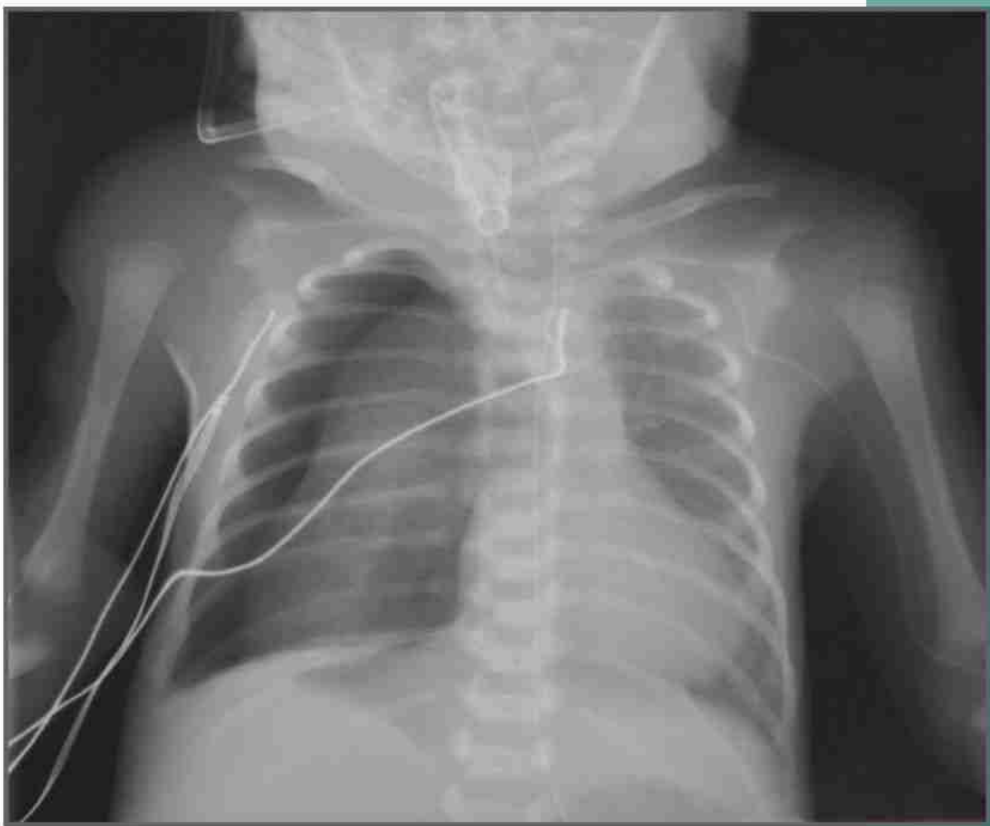
1. Committee on Fetus and Newborn. Hypothermia and neonatal encephalopathy. *Pediatrics*. 2014;133(6):1146–1150. Reaffirmed September 2021
2. Lemyre B, Chau V. Hypothermia for newborns with hypoxic-ischemic encephalopathy. *Paediatr Child Health*. 2018;23(4):285–291. Reaffirmed January 2024

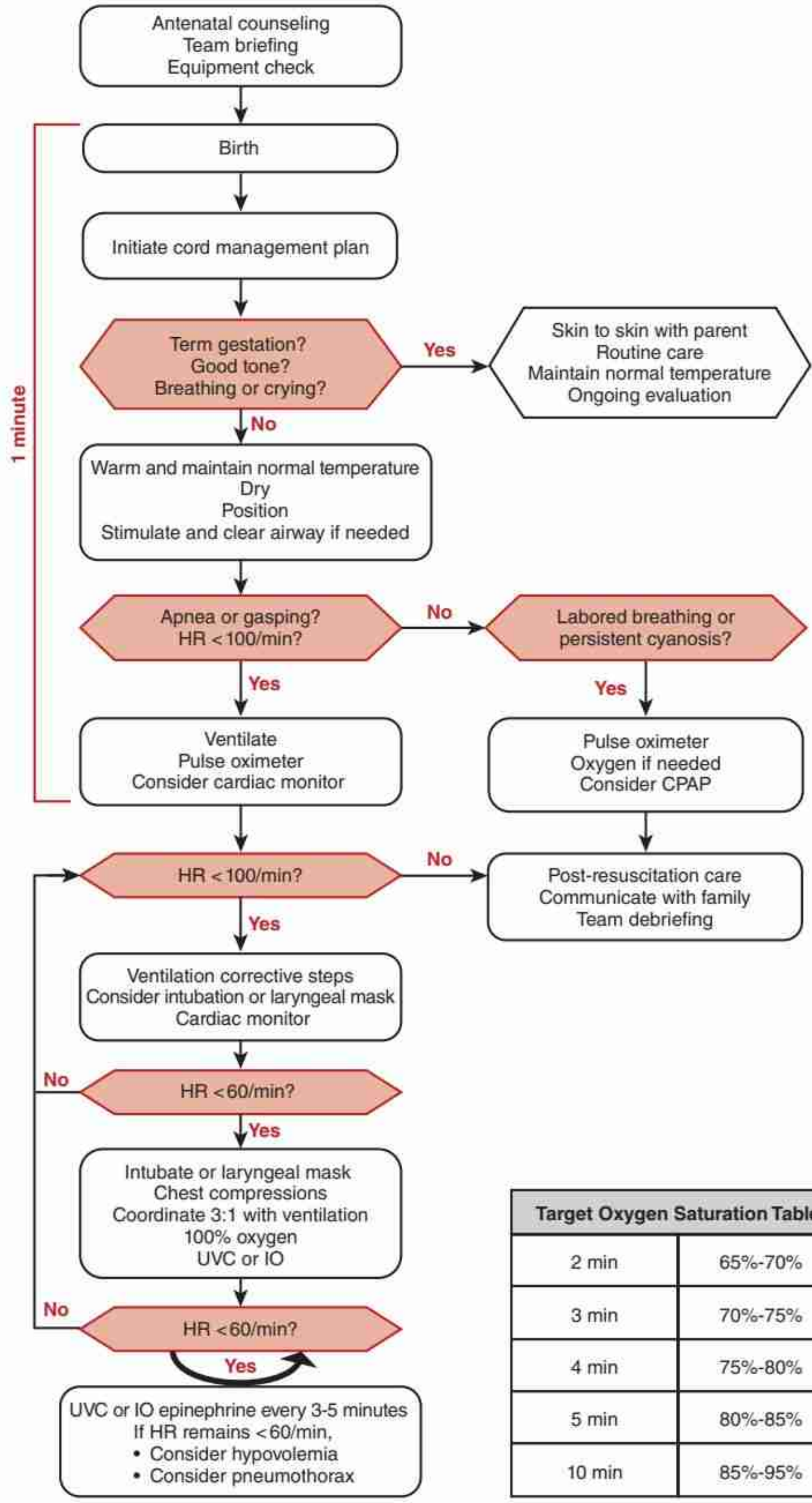
Lesson 10

Special Considerations

What you will learn

- When to suspect a pneumothorax or a pleural effusion
- How to manage a pneumothorax
- How to manage fluid collections in the thorax and abdomen
- How to manage a suspected airway obstruction
- How to manage congenital lung abnormalities that may complicate resuscitation
- How to manage complications resulting from maternal opiate or anesthetic exposure
- How to care for a newborn infant with myelomeningocele
- How to care for a newborn infant with an abdominal wall defect





Target Oxygen Saturation Table	
2 min	65%-70%
3 min	70%-75%
4 min	75%-80%
5 min	80%-85%
10 min	85%-95%

Key Points

1. Suspect a pneumothorax if a newborn infant fails to improve despite resuscitative measures or suddenly develops severe respiratory distress. In an emergency, a pneumothorax may be detected by decreased breath sounds and increased transillumination on the affected side.
2. Suspect a pleural effusion if a newborn infant has respiratory distress and generalized edema (hydrops fetalis).
3. Suspect ascites if a newborn infant has respiratory distress and abdominal distension.
4. A pneumothorax, pleural effusion, or ascites that causes cardiorespiratory compromise is treated by aspirating the air or fluid with a needle-catheter-extension set-stopcock assembly attached to a syringe and inserted into the chest or abdomen.
5. If thick secretions obstruct the airway despite a correctly positioned endotracheal tube, attempt to remove the secretions using a suction catheter (5F-8F) inserted through the endotracheal tube. If the obstruction persists, directly suction the trachea with a tracheal aspirator attached to the endotracheal tube.
6. Respiratory distress associated with the Robin sequence can be improved by placing the infant prone and inserting a small endotracheal tube (2.5 mm) into the nose so the tip is in the pharynx. If this does not result in adequate air movement, a laryngeal mask may provide a lifesaving airway. Endotracheal intubation is frequently difficult in this situation.
7. Respiratory distress associated with bilateral choanal atresia can be improved by inserting an endotracheal tube into the mouth with the tip in the posterior pharynx.
8. If a congenital diaphragmatic hernia is suspected, avoid providing assisted ventilation with a face mask. Quickly intubate the trachea and insert an orogastric tube with continuous or intermittent suction to decompress the stomach and intestines.
9. If the pregnant patient received opiates in labor and the newborn infant is not breathing, provide airway support and assisted ventilation until the infant has adequate spontaneous respiratory effort.

10 Avoid placing infants with myelomeningocele (spina bifida) on their back. Position the newborn lying on their side, on their stomach, or on a "doughnut" made from towels or latex-free foam.

11 Place the lower body and abdomen of an infant with gastroschisis or omphalocele in a sterile, clear plastic bowel bag and secure the bag across the infant's chest. Position the infant on the right side to optimize bowel perfusion.

This lesson reviews less common circumstances that you may encounter during neonatal resuscitation. It includes descriptions of several advanced procedures. This educational program introduces the concepts and skills required for these procedures, but completion of this lesson does not imply that an individual has the competence to perform these procedures in the clinical setting. Each hospital is responsible for determining the level of competence and qualifications required for someone to assume clinical responsibility for these advanced procedures.

Because these scenarios do not occur frequently, it is important to be able to recognize them and be prepared to respond quickly and efficiently. As you read the following case, imagine yourself as part of the resuscitation team.

Case: A newborn infant with tension pneumothorax

A pregnant patient is admitted in labor at 40 weeks' gestation with clear fluid and a Category III fetal heart rate pattern. An emergency cesarean birth is planned. Your resuscitation team assembles in the operating room, completes a pre-resuscitation team briefing, and prepares equipment and supplies for a complex resuscitation. After birth, the initial steps are performed with the cord intact, but the infant remains limp and apneic. The umbilical cord is clamped and cut, and the infant is handed to the resuscitation team. One team member begins documenting the resuscitation events as they occur.

You begin assisted ventilation with a face mask while a team member places a pulse oximeter sensor on the infant's right hand, but the heart rate is 40 beats per minute and not increasing. You perform the ventilation corrective steps, including increasing the ventilating pressure, and achieve chest movement; however, the infant's heart rate does not increase. A team member places cardiac monitor leads on the infant's chest. An endotracheal tube is rapidly inserted for continued ventilation, but there is no improvement in the infant's heart rate. Your team increases the oxygen concentration (FIO_2) to 100% and begins coordinated chest compressions while an umbilical vein catheter is prepared and inserted. The infant's heart rate does not improve after 60 seconds of coordinated compressions and ventilation. A dose of intravenous epinephrine is given through the umbilical catheter, followed by a normal saline flush, but the infant's condition still does not improve. The team reevaluates the insertion of the endotracheal tube and the efficacy of ventilation and compressions while considering special circumstances that may complicate resuscitation. Listening to the chest, you recognize that breath sounds are absent on the right side. Your team suspects a tension pneumothorax. Rapid transillumination of the chest confirms the suspicion and a team member quickly prepares a catheter-over-needle aspiration device. Chest compressions are stopped while a catheter is inserted, and air is aspirated from the chest. Upon decompression of the pneumothorax, the infant's heart rate rapidly improves. The team continues ventilation, and the FIO_2 is adjusted according to pulse oximetry results. A small amount of air continues to flow through the catheter aspiration system, and the infant is transferred to the nursery for a chest radiograph and additional treatment. Shortly afterward, you update the parents and conduct a debriefing to review your team's preparation, teamwork, and communication.

Abnormal air and fluid collections

Abnormal air or fluid collections that prevent the newborn infant's lung from fully expanding within the chest can lead to severe respiratory distress and persistent bradycardia.

Pneumothorax

It is not uncommon for small air leaks to develop as the newborn infant's lungs fill with air. When air collects in the pleural space surrounding the lung, it is called a pneumothorax (Figure 10.1). Although a pneumothorax may occur spontaneously, the risk is increased by assisted ventilation, particularly in preterm infants, infants with meconium aspiration, and infants with other lung abnormalities.

A small pneumothorax may be asymptomatic or cause only mild respiratory distress. If the pneumothorax becomes larger, the pressure from the trapped air can cause the lung to collapse. If the pneumothorax becomes large enough, it can interfere with blood flow within the chest, causing severe respiratory distress, oxygen desaturation, and bradycardia. This is called a tension pneumothorax. It is a life-threatening emergency and requires urgent treatment to evacuate the air.

You should consider the possibility of a pneumothorax if a newborn infant fails to improve despite resuscitative measures or if an infant suddenly develops severe respiratory distress. Breath sounds may be diminished on the side of the pneumothorax, but breath sounds can be misleading because they are easily transmitted across the infant's chest and can sound normal even in the presence of a pneumothorax. On the other hand, decreased breath sounds on the left side may be caused by an endotracheal tube inserted into the right main bronchus (Table 10-1).

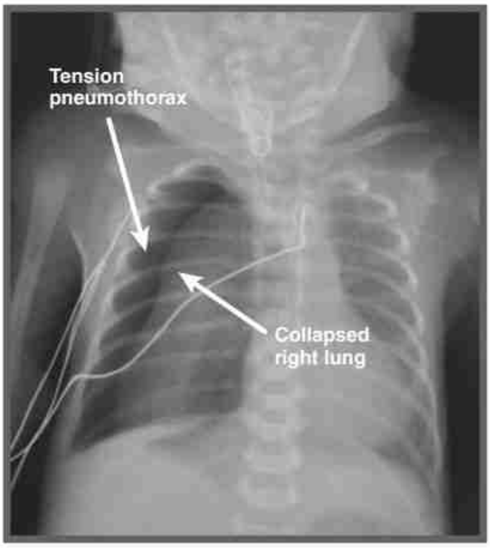


Figure 10.1. Pneumothorax causing collapse of the right lung.

Table 10-1. Causes of Diminished Breath Sounds

- Inadequate ventilation technique
- Ventilation device leak or equipment failure
- Malpositioned endotracheal tube
- Pneumothorax
- Pleural effusion
- Tracheal obstruction
- Congenital diaphragmatic hernia
- Pulmonary hypoplasia or agenesis
- Enlarged heart

Figure 10.2. Positive transillumination of a left-sided pneumothorax. The light spreads and glows across a wide area.

Transillumination of the chest is a rapid screening test that may be helpful. In a darkened room, hold a high-intensity fiber-optic light against the chest wall and compare the transmission of light on each side of the chest (Figure 10.2). During transillumination, light on the side with a pneumothorax will appear to spread farther and glow brighter than on the opposite side. In a life-threatening situation, a positive transillumination test result can help to direct immediate treatment. Be careful when interpreting the results of transillumination in very preterm infants, because their thin skin may cause the chest to appear bright even in the absence of a pneumothorax. With appropriate training and resources, bedside point-of-care ultrasound (POCUS) can be used to help rule out a pneumothorax. If a transilluminator, or POCUS, is not immediately available and the infant is in severe distress, you may proceed with emergency treatment on the basis of your clinical suspicion. If the infant's condition is stable, the definitive diagnosis of a pneumothorax is made with a chest radiograph.

A small pneumothorax usually will resolve spontaneously and often does not require treatment. The infant should be monitored for worsening distress. If the infant is maintaining normal oxygen saturation, supplemental oxygen is not indicated and does not result in faster resolution of the pneumothorax. If a pneumothorax causes significant respiratory distress, bradycardia, or hypotension, it should be relieved urgently by inserting a catheter into the pleural space and evacuating the air. If the infant has ongoing respiratory distress, insertion of a thoracostomy tube attached to continuous suction may be required.

Pleural effusion

Fluid that collects in the pleural space is called a pleural effusion (Figure 10.3). Similar to a pneumothorax, a large pleural effusion can prevent the lung from expanding. The fluid may be caused by edema, infection, or leakage from the infant's lymphatic system. Frequently, large pleural effusions are diagnosed before birth by ultrasonography. There may be a history of severe fetal anemia, twin-to-twin transfusion, cardiac arrhythmia, congenital heart disease, congenital infection, or a genetic syndrome. You should suspect a pleural effusion if a newborn has respiratory distress and generalized body edema (hydrops fetalis). Because the fluid collection interferes with lung expansion, breath sounds may be decreased on the affected side. The definitive diagnosis of a pleural effusion is made with a chest radiograph or ultrasound.

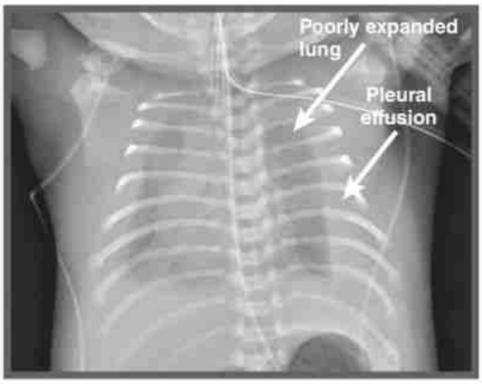


Figure 10.3. Large bilateral pleural effusions.

A small pleural effusion may not require treatment. If respiratory distress is significant, you may need to insert a catheter into the pleural space to drain the fluid. If a large pleural effusion is identified before birth, the obstetrician may remove fluid before delivery. In addition, emergency drainage may be required after birth. If time permits, an infant with a large pleural effusion identified by antenatal testing should be born in a facility where emergency airway management and fluid drainage by an experienced team is immediately available in the birth setting.

Ascites

Fluid that collects outside the intestines within the abdominal space is called ascites. Similar to a pleural effusion, a large volume of ascites can prevent the lung from expanding. Ascites may be present at the time of birth as a component of fetal hydrops or as an isolated finding complicating a fetal intestinal perforation or obstruction, lymphatic abnormality, urinary tract obstruction, genetic syndrome, or congenital infection. Frequently, ascites is diagnosed before birth by fetal ultrasonography. You should suspect ascites if a newborn has respiratory distress and abdominal distention. Generalized edema (fetal hydrops) may also be present.

In the immediate newborn period, ascites may not require treatment. If respiratory distress is significant, you may need to insert a catheter into the abdomen to drain the fluid. If a large volume of ascites is identified before birth, the obstetrician may remove fluid before delivery. In addition, emergency drainage may be required after birth. If time permits, an infant with a large volume of ascites identified by antenatal testing should be born in a facility where emergency airway management and fluid drainage by an experienced team is immediately available in the birth setting.

Evacuating a pneumothorax or pleural effusion

The air or fluid is aspirated by inserting a catheter into the pleural space on the affected side. This procedure is called *thoracentesis*. Ideally, thoracentesis should be performed using sterile technique with appropriate anesthetic for pain management; however, modifications may be required during emergency aspiration of a tension pneumothorax.

1. Take a brief time-out and confirm the side on which you plan to aspirate.
2. Aspiration site and positioning.
    a. **For a pneumothorax, the aspiration site is either the fourth intercostal space at the anterior axillary line or the second intercostal space at the midclavicular line (Figure 10.4).** Using a small blanket roll, position the infant on their back (supine) with the affected side directed slightly upward to allow the air to rise to the upper (superior) portion of the chest.

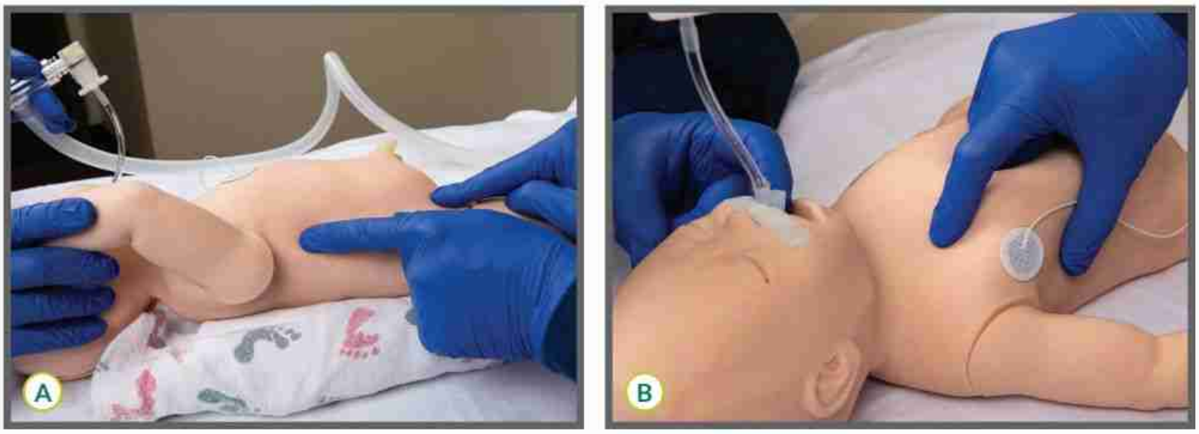


Figure 10.4. Locations for percutaneous aspiration of a pneumothorax: fourth intercostal space at the anterior axillary line (A), second intercostal space at the mid-clavicular line (B).

b. **For a pleural effusion, the aspiration site is the fifth or sixth intercostal space along the posterior axillary line.** Place the infant on their back (supine) to allow the fluid to collect in the lower (posterior) portion of the chest (Figure 10.5).

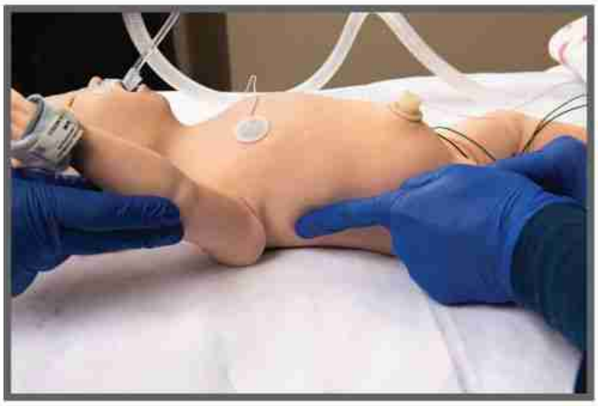


Figure 10.5. Location for aspiration of a pleural effusion.

3. Prepare the insertion site with topical antiseptic and sterile towels.

4. Insert a 20- or 24-gauge percutaneous catheter-over-needle device* perpendicular to the chest wall and just over the top of the rib. The needle is inserted over the top of the rib, rather than below the rib, to avoid puncturing the blood vessels located under each rib.

   a. For a pneumothorax, direct the catheter slightly upward toward the front of the chest (Figure 10.6).

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*Note: If an appropriate catheter-over-needle device is not available, a small "butterfly" needle may be used. In this case, the syringe and stopcock will be connected to the tubing attached to the needle.

Figure 10.6. Aspiration of pneumothorax. The needle is inserted over the rib and directed slightly upward toward the front of the chest. Note: The aspiration site is not covered with sterile towels for photographic purposes; however, modified sterile technique is acceptable for emergency aspiration.

Figure 10.7. Syringe, stopcock, extension set, and catheter assembly used to aspirate a pneumothorax. The stopcock is opened between the syringe and extension set/catheter during aspiration. The stopcock is closed if the syringe becomes full and must be emptied. The same assembly is used to drain a pleural effusion.

b. For a pleural effusion, direct the catheter slightly downward toward the back.

5. Once the pleural space is entered, the needle is removed, and a large syringe (20-60 mL) connected to a 3-way stopcock and extension set is attached to the catheter (Figure 10.7).

a. When the stopcock is opened between the syringe and the extension set/catheter, the air or fluid can be evacuated.

b. When the syringe is full, the stopcock may be closed to the infant's chest while the syringe is emptied.

c. After the syringe is emptied, the stopcock can be reopened to the infant's chest and more fluid or air may be aspirated until the infant's condition has improved.

d. To avoid accidental reinjection of air or fluid into the chest cavity, care must be taken when manipulating the stopcock.

e. When evacuating a pleural effusion, maintain a sample of the fluid for diagnostic evaluation.

6. A radiograph should be obtained to document the presence or absence of residual pneumothorax or effusion.

Evacuating abdominal ascites

The fluid is aspirated by inserting a catheter into the abdominal (peritoneal) space. This procedure is called *paracentesis*. Ideally, paracentesis should be performed using sterile technique with appropriate anesthetic for pain management; however, modifications may be required during emergency aspiration of abdominal ascites.

1. Take a brief time-out and confirm the location where you plan to aspirate.
2. Identify the insertion site. If ultrasound equipment is available and time permits, ultrasonography may help identify the entry site and insertion depth. If ultrasound equipment is not immediately available, the usual insertion site is in the right lower quadrant two-thirds of the distance between the infant's umbilicus and the bony prominence of the right hip (anterior superior iliac spine) (Figure 10.8).

Figure 10.8. Location for aspiration of abdominal ascites.

3. Prepare the insertion site with topical antiseptic and sterile towels.
4. Prepare a 20- or 24-gauge percutaneous catheter-over-needle device,* extension set, a 3-way stopcock, and a large syringe (20-60 mL) (Figure 10.9).

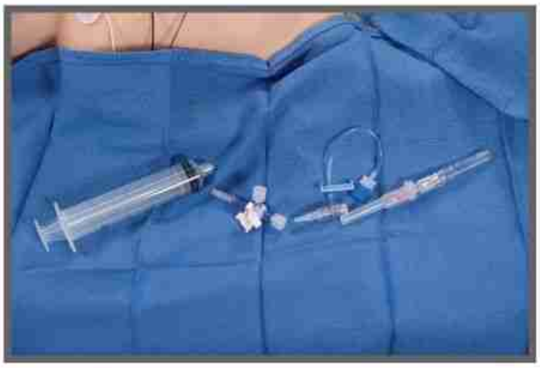

Figure 10.9. Supplies for abdominal paracentesis.

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*Note: If an appropriate catheter-over-needle device is not available, a small "butterfly" needle may be used. In this case, the syringe and stopcock will be connected to the tubing attached to the needle.

5. Insert the cannula/needle at a 45-degree angle to the skin with the needle tip directed toward the infant's back (Figure 10.10).
6. Advance the needle until fluid fills the catheter. Remove the needle, connect the extension set, 3-way stopcock, and syringe to the catheter, open the stopcock to the infant, and aspirate the fluid (Figure 10.11).
   a. When the syringe is full, the stopcock may be closed to the infant while the syringe is emptied through the open (third) stopcock port.
   b. After the syringe is emptied, the stopcock can be reopened to the infant and more fluid may be aspirated until the infant's condition has improved.
   c. When evacuating ascites, maintain a sample of the fluid for diagnostic testing.
7. Once the infant's condition has stabilized, ultrasonography may be performed to document the presence or absence of residual ascites.

Figure 10.10. Aspiration of abdominal ascites. The needle is inserted at a 45-degree angle to the skin with the tip directed toward the infant's back.

Figure 10.11. Syringe, stopcock, extension set, and catheter assembly used to aspirate abdominal ascites. The stopcock is opened between the syringe and extension set/catheter during aspiration.

Managing suspected airway obstruction

Airway obstruction is a life-threatening emergency. The newborn's airway may be obstructed by thick secretions or a congenital anomaly that leads to an anatomic obstruction.

Thick secretions

Thick secretions, such as meconium, blood, mucus, or vernix, may cause complete tracheal obstruction. If you are attempting ventilation but the infant is not improving and the chest is not moving, perform each of the ventilation corrective steps until you have inflated the lungs.

If you have correctly inserted an endotracheal tube for ventilation but still cannot achieve chest movement, the trachea may be obstructed by thick secretions. As described in Lesson 5, you may attempt to remove secretions from the trachea using a suction catheter (5F-8F) inserted through the endotracheal tube.

If the secretions are thick enough to completely obstruct the airway, you may not be able to clear them using a thin suction catheter. In

Figure 10.12. Suctioning thick secretions that obstruct ventilation using an endotracheal tube and a tracheal aspirator.

this case, directly suction the trachea with a tracheal aspirator attached to an endotracheal tube (Figure 10.12). Set the suction pressure to 80 to 100 mg Hg, connect suction tubing to the aspirator, and attach the aspirator directly to the endotracheal tube connector. Some endotracheal tubes have an integrated aspiration device designed for suctioning the trachea. Occlude the aspirator's suction-control port with your finger. You may need to gradually withdraw the tube to remove secretions from the trachea and posterior pharynx before reinserting a new endotracheal tube for ventilation.

Anatomic obstructions

Robin Sequence

The Robin sequence describes a combination of facial anomalies that occur because the lower jaw (mandible) does not develop normally. The lower jaw is small and set back in relation to the upper jaw (maxilla). The newborn's tongue is positioned farther back in the pharynx than normal and obstructs the airway (Figure 10.13). It is common for infants with the Robin sequence to also have a cleft palate. This combination of findings may be isolated or part of a genetic syndrome.

If a newborn infant with Robin sequence has labored breathing, turn the infant onto their stomach (prone). In this position, the tongue may move forward and open the airway. If prone positioning is not successful, insert a small endotracheal tube (2.5 mm) through the nose with the tip positioned deep in the posterior pharynx, past the base of the tongue, and above the vocal cords. It is not inserted into the trachea

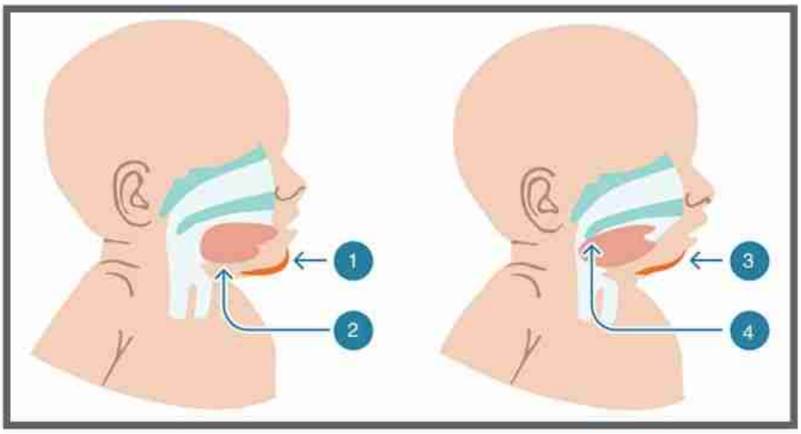


Figure 10.13. Newborn infant with normal anatomy (left). 1. Jaw, 2. Tongue. Newborn infant with Robin sequence (right). 3. Abnormally small jaw, 4. Tongue displaced against posterior pharynx.

(Figure 10.14), and a laryngoscope is not required to do this. This helps to relieve the airway obstruction and facilitates spontaneous breathing.

If the infant has severe difficulty breathing and requires resuscitation, face mask ventilation and endotracheal intubation may be very difficult. If none of the previous procedures results in adequate air movement, and attempts at face mask ventilation and endotracheal intubation are unsuccessful, a laryngeal mask may provide a lifesaving rescue airway.

Choanal Atresia

Choanal atresia is a condition in which the nasal airway is obstructed by bone or soft tissue (Figure 10.15). Because newborn infants normally breathe through their nose, infants with choanal atresia may have difficulty breathing unless they are crying and breathing through their mouth. In most cases, the obstruction occurs only on one side and does not cause significant symptoms in the newborn period.

Newborn infants with choanal atresia may experience cyclic episodes of obstruction, cyanosis, and oxygen desaturation that occur when they are sleeping or feeding and resolve when they are crying. If the obstruction is bilateral, the infant may have difficulty breathing immediately after birth; however, the presence of choanal atresia should not prevent you from achieving effective ventilation with a face mask.

You can test for choanal atresia by passing a thin suction catheter into the posterior pharynx through the nares. If the catheter will not pass, choanal atresia may be present.

If the infant has bilateral choanal atresia and respiratory distress, you can keep the mouth and airway open by inserting an endotracheal tube positioned with the tip just beyond the tongue in the posterior pharynx. This provides temporary stabilization until the infant can be evaluated by a specialist.

Other Rare Conditions

Other conditions, such as oral, nasal, or neck masses (Figure 10.16); laryngeal and tracheal anomalies; and vascular rings that compress the trachea within the chest, have been reported as rare causes of airway compromise in the newborn infant. Some of these malformations will be evident in the external examination. Depending on the location of the obstruction, it may be very difficult or impossible to achieve successful face mask ventilation or to insert an endotracheal tube. Special expertise and equipment may be required for successful intubation. If the obstruction is above the level of the vocal cords and you cannot ventilate or intubate the infant, insertion of a laryngeal mask may provide a lifesaving rescue airway. If such problems are identified before

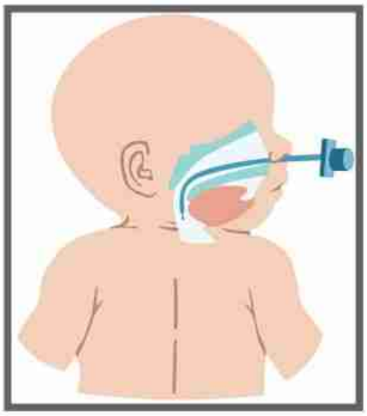


Figure 10.14. Endotracheal tube inserted deep in posterior pharynx for relief of airway obstruction in a newborn with Robin sequence. The tip of the tube is in the nasopharynx, above the vocal cords, *not* in the trachea.

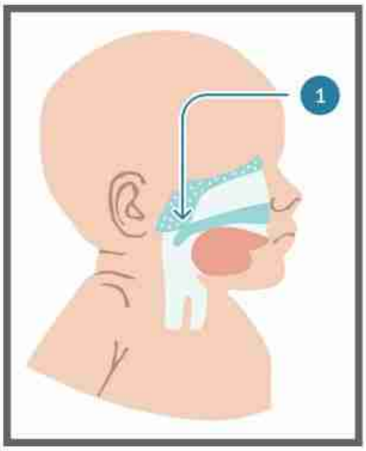


Figure 10.15. Choanal atresia causing obstruction of the nasal airway. 1. Congenital obstruction of posterior nasopharynx.

Figure 10.16. Newborn infant with a neck mass (cystic hygroma). (From Boyle KB, Anderson JM. A newborn who has a neck mass and scalp abrasion. *NeoReviews.* 2006;7[4]:e211–e216.)

birth, and time allows, the infant should be born in a facility where emergency management of the airway by a trained multidisciplinary team is immediately available in the birth setting.

Abnormalities of fetal lung development that can complicate resuscitation

Congenital diaphragmatic hernia

The diaphragm normally separates the abdominal and thoracic contents. When the diaphragm does not form correctly, the intestines, stomach, and liver can enter the chest and prevent the lungs from developing normally (Figure 10.17). This defect is called a congenital diaphragmatic hernia (CDH). The most common type of CDH occurs on the infant's left side. Frequently, the defect is identified by antenatal ultrasonography, and the infant's birth can be planned to occur in a high-risk center with expertise in the management of CDH.

The infant may have an unusually flat-appearing (scaphoid) abdomen, respiratory distress, and hypoxemia. If ventilation is administered by face mask, gas enters the stomach and intestines. As these structures expand within the chest, lung inflation will be increasingly inhibited and breath sounds will be diminished on the side of the hernia. If the ventilating pressure is increased in an attempt to improve inflation, the infant may develop a pneumothorax. Pulmonary hypertension is commonly associated with CDH and may contribute to severe hypoxemia.

Avoid face mask ventilation for infants with a diaphragmatic hernia.

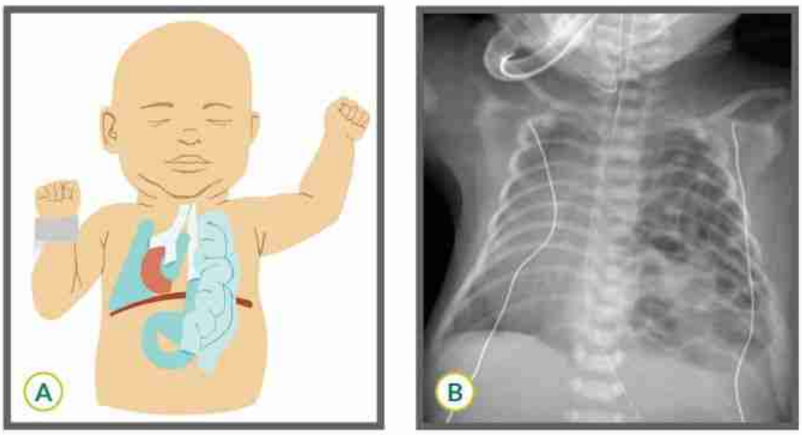


Figure 10.17. Congenital diaphragmatic hernia. The schematic drawing shows the defect in the diaphragm allowing abdominal contents to herniate into the left chest (A). A chest radiograph shows air-filled intestines in the left chest (B).

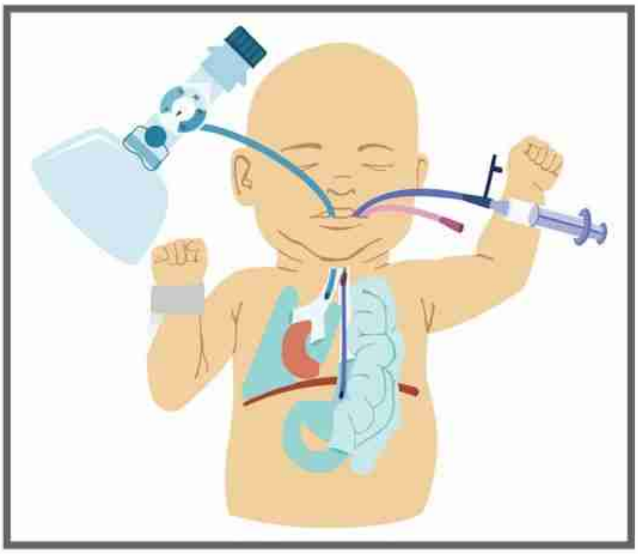


Figure 10.18. Stabilizing treatment for an infant with a left congenital diaphragmatic hernia. An endotracheal tube is in the trachea and a double-lumen sump tube (Replogle tube) is in the stomach. The sump tube is aspirated intermittently or attached to vacuum suction. Both tubes are secured (tape and cardiac monitor leads not shown).

In most cases, promptly intubate the trachea, insert a large orogastric catheter (10F), and use intermittent or continuous suction to prevent gaseous distension (Figure 10.18). A double-lumen sump tube (Replogle tube) is most effective. Anticipate that the infant's pre-ductal oxygen saturation will gradually increase with gentle assisted ventilation but may not exceed 80% to 85% during the initial stabilization period. Consensus guidelines recommend limiting the peak inflation pressure during ventilation to 25 cm H_2O.

Some newborn infants with a small left CDH and prenatal studies predicting good lung development may have a trial of spontaneous breathing and may not require immediate intubation. However, if the infant develops respiratory distress, or ventilation is required, prompt tracheal intubation is recommended. Consultation with local experts is advised.

Pulmonary hypoplasia

Normal lung development requires adequate space within the chest. Any condition that occupies space in the chest or causes a prolonged, severe decrease in amniotic fluid (oligohydramnios) may result in incomplete development of the lungs. This is called pulmonary hypoplasia. Examples of conditions causing pulmonary hypoplasia include CDH and obstruction or absence of both fetal kidneys. At the time of birth, the infant's chest may appear small and bell-shaped. If pulmonary hypoplasia is caused by oligohydramnios, the infant may have deformities of the hands, feet, nose, and ears caused by compression within the uterus.

Higher inflating pressures may be required to ventilate the infant's lungs, and this increases the risk of developing a pneumothorax. Alternative methods of mechanical ventilation available in high-risk centers may be required immediately after birth. Severe pulmonary hypoplasia may be incompatible with survival.

Respiratory depression at birth

Opiate exposure

Opiates given during labor to relieve pain may cross the placenta and decrease the newborn infant's activity and respiratory drive. If an infant has respiratory depression after intrapartum opiate exposure, manage the infant's airway and provide respiratory support with ventilation, as described in previous lessons. If the infant has prolonged apnea, insertion of an endotracheal tube or a laryngeal mask may be required for ongoing respiratory support.

Although the opiate antagonist naloxone has been used in this setting, there is insufficient evidence to evaluate the safety and efficacy of this practice. Very little is known about the pharmacology of naloxone in the newborn. Animal studies and case reports have raised concerns about complications from naloxone, including pulmonary edema, cardiac arrest, and seizures.

Other causes of neonatal respiratory depression

Intrapartum opiate exposure is not the only reason that newborns may have decreased spontaneous activity after birth. If ventilation results in a normal heart rate and oxygen saturation but the infant does not breathe spontaneously, the infant may have depressed respiratory drive or muscle activity due to a medication self-administered by the pregnant patient, hypoxia, severe acidosis, a structural brain abnormality, or a neuromuscular disorder. Medications given during labor, such as magnesium sulfate and general anesthetics, can depress respirations in the newborn infant. There are no medications that reverse the effects of these drugs. Again, the focus is to provide airway support and effective ventilation until the medication's effect has resolved. Transport the infant to the nursery for further evaluation and management while providing ventilation and monitoring the infant's heart rate and oxygen saturation.

Special considerations for a newborn infant with myelomeningocele (spina bifida)

Myelomeningocele is a type of neural tube defect that affects the spinal cord and vertebrae (Figure 10.19). It most commonly involves the lower back (lumbar area). The defect occurs during the first few weeks of fetal

Figure 10.19. Newborns with open myelomeningocele. (From Birgisson NE, Lober RM, Grant GA. Prenatal evaluation of myelomeningocele: a neurosurgical perspective. *NeoReviews.* 2016;17[1]:e28–e36.)

development when the precursor of the spinal cord, the neural tube, does not completely close. A sac of fluid containing part of the spinal cord and nerves may protrude through an opening in the infant's back. It is important to protect the sac and the neural tissue from trauma. Infants with myelomeningocele may also have hydrocephalus and a defect of the brainstem and cerebellum (Arnold-Chiari malformation) that can cause apnea or vocal cord paralysis.

- Before birth, prepare a "doughnut" with towels or latex-free foam covered with towels in case the infant must be positioned on their back (supine). This will allow the defect to be placed within the "doughnut hole."
- Newborn infants with neural tube defects are at risk of developing latex allergy. Use only latex-free equipment and supplies when caring for newborn infants with a neural tube defect.
- After birth, place the newborn infant on their side or on their stomach (prone) to avoid pressure on the fluid sac and its contents. If the infant must be supine for airway management, position the infant on the prepared "doughnut" with the defect over the open "doughnut hole."
- Avoid drying or rubbing the defect during the initial steps of newborn care.
- Proceed with resuscitation steps as needed.
- Once the infant's condition is stable, follow local guidelines for covering the lesion. Some experts recommend placing non-latex, transparent plastic wrap across the lesion and wrapping it around the infant's abdomen/waist (with or without a nonadherent, moist gauze between the lesion and the plastic wrap).
- Use caution to avoid rupturing the sac.

Special considerations for a newborn infant with an abdominal wall defect

The most common abdominal wall defects found in newborn infants are gastroschisis and omphalocele. Both are often identified via prenatal ultrasonography, and birth can be planned at a high-risk center.

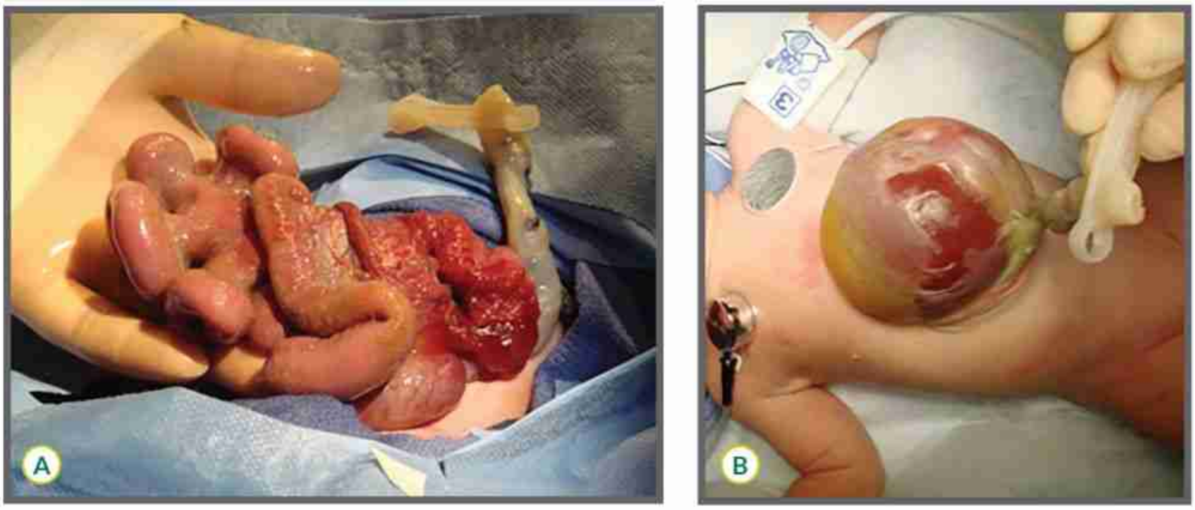


Figure 10.20. Abdominal wall defects. Gastroschisis (A) with no sac covering the protruding bowel. The defect is to the right of the umbilicus. Omphalocele (B) with abdominal contents within a sac. The defect involves the umbilical cord. (From Slater BJ, Pimpalwar A. Abdominal wall defects. *NeoReviews.* 2020;21[6]:e383–e391.)

Gastroschisis (Figure 10.20A) is a defect in which the infant's bowel protrudes through an opening in the abdominal wall. Most often, the defect is on the right side of a normal-appearing umbilical cord. Although infants with gastroschisis are often born preterm or small for gestational age, most do not have any other anomalies.

Omphalocele is a defect in the abdominal wall that includes the umbilical cord (Figure 10.20B). The infant's bowel is often contained within a large membranous sac that may hold other abdominal organs. The sac may rupture before or after delivery, exposing the abdominal contents. Infants with omphalocele frequently have other congenital anomalies or genetic syndromes.

For both defects, it is important to protect the bowel and abdominal organs from trauma.

The following are special considerations for gastroschisis:

- Ask the obstetric provider to clamp and cut the umbilical cord at least 10 to 20 cm (4-8 inches) from the infant because the cord may be used as part of the surgical repair.
- Place the infant and the exposed bowel in a sterile, clear plastic bowel bag and secure the bag across the infant's chest.
- Position the infant and exposed bowel on the right side to optimize perfusion.
- Cardiac monitor leads can be placed on the infant's upper chest and arms.
- Avoid prolonged face mask ventilation to prevent air from distending the bowel. If assisted ventilation is necessary, consider inserting an endotracheal tube or a laryngeal mask.

- Insert a large orogastric catheter (8F or 10F) and use low intermittent or continuous suction to prevent gaseous distension of the bowel. A double-lumen sump tube (Replogle tube) is most effective.
- Minimize handling of the exposed bowel, but frequently monitor its color to identify worsening perfusion.
- In an emergency, an umbilical vein catheter can be inserted; however, attempt to leave as much intact umbilical cord length as possible to assist the surgical repair.
- The exposed bowel increases heat and fluid losses. Careful attention to temperature management and fluid administration is necessary.

The following are special considerations for omphalocele:

- Be careful to clamp and cut the umbilical cord well above the bowel or abdominal organs enclosed within the defect.
- Place the infant's lower body, including the omphalocele, in a sterile, clear plastic bowel bag and secure the bag across the infant's chest.
- Position the infant and omphalocele on the right side to optimize perfusion.
- Cardiac monitor leads can be placed on the infant's upper chest and arms.
- Insert a large orogastric catheter (8F or 10F) and use intermittent or continuous suction to prevent gaseous distension of the bowel. A double-lumen sump tube (Replogle tube) is most effective.
- Handle the omphalocele gently to avoid rupturing the sac or injuring the abdominal contents.
- Assess the infant's respiratory status. Newborns with large omphaloceles may require respiratory support, including continuous positive airway pressure (CPAP) or mechanical ventilation.
- An umbilical vein catheter cannot be used for emergency vascular access. If emergency access is required during resuscitation, an intraosseous needle can be used.

Focus on Teamwork

The special considerations described in this lesson highlight several opportunities for effective teams to use the NRP® Key Behavioral Skills.

Behavior	Example
Anticipate and plan. Use available information. Communicate effectively.	Through effective communication with the obstetric team, identify important antenatal risk factors, such as antepartum or intrapartum narcotic exposure, abnormal amniotic fluid volume, and the results of prenatal ultrasound examinations. Share the information with your team so that you can anticipate high-risk deliveries and adequately prepare for resuscitation.
Use available resources.	Be aware of what resources are available to stabilize a newborn with a difficult airway. Where is the equipment stored?

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own hospital setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. Which health care professionals can perform an emergency thoracentesis or paracentesis?
2. Is someone with these skills immediately accessible if needed?
3. Is a kit with all necessary supplies for these procedures immediately accessible if needed?
4. Do you have latex-free equipment and supplies in your birth setting?
5. Do you have sterile, clear plastic bowel bags in your birth setting?
6. How does your team know that an infant with a serious congenital anomaly will be born?
7. Does your obstetric team have a mechanism for communicating with your resuscitation team and planning for the birth and immediate newborn care?

Process and outcome measures

1. How often are newborn infants with serious congenital anomalies diagnosed only after birth?
2. How often are newborn infants at your hospital diagnosed with a pneumothorax?
3. How long does it take to assemble a team qualified to manage an unanticipated newborn emergency?

LESSON 10 REVIEW

1. A newborn infant's heart rate is 50 beats per minute and has not improved with ventilation through a face mask or properly inserted endotracheal tube. The infant's chest is *not* moving with assisted ventilation through the endotracheal tube. You should (suction the trachea using a 5F to 8F suction catheter or tracheal aspirator)/(proceed immediately to chest compressions).
2. A newborn infant has respiratory distress after birth. The infant has a small lower jaw and a cleft palate. The infant's respiratory

distress may improve if you insert a small endotracheal tube in the nose, advance it into the pharynx, and position the infant (supine [on the back])/(prone [on the stomach]).

3. You attended the birth of an infant who received assisted ventilation during the first minutes after birth. The infant's condition improved, and the infant has been monitored in the nursery. A short time later, the infant developed acute respiratory distress. You should suspect (a pneumothorax)/(a congenital heart defect) and should rapidly prepare (a needle aspiration device)/(epinephrine).

4. You attend the birth of an infant with a large congenital diaphragmatic hernia diagnosed during antenatal testing. Promptly after birth, you should (begin face mask ventilation and insert an orogastric tube in the stomach)/(intubate the trachea and insert an orogastric tube in the stomach).

5. A pregnant patient received an opiate medication for pain relief 1 hour before delivery. After birth, the infant does not have spontaneous respirations and does not improve with stimulation. Your first priority is to (start ventilation)/(administer the opiate antagonist naloxone).

6. After birth, position newborn infants who have a myelomeningocele on their (back)/(stomach or side).

7. After birth, place a newborn infant with a gastroschisis in a sterile, clear plastic bowel bag and position the infant on the (back)/(right side).

Answers

1. You should suction the trachea using a 5F to 8F suction catheter or tracheal aspirator.

2. The infant's respiratory distress may improve if you insert a small endotracheal tube in the nose, advance it into the pharynx, and position the infant prone (on the stomach).

3. You should suspect a pneumothorax and rapidly prepare a needle aspiration device.

4. Promptly after birth, you should intubate the trachea and insert an orogastric tube in the stomach.

5. Your first priority is to start ventilation.

6. Position a newborn infant who has a myelomeningocele on their stomach or side.

7. Position a newborn infant with gastroschisis on their right side.

Lesson

11

Ethics and Care at the End of Life

What you will learn

- The ethical principles associated with neonatal resuscitation
- When it may be appropriate to withhold resuscitation
- What to do when the prognosis is uncertain
- What to do when an infant dies
- How to help parents and staff through the grieving process

Key Points

1. The ethical principles of neonatal resuscitation are the same as those followed in resuscitating an older child or adult.
2. The primary consideration for decisions regarding life-sustaining treatment for seriously ill newborn infants should be what is best for the infant.
3. Parents are generally considered the best surrogate decision-makers for their infants and should be involved in shared decision-making whenever possible.
4. For parents to fulfill this responsibility, they need comprehensive, relevant, and up-to-date information about the risks and benefits of each treatment option.
5. Parents need to be informed that, despite your best efforts, the ability to give an accurate prognosis for an extremely preterm infant remains limited, either before or immediately after birth.
6. If the responsible physicians believe that there is no chance for survival, initiation of resuscitation is not an ethical treatment option and should not be offered.
7. In conditions associated with a high risk of mortality or significant burden of morbidity for the newborn infant, parents should participate in the decision regarding whether attempted resuscitation is in their infant's best interest. If there is agreement that intensive medical care will not improve the chances for the newborn's survival or will pose an unacceptable burden on the infant, it is ethical to withhold resuscitation.
8. There may be laws in the area where you practice that apply to the care of newborn infants. If you are uncertain about the laws in your area, consult your hospital ethics committee or attorney.
9. Humane, compassionate, and culturally sensitive palliative care should be provided for all newborn infants for whom resuscitation is not initiated or is not successful.

About this lesson

Although this lesson is directed at the resuscitation team member who guides medical decision-making, all members of the resuscitation team should understand the reasoning behind the decisions. As much as possible, there should be unified support for the parents during their personal period of crisis. This lesson refers to "parents," although it is recognized that sometimes the mother(s), father(s), or partner(s) may be alone during the crisis and, other times, support will be available from extended family or significant others. This lesson is applicable to health care providers who participate in all aspects of care of pregnant patients and newborn infants, including antenatal care providers, pediatric and neonatology care providers doing preconception and prenatal consultations, inpatient perinatal care providers, and professionals providing care to families who have experienced a neonatal death.

It is important to recognize that the recommendations made in this lesson are determined, to an extent, by the cultural context and available resources in the United States and Canada and may require adaptation before being applied to other cultures and countries. These recommendations were based on mortality and morbidity data available at the time of publication. Decisions regarding initiation or noninitiation of resuscitation should be based on current local data and available therapies.

The following case is an example of the ethical considerations involved in neonatal resuscitation and how end-of-life care may be provided. As you read the case, imagine yourself as part of the care team.

Case: A baby who could not be resuscitated

A pregnant patient is admitted to the hospital at 23 weeks' gestation with contractions, fever, fetal heart rate decelerations, and ruptured membranes leaking purulent amniotic fluid. This patient received consistent prenatal care and the gestational age was estimated by a first-trimester ultrasound examination. You meet with the obstetric care provider and discuss the pregnancy history. Together, you review current national and local data describing the anticipated short- and long-term outcomes at this extremely early gestation. Afterward, both of you meet with the parents to provide information, discuss goals, explain the range of treatment options, and develop a care plan. You explain that some parents might decide that life-sustaining medical treatment is not in their baby's best interest in view of the high risk of mortality and morbidity and might, instead, choose palliative care focusing on the baby's comfort after birth. After considering the content of your discussion, the parents indicate that they want a trial of life-sustaining therapy with respiratory support and assisted ventilation, including intubation, but they do not want chest compressions or epinephrine administered. The parents request the presence of the hospital clergy during resuscitation, and this is quickly arranged. You document your discussion in the medical chart and meet with your resuscitation team to review the care plan.

Your team performs a pre-resuscitation briefing and prepares the supplies and equipment for a complex resuscitation. At the time of birth, the infant is limp and apneic, and has thin, gelatinous skin. The infant is carried to the radiant warmer, wrapped in polyethylene plastic, and placed on a thermal mattress, and a hat is placed on the infant's head. The initial steps are performed, and assisted ventilation is administered. A team member places a pulse oximeter sensor and cardiac monitor leads. The infant's heart rate is 40 beats per minute and not improving with face mask ventilation that moves the chest. The infant is successfully intubated and ventilation is continued; however, the heart rate does not increase and the oxygen saturation remains well below the target range. Despite appropriate ventilation, the infant's heart rate gradually decreases. You explain the baby's condition to the parents and your assessment that resuscitation will not be successful. You agree to remove the endotracheal tube, wrap the baby in a clean blanket, and bring the baby to the parents to be held and comforted. A ceremonial blessing is performed by the hospital clergy. Staff members and additional family provide ongoing support. The baby is pronounced dead when no signs of life remain.

Shortly afterward, you return to the parents' room, express condolences, answer their questions about the resuscitation attempt, and ask the parents about performing an autopsy. You offer to schedule a follow-up visit in several weeks to check in with the family and provide support. The next day, a funeral home is identified. About 1 month later, you meet with the parents to answer any questions they may have, discuss the autopsy results, explore how they are coping with their loss, and suggest grief counseling resources available in the community.

Ethical principles

The ethical principles of neonatal resuscitation are the same as those followed in resuscitating an older child or adult. Common ethical principles that apply to all medical care include respecting an individual's rights to make choices that affect their life (autonomy), acting to benefit others (beneficence), avoiding harm (nonmaleficence), and treating people truthfully and fairly (justice). These principles underlie why we ask patients for informed consent before proceeding with treatment. Exceptions to this rule include life-threatening medical emergencies where there is inadequate time to obtain informed consent before proceeding with treatment and situations where patients are not competent to make their own decisions. These 2 exceptions are relevant to neonatal resuscitation. Sometimes neonatal resuscitations are associated with medical emergencies that interfere with the informed consent process, and newborn infants cannot make their own decisions.

Shared decision-making

Unlike adults, newborn infants cannot express their desires or make decisions for themselves. A surrogate decision-maker must be identified to assume the responsibility of guarding the infant's best interests. Generally, parents are considered the best surrogate decision-makers for their own babies and should be involved in shared decision-making when possible. For parents to fulfill this responsibility, they need relevant, accurate, and honest information about the risks and benefits of each treatment option. In addition, they must have adequate time to thoughtfully consider each option, ask questions, and seek other opinions. At the start of your counseling session, it is helpful to elucidate parental values, beliefs, and preferences regarding how information is presented. This may allow you to personalize your counseling and adjust the informational content to best suit their individual needs.

Unfortunately, the need for resuscitation is sometimes an unexpected emergency with little opportunity to obtain fully informed consent before proceeding. Even when you have the opportunity to meet with parents, uncertainty about the extent of congenital anomalies, the actual gestational age, the likelihood of survival, and the potential for severe disabilities may make it difficult for parents to decide what is in their infant's best interest before birth. Complete information may not be available until after birth and perhaps not for several hours or days. These uncertainties should be addressed with the parents when the initial treatment plan is developed, and contingencies should be discussed. Parents and health care providers must be prepared to reevaluate their goals and plans based on the findings after birth and the baby's response to treatment. Discussions about the baby's best interests may continue well beyond the immediate newborn period.

Considerations involved in the decision regarding whether to initiate resuscitation of an extremely preterm infant

Parents should be provided with comprehensive, relevant, and up-to-date prognostic information. Antenatal outcome estimates for survival and disability among extremely preterm newborn infants typically have been based on gestational age and estimated weight. Unless the pregnancy was conceived by assisted reproductive technology where the date of fertilization or implantation can be precise, techniques used for obstetric dating are accurate to 3 to 5 days if applied in the first trimester, but only to ± 1 to 2 weeks subsequently. Estimates of fetal weight are accurate only to ± 15% to 20% and may be misleading if there is fetal growth restriction. Even small discrepancies of 1 or 2 weeks between estimated and actual gestational age, or a 100- to 200-g difference in birth weight, may have implications for survival and long-term morbidity.

The pregnant person's health, obstetric complications, and genetic factors also influence outcome. Scoring systems that include variables such as fetal sex, use of antenatal steroids, and multifetal gestation have been developed to improve prognostic accuracy. Be cautious when interpreting results from prognostic studies. Some investigators may describe the proportion of infants with each outcome based on the total number of live-born infants, while others describe the same outcome based on the number of infants resuscitated, the number of infants admitted to the nursery, or the number surviving until discharge. By simply changing the inclusion criteria for the calculation, the likelihood of an adverse outcome will change.

Remember that prognostic scores provide a range of plausible outcomes based on a sample of infants; however, they cannot definitively predict the outcome for any individual infant. Outcomes reported in published studies may not reflect current treatment practices or outcomes at your institution. In addition, the infant's appearance at the time of birth is not an accurate predictor of survival or disability. Parents need to be informed that, despite your best efforts, the ability to give an accurate prognosis for a specific newborn infant either before or immediately after birth remains limited.

Guidelines for the care of infants born at an extremely low gestational age are complex and evolving. For the most comprehensive and up-to-date guidance, refer to the current American Academy of Pediatrics Committee on Fetus and Newborn Clinical Report, the Canadian Paediatric Society Position Statement, the American College of Obstetricians and Gynecologists Obstetric Care Consensus, and the Society of Obstetricians and Gynaecologists of Canada Clinical Practice Guideline.

Situations in which it is ethical not to initiate resuscitation

The birth of extremely preterm infants and those with significant chromosomal abnormalities or congenital malformations frequently raises difficult questions about the initiation of resuscitation. Although general recommendations can guide practice, each situation is unique, and decision-making should be individualized.

If the responsible physicians believe that there is no chance for survival, the initiation of resuscitation offers no benefit to the infant and should not be offered. Humane, compassionate, and culturally sensitive palliative care focused on ensuring the baby's comfort is the medically and ethically appropriate treatment.

In conditions associated with a high risk of mortality or significant burden of morbidity for the infant, caregivers should discuss the risks and benefits of life-sustaining medical treatment with the parents and involve them in decision-making about whether attempting resuscitation is in their baby's best interest. If there is agreement between the parents and the caregivers that attempts at life-sustaining medical treatment are not likely to be successful or will pose an unacceptable burden on the baby, it is ethical to provide compassionate palliative care and not initiate resuscitation. If the parents' preferences regarding resuscitation are either unknown or uncertain, resuscitation should be initiated pending further discussions.

The following statement, adapted from the American Medical Association (AMA) code of Medical Ethics (AMA Opinion 2.2.4 [2025]), summarizes this approach to decision-making and is supported by the Neonatal Resuscitation Program® (NRP®).

Help the parents formulate goals for care that will promote their child's best interest

Factors that should be weighed are as follows:

1. The chance that the intervention will achieve the intended clinical benefit
2. The risks involved with treatment and nontreatment
3. The degree to which the therapy, if successful, will extend life
4. The pain and discomfort associated with the therapy
5. The anticipated quality of life for the newborn with and without treatment

Considerations when there is uncertainty about the chances of survival or serious disability

If parents are uncertain how to proceed, or your examination suggests that the prenatal assessment of disability was incorrect, initial resuscitation and stabilization allows you additional time to gather more complete clinical information, further elucidate parental values, and review the situation with the parents and consultants.

Upon further review, you and the parents may determine that continuing life-sustaining therapy is not in their baby's best interest and decide to redirect the treatment plan. Withholding resuscitation and withdrawing life-sustaining treatment during or after resuscitation are ethically equivalent. If the responsible health care providers and parents determine that life-sustaining treatment is no longer in the baby's best interest, they may choose to redirect from life-sustaining treatment to palliative care and focus on ensuring the baby's comfort.

Laws related to neonatal resuscitation

Medical ethics provide guidelines regarding how health care providers *should* act within a society. Based on these guiding principles, governments create and enforce laws that describe how individuals *must* act. There is currently no federal law in the United States mandating neonatal resuscitation in all circumstances. There may be laws in the area where you practice that apply to the care of newborn infants. If you are uncertain about the laws in your area, you should consult your hospital ethics committee or attorney. In most circumstances, it is ethically and legally acceptable to withhold or withdraw resuscitation efforts if the parents and health care providers agree that further medical intervention would be futile, would merely prolong dying, or would not offer sufficient benefit to justify the burdens imposed on the infant.

Specific rights and responsibilities of minors, non-birth parents, and unmarried partners may vary between states. You should meet with your hospital's legal counsel if you have questions about the regulations in the location where you practice.

Informing parents that their baby is dying

If the newborn infant in your care is not responding to treatment and is dying, your role is to support the parents by being honest and speaking in an empathic and caring manner. Ask if they have chosen a name for their baby and, if they have, refer to the baby by name. Explain what treatment you have provided and your assessment of the baby's current condition. State clearly and without euphemism that, despite treatment, their baby is dying. Explain how you plan to provide care for their dying baby and what options are available.

Some parents may be interested in pursuing organ or tissue donation. Although many neonatal deaths will not meet eligibility criteria because of small size or the time interval between withdrawal of life-sustaining therapy and death, many potentially eligible donations have been lost because the neonatal team failed to make a timely referral to their organ procurement agency. When a neonatal death is anticipated, it is important to consult your regional organ procurement agency regarding eligibility criteria so that you can advise the parents about potential donation options.

Taking care of an infant who is dying

The most important goal is to minimize suffering by providing humane and compassionate care. Offer to bring the baby to the parents. Silence the alarms on monitors and medical equipment before removing them. Remove any unnecessary tubes, tape, monitors, or medical equipment, and gently clean the infant's mouth and face. If the cause of the infant's death is uncertain or the death will be investigated by the coroner or medical examiner, it may be important to leave all medical devices and tubes in place. Wrap the infant in a clean, warm blanket. Opiates may be administered as needed, either orally, nasally, or intravenously, to relieve the infant's discomfort. Prepare the parents for what they may see, feel, and hear when they hold their dying baby, including the possibility of gasping, agonal respirations, color changes, persistent heartbeat, and continuing movements. If the infant has obvious congenital anomalies, briefly explain to the parents what they will see. Help them look beyond any deformities by pointing out a good or memorable feature.

Some units prepare a memory box for the parents with the infant's handprints or footprints, photographs, and other items.

Parents should be offered private time with their baby in a comfortable environment, but a health care provider should check at intervals to see if anything is needed. The infant's chest should be auscultated intermittently for at least 60 seconds, as a very slow heart rate may persist for hours. Disturbing noises such as phone calls, pagers, monitor alarms, and staff conversations should be minimized. When the parents are ready for you to take the baby, the baby should be taken to a designated, private location until ready to be transported to the morgue.

A member of the neonatal team should discuss the locally available options for performing a complete or limited autopsy. An autopsy can help determine the precise cause of death, confirm prenatal diagnoses, and reveal important new diagnoses. By further delineating the cause of death, an autopsy may reduce parental concerns and provide additional insight into the potential implications for future pregnancies.

It is helpful to understand the cultural and religious expectations surrounding death in the community you serve. Some families grieve quietly while others are more demonstrative; however, all modes are acceptable and should be accommodated. Some parents may prefer to be alone, while others may want their other children, their extended family, their friends, community members, and/or clergy to be with them. Families may request to take their baby to a hospital chapel or a more peaceful setting outside, or they may ask for help with arrangements for blessings or rites for their dead or dying baby. You should be as flexible as you can in responding to their wishes.

It is helpful to anticipate this difficult situation and develop a protocol in advance. Plan which staff members will be responsible for providing palliative care and how other members of the team can provide support. Members of the neonatal team may play an important role even if the infant is born so prematurely that life-sustaining therapy is not indicated. They may offer reassurance to the parents that the gestational age assessment is correct and use their expertise to help provide comfort care for the baby. Many nurseries develop a package of helpful information for staff members, including phone numbers for key support staff, instructions for completing the required administrative tasks, reminders about how to prepare the infant's body, and bereavement information for the family.

Planning follow-up for the parents

Before the parents leave the hospital, make sure you have contact information for them, and provide them with details about how to contact the attending physician, bereavement professionals, and, if available, a perinatal loss support group. If your institution does not provide these services, it may be helpful to contact your regional perinatal referral center to obtain contact information for the parents. It is important to involve the family's primary care physician and/or obstetric provider so they can provide additional support. The attending physician may schedule a follow-up appointment to answer any unresolved questions, review results of the autopsy or other studies pending at the time of death, and assess the family's needs. Parents should be directed to the obstetric provider if they have questions regarding events and care before birth. Some hospitals sponsor parent-to-parent support groups and plan an annual memorial service, bringing together families who have suffered a perinatal loss. Recognize that some families may not want any additional contact from the hospital staff. This desire must be respected. Unexpected communications, such as a quality assurance survey from the hospital or newsletters about infant care, may be an unwanted reminder of the family's loss.

Supporting the nursery staff after a perinatal death

Staff members who participated in the care of the infant and family also need support. They will have feelings of sadness and may be feeling anger and guilt. Consider holding a debriefing session shortly after the infant's death so you can openly discuss questions and feelings in a professional, supportive, and nonjudgmental forum. Some staff members may disagree with the parents' decisions. These feelings may be discussed during the debriefing but should not be expressed to the family. Questions and issues regarding care decisions and actions should be discussed only in a qualified peer review session, and the discussions should follow hospital policy for such sessions.

Focus on Teamwork

The ethical considerations and end-of-life care described in this lesson highlight several opportunities for effective teams to use the NRP Key Behavioral Skills.

Behavior	Example
Anticipate and plan.	Plan how you will provide antenatal counseling and manage difficult ethical decisions. Develop a protocol to use when caring for a dying baby and supporting the grieving family.
Communicate effectively.	When counseling parents, use clear language and terminology that they will understand. Visual aids and written materials may be helpful. Use an appropriately trained medical interpreter if a family member is not proficient in the language spoken by the health care team or has a hearing disability. Consider counseling parents jointly with the obstetric and maternal-fetal medicine staff to ensure that accurate and consistent information is provided.
Use available information.	Review both national and local outcome data and understand their limitations. Use all available prognostic information.

Use available resources. Call for additional help when needed.	Become familiar with the resources in your hospital and community that can help to resolve conflicts, answer legal questions, and provide bereavement services. If necessary, consult with specialists at your regional referral center to obtain up-to-date outcome information.
Maintain professional behavior.	Ensure that all members of the health care team understand the treatment plan. Disagreements should be discussed in an appropriate forum. Consult the hospital ethics committee or legal counsel if necessary.
Know your environment.	Understand the cultural and religious expectations surrounding death in your community.

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own hospital setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. Is up-to-date prognostic information for extremely preterm infants and infants with serious congenital anomalies readily available for staff providing antenatal counseling?
2. Do you have a package of information for staff with instructions for helping the family make memories, completing administrative tasks, and preparing the infant's body?
3. Do you have a package of information about local resources for grieving families?
4. Do you know how to urgently contact clergy for families who desire religious counseling or blessings for their infant?
5. Do you know how to contact your hospital attorney to answer questions about laws related to resuscitation in your area?
6. Does your unit offer education and other programs to support staff providing palliative, end-of-life, and bereavement care?
7. Does your perinatal team meet to discuss how you will care for infants at the limits of viability to develop a consistent approach?
8. How are individual care plans that are developed before an infant is born communicated to the staff who will be present at the infant's birth?

Process and outcome measures

1. What percentage of parents meet with a neonatal care provider for antenatal consultation before an extremely preterm infant is born?

2. In what percentage of high-risk births is a care plan documented in the medical chart?
3. How often do grieving parents leave the hospital with an established follow-up plan?
4. How often is the organ procurement agency in your area contacted before an infant's death?
5. In what percentage of neonatal deaths does the chart document that the parents were asked about performing an autopsy?
6. In what percentage of neonatal deaths are autopsies performed?

LESSON 11 REVIEW

1. In conditions associated with a high risk of mortality or significant burden of morbidity for the infant, parents (should)/(should not) participate in the decision regarding whether attempted resuscitation is in their baby's best interest.

2. The ethical principles of neonatal resuscitation are the (same)/(different) as those followed in resuscitating an older child or adult.

Answers

1. In conditions associated with a high risk of mortality or significant burden of morbidity for the baby, parents should participate in the decision regarding whether attempted resuscitation is in their baby's best interest.

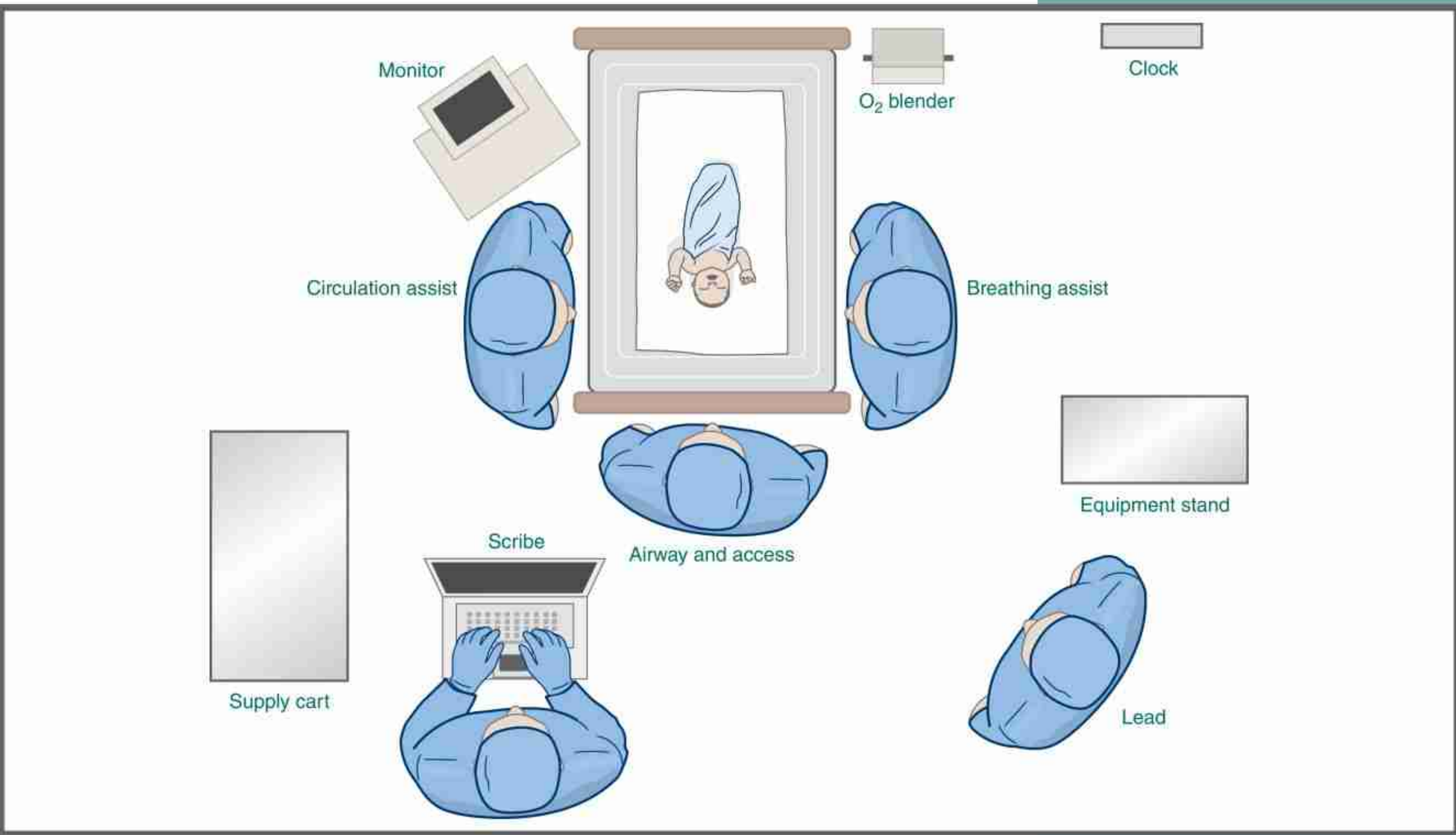
2. The ethical principles of neonatal resuscitation are the same as those followed in resuscitating an older child or adult.

Improving Resuscitation Team Performance

Supplemental Lesson 12

What you will learn

- How attention to ergonomics and human factors improves resuscitation team performance
- The 3 essential elements of a pre-resuscitation team briefing
- How to develop resuscitation schemes by assigning team roles, tasks, and positions
- How to use simulation and debriefing to test and improve your resuscitation schemes



Key Points

1. Beyond individual team members learning the cognitive and technical skills of resuscitation, considering human factors and the ergonomics of resuscitation can further improve safety and performance.
2. By understanding how humans perform a series of tasks in a real work environment, teams can predict where errors may occur, design systems that prevent these errors, and optimize team performance.
3. During your pre-resuscitation briefing, define the situation, assign roles with standardized tasks, and position team members in the environment.
4. Assigning roles sets expectations, allows adult learners to practice tasks repeatedly, increases learners' confidence in their ability to perform, decreases extraneous noise, and reduces cognitive load.
5. Schemes (descriptive plans or conceptual models) for resuscitation in the birth setting need to be individualized. Each hospital's role and task list will vary depending on the professional disciplines involved, the scope of practice for each discipline, and the number of resuscitation team members available for different resuscitation scenarios.
6. During a resuscitation, roles may need to be added or changed. How information is provided to arriving personnel and what roles they assume should be predetermined.
7. After you have created your schemes, conduct frequent simulated resuscitations to audit team performance, find weaknesses in your plan, and identify opportunities for improvement.

The role of ergonomics and human factors in neonatal resuscitation

This lesson focuses on improving resuscitation team performance. When resuscitation team members are assigned roles, and human factors and ergonomics are considered when assigning specific tasks to those roles, team members can work in synchrony. The resuscitation proceeds quickly and efficiently through an organized series of interventions and effective communication. The teamwork is so well organized that it appears choreographed.

The science of ergonomics analyzes human anatomy, physiology, and biomechanics to better understand how the work environment can be adapted to improve safety and performance. Ergonomics evaluates how equipment is used and what demands the equipment places on the user.

Over time, new technology has been added to the Neonatal Resuscitation Program® (NRP®) Algorithm. While new technology may improve the care we provide, it also adds to the quantity of data we must interpret and may increase the cognitive load on team members. Increasing the number of devices, people, complexity of tasks, and cognitive load may correlate with an increase in noise, a decrease in effective communication, and an increase in deviations from the NRP Algorithm.

Often, simple adjustments to the working environment can make a significant difference in performance. During neonatal resuscitation, appropriate positioning of people and equipment is essential. For example,

- If there is excessive glare on the pulse oximeter screen or the pulse oximeter is obstructed from view and team members cannot see the display, they may not assess the infant's oxygen saturation and adjust the oxygen concentration (FIO_2).
- If the oxygen blender is on the right side of the radiant warmer, it is difficult for team members positioned at the head of the bed or on the left side to adjust the FIO_2.
- If a tall provider attempts to intubate a newborn infant using a low radiant warmer that has no height adjustment, their awkward body position may decrease the likelihood of successful intubation.
- Obtaining an urgent chest radiograph is difficult if the radiant warmer is positioned in a corner of the room that is not easily accessible by an x-ray machine.

Human factors research investigates how humans interact with their environment, products, other humans, and technology. It combines an understanding of psychology, sociology, biomechanics, industrial design, and other related disciplines. Human factors research has taught us that individual team members may know the steps of resuscitation and have the technical skills to perform them, but that time can be wasted if roles are ambiguous and tasks are not assigned because team members will duplicate some tasks and omit others. By understanding how humans will perform a series of tasks in a real work environment, human factors experts attempt to predict where errors may occur, design systems that prevent these errors, and optimize team performance. For example,

- Using tables with precalculated epinephrine dosages can decrease the risk of making mathematical errors during a stressful situation.

Table 12-1. Strategies to Address Ergonomic and Human Factors Obstacles

Use cognitive aids such as the NRP Algorithm, Target Oxygen Saturation Table, and tables with endotracheal tube insertion depth and precalculated epinephrine dosages.
Use a standardized team briefing script.
Use a standardized supplies and equipment checklist.
Assign roles as part of a routine pre-resuscitation team briefing.
Create a standard description of the tasks that each role is expected to complete during a resuscitation.
Create standardized protocols and scripts for introducing additional team members arriving at a complex resuscitation.
Assign 1 team member the role of crowd control during a complex resuscitation.
Conduct frequent simulation training in the actual resuscitation environment.
Develop organized schemes to position personnel and equipment appropriately within the resuscitation environment.
Evaluate the accessibility and ergonomic function of resuscitation supplies and equipment.
Assess the tone and alarm volume on monitors used during resuscitation to be certain they can be heard but do not add to auditory overload.

- Incorporating human factors into resuscitation simulation and team briefing before a high-risk birth increases provider confidence and decreases distractions and noise.

Table 12-1 lists strategies to improve safety and team performance by addressing common ergonomic and human factors obstacles.

How to perform a structured pre-resuscitation team briefing

You learned about the importance of conducting a pre-resuscitation team briefing in Lesson 2. The team briefing is used to review the risk factors and any plan of care developed during antenatal counseling. At this briefing, the team leader is identified, possible scenarios your team may encounter are discussed, and roles and responsibilities are assigned.

There are 3 essential elements when planning a pre-resuscitation team briefing.

- *Defining* the situation
- *Assigning* roles and setting clear, detailed expectations for each role
- *Positioning* each team member within the resuscitation environment

Standardizing the pre-resuscitation team briefing to include these essential elements will help decrease variability and increase reliability. Reliable systems improve team performance and outcomes.

When possible, the pre-resuscitation team briefing should take place well before the anticipated birth. One way to ensure that teams have the opportunity to assemble prior to an event is to schedule a meeting with the obstetric team at the beginning of each shift to identify potential high-risk births. This allows the teams to meet face-to-face, assign roles, answer questions, and create both primary and contingency plans.

The importance of assigning roles and setting expectations

The NRP Key Behavioral Skills promote preparation for, and successful coordination of, resuscitation in the birth setting. There is growing evidence that enhanced behavioral and team leadership skills improve resuscitation outcomes. Stress increases when team members do not know what to expect from one another and the team leader does not know, or incorrectly assumes, what team members are going to do. Assigning roles sets expectations and allows adult learners to practice these specific tasks repeatedly, which results in increased confidence in their ability to perform. When team members know their roles and expectations are set in advance, there is less extraneous noise during the resuscitation. The decreased noise translates into fewer distractions from required tasks and reduces cognitive load.

One method to standardize role assignments is based on a team member's position at the radiant warmer. Each team member is given a specific role with a predefined list of tasks and a designated location at the radiant warmer that optimizes ergonomics. Role assignments take the guesswork out of who does what and have been shown to improve resuscitation performance.

Resuscitation schemes

Schemes are detailed, systematic plans of action that may be illustrated in the form of outlines or conceptual models. A resuscitation scheme describes your plan for organizing the personnel, equipment, and tasks during a resuscitation. The full resuscitation scheme specifies which personnel will be present, what supplies and equipment will be available, what role each person will have, what tasks will be assigned to each role, and where each team member will be placed during the resuscitation. The scheme must consider the number of tasks each team member can efficiently perform and whether the equipment required to perform those tasks is easily accessible within the resuscitation environment. A schematic is an illustration or table that describes your plan.

Designing schemes for a variety of resuscitation scenarios in your own environment is well worth the effort. High-performing teams with well-defined schemes experience less cognitive load, which allows them to focus their attention on other skills. Schemes for resuscitation in the birth setting need to be individualized to your specific location, equipment, and personnel.

Table 12.2 is a sample schematic describing roles and pre-birth task assignments for a 5-member team preparing for a very preterm birth.

Table 12-2. Sample pre-birth task assignments for a very preterm birth

Time	Airway & Access (Head of bed)	Breathing (Right)	Circulation (Left)	Lead (Back Right)	Scribe (Back Left)
Pre-delivery	**Meet with OB:** • Confirm 1. Pertinent history 2. Deferred cord clamp plan 3. OR temperature 4. Placement into plastic bag • Talk to family • Determine special equipment or personnel needs **At Warmer** • Double check: 1. Laryngoscope 2. ETTs 3. T-piece 4. CO_2 detector 5. Premature sized masks • Adjust warmer height	**Prepare Ventilation:** • Ventilator set-up • Test T-piece: 25/5 • Set FiO_2 • Prepare premature sized masks • CO_2 detector on mask • Pulse ox and probe cover (lower right) **Prepare ETT:** • Videolaryngo-scope • 0 and 00 blades (top right) • 2.5 ETT w/stylet (top right) • ETT securing device (lower right) • Measuring tape **CPAP prep** • CPAP at bedside set to 6 cm H_2O • Surfactant warming	**Prepare Bed:** • 2 blankets, 1 blue pad, 1 thermal mattress • Warmer to max • Activate thermal blanket • Hat (top left) • Suction catheter at 80 mm Hg (right) • Bulb syringe (top right) • ECG leads (left) • Stethoscope **Prepare monitor:** Audible ECG set on	**Prepare line tray:** • 3.5 Fr UAC • 3.5 Fr UVC • UVC/UAC supply tray • 2 stopcocks • Equipment stand • 2 × 3-mL syringes • 3 sterile towels • Prime IV lines	**Prepare Supplies:** • Humidity: add sterile H_2O to incubator • 3 × 5-mL saline with heparin flushes • Glucose meter ready • 2 × infusion pumps • Pre-admission order set complete • VLBW IV fluids ordered • Alert NICU clerk • Calculator • Computer turned on, Neonatal Resuscitation Log ready

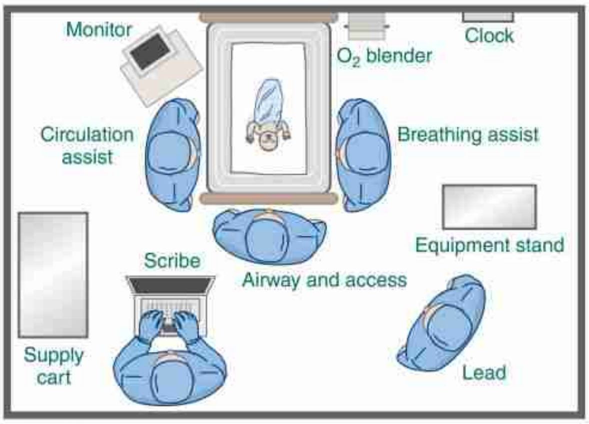


Figure 12.1. Sample 5-member team position schematic for a complex resuscitation.

The schematic describes where personnel stand and where important supplies are placed on the radiant warmer to ensure easy accessibility during resuscitation or post-resuscitation care. Figure 12.1 is a sample schematic for the placement of each team member by role based on the configuration of this particular hospital's resuscitation environment.

Following the 5-member schematic shown in Figure 12.1, examples of the tasks that may be assigned by role after birth are described in the following text.

- **Airway and Access:** The person at the head of the bed is well positioned to manage the airway. Tasks assigned to this role may include applying a hat, positioning the newborn infant's head and neck, performing bulb suction, positioning the face mask, providing face mask ventilation, and intubating the newborn infant if necessary. If chest compressions are needed, this team member hands over ventilation to the Breathing Assist role, allows the Circulation Assist to move to the head of the bed to provide chest compressions, and then moves into position to insert an emergency umbilical venous catheter.

- **Breathing Assist:** The person on the right side of the bed is well positioned to access the right hand or wrist, monitor pulse oximetry, and adjust the oxygen blender. The team member in this role focuses on assisting with the assessment and support of breathing. Tasks assigned to this role may include turning on the Apgar timer, applying the pulse oximeter sensor, assisting with ventilation corrective steps, monitoring for chest movement, placing a carbon dioxide (CO_2) detector on the face mask if requested, monitoring for color change on the CO_2 detector, assisting with intubation and securing the endotracheal tube if needed, assessing breath sounds, monitoring oxygen saturation, and adjusting the FiO_2. If chest compressions are needed, this person takes over ventilation through the endotracheal tube.
- **Circulation Assist:** The person on the left side of the bed is well positioned to see the infant's chest but cannot easily reach the infant's right hand or the oxygen blender. The team member in this role focuses on assisting with temperature control, assessing circulation, and providing chest compressions if needed. Tasks assigned to this role include placing cardiac monitor leads, assessing heart rate with a stethoscope, ensuring the polyethylene plastic bag or wrap remains over the newborn infant's shoulders, assisting with securing the endotracheal tube as needed, and administering chest compressions from the head of the bed.
- **Lead:** This person is ideally positioned to maintain situation awareness and lead the team. Ideally, the team member in this role is not assigned other tasks. Depending on the availability of additional personnel and scope of practice, the Lead may be needed to assist with emergency procedures. If this occurs, another team member must assume the Lead role.
- **Scribe:** This person is well positioned to see the monitors, clock, and all team members. The team member in this role documents events as they occur, notifies the team of critical time points, maintains critical communication with the Lead, and may call for additional support. In a 5-member team, if chest compressions are required and additional support is not available, this person will hand over recording to the Lead and assume the task of preparing and administering emergency medications.

At a hospital that has more personnel available, the same scenario may be managed using a 6- or 7-member team. In these schemes, the team may have designated Medication and Access roles. As the team gets larger, managing the number of people who can efficiently work in a small space becomes an important consideration. A larger team may include a Manager whose tasks include crowd control, information dissemination (eg, laboratory results), parent support, and assignment of roles as new personnel arrive.

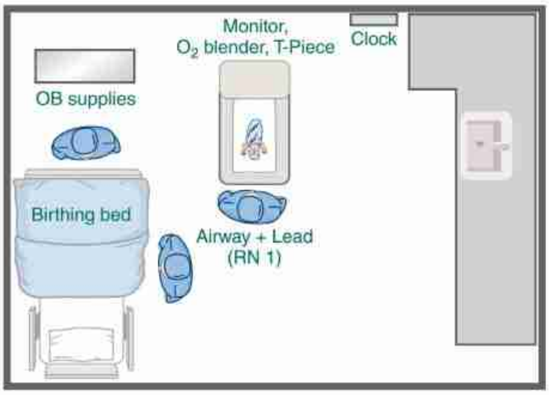


Figure 12.2. Evolution of roles and positions as personnel arrive for an unexpected resuscitation. A term newborn infant requires unanticipated assisted ventilation. One nurse (RN 1) is present for the birth.

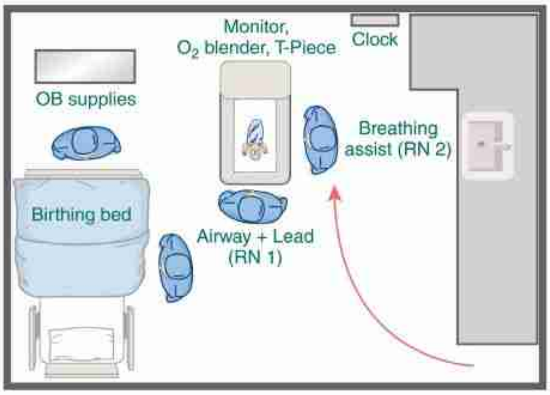


Figure 12.3. A second nurse arrives (RN 2) and assumes the Breathing Assist role.

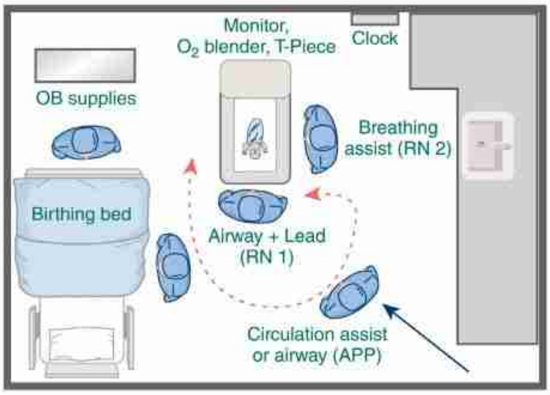


Figure 12.4. An advanced practice provider (APP) arrives and is directed to take the Circulation Assist role if face mask ventilation is effective or to assume the Airway role if the newborn infant needs to be intubated. If the APP assumes the Airway role to intubate, RN 1 will maintain the Lead role.

Roles may change if the resuscitation is unexpected

If a resuscitation is unexpected, roles may need to be added to the resuscitation scheme or changed in a planned and coordinated way depending on the newborn infant's needs and team members' scope of practice. How information is provided to arriving personnel and what roles they assume should be predetermined.

For example, if only 1 nurse attends the birth of a term infant who unexpectedly requires resuscitation, the nurse initially assumes the Airway and Lead role at the head of the bed, initiates assisted ventilation, and presses an emergency call button for immediate assistance. The first person who comes to assist (in this scenario, another nurse) is predesignated to assume the Breathing Assist role on the infant's right side. This nurse places a pulse oximeter sensor, assesses the infant's response to assisted ventilation and adjusts the FiO_2 as needed, and places cardiac monitor leads if the infant is not showing improvement. The third person to arrive, an advanced practice provider, is directed by the Airway nurse to take the Circulation Assist role if face mask ventilation is effective or the Airway role if intubation is required. If the third person assumes the Airway role, the original nurse moves to the left side of the bed and assumes the Circulation Assist role. Team members arriving later may assume the Lead and Scribe roles.

The schematics in Figures 12.2 through 12.4 illustrate how these roles might evolve. In this hospital's environment, the pulse oximeter and oxygen blender are integrated within the radiant warmer, and emergency supplies are stored in a drawer below the warmer.

Creating your own system for standardizing roles and tasks

Each hospital's role and task list will vary depending on the professional disciplines involved, the scope of practice for each discipline, the placement of equipment around the warmer, and the number of resuscitation team members available for different resuscitation scenarios. Even hospitals that routinely provide only uncomplicated obstetric services must plan schemes for complex resuscitations because unanticipated complications can arise, such as a depressed newborn infant secondary to shoulder dystocia or placental abruption, deliveries complicated by meconium aspiration, undiagnosed congenital malformations, unanticipated preterm birth, or other complications resulting in neonatal respiratory or neurologic depression.

- The first step is to determine the personnel available to attend resuscitations of varying complexity at your facility.
- Next, make a comprehensive list of every task that must be done to prepare for the birth and resuscitation of newborn infants in these scenarios. For example, the list of tasks required to resuscitate a term newborn infant who requires brief assisted ventilation at birth and quickly recovers will be much shorter than the list of tasks required to prepare for and resuscitate an infant born at 26 weeks' gestation.
- Once you have determined the available personnel and the tasks to be performed, you can begin the process of assigning proposed roles and tasks. Decide where each person should stand and where supplies and equipment can be placed to ensure they are easily accessible to the person who must use them.
- Finally, simulate a series of carefully monitored scenarios, test your proposed role and task assignments, identify potential barriers or inefficient processes, make adjustments to optimize team performance, and test your new proposal until you develop a final plan that describes your scheme for each scenario.

Assessing the effectiveness of your new standardized system

After you have created your schemes, conduct frequent simulated resuscitations using different scenarios to audit your performance, find weaknesses in your plan, and identify opportunities for improvement. Simulation can help your team identify ergonomic and human factors issues, evaluate the effectiveness of your pre-resuscitation briefing, and reinforce team roles and responsibilities. Consider video recording your scenarios to support detailed debriefings. Review the video recordings with your team and watch carefully for inefficient practices and potential safety threats.

- Begin with a simple assisted ventilation scenario, adjust your assigned tasks as needed, and work up to a complex resuscitation involving umbilical vein catheter insertion and medications.
- Adjust the tasks assigned to each role until team members are able to work quickly and efficiently without getting in each other's way. Your simulation may reveal a series of small problems that can be resolved with simple solutions. You may notice that the placement of monitors

is not ideal for all team members or discover that the supplies for an assigned task are not easily accessible. For example,

- The person placing the pulse oximeter sensor on the infant's right hand or wrist should be on the infant's right side; otherwise, the team member has to reach over the infant.
- The person adjusting the F_{IO_2} should be able to reach the dial on the oxygen blender.
- The person calling for additional help should be able to reach the call button or phone without interfering with their other tasks.

- Be sure to include the Scribe role during simulation because the Scribe must be able to see the infant, see the monitors, see and hear the team members, and see the time device being used for code documentation.

Supplemental Lesson 13

Resuscitation Outside the Delivery Room

What you will learn

- How to apply Neonatal Resuscitation Program® (NRP®) principles to newborn infants who require resuscitation outside the delivery room setting
- How to apply NRP principles to newborn infants who require resuscitation beyond the immediate transition period

Key Points

1. Although resuscitation of the newborn infant outside the delivery room setting presents different challenges, the physiologic principles and basic steps of the Neonatal Resuscitation Program (NRP) Algorithm remain the same.

2. Regardless of the location of birth, ventilation of the lungs is the initial priority for resuscitating the newborn infant immediately after birth.

3. All locations where newborn infants receive care, including each postpartum room, should have immediate access to a bulb syringe, a self-inflating bag, and appropriately sized resuscitation face masks.

4. Ventilation of the lungs is the priority for resuscitating most newborn infants after the initial transition period. Once adequate ventilation is ensured, obtain additional information about the infant's history to guide interventions.

5. Because most sudden cardiorespiratory events occurring in newborn infants after the initial transition period have an underlying respiratory etiology, this program recommends using a 3:1 compression-to-ventilation ratio with 120 events per minute (90 compressions + 30 ventilations) for newborn infants who require chest compressions during the initial hospitalization. This recommendation may be modified by health care providers who suspect a primary cardiac arrhythmia or an electrolyte disturbance.

6. There is currently insufficient evidence to make a universal recommendation that is appropriate for all newborn infants regarding when to transition from using the NRP Algorithm to the Pediatric Advanced Life Support (PALS) algorithms. Rather than attempting to identify an age at which the PALS algorithms should be followed, consideration of the etiology of the acute event requiring resuscitation is likely to be more helpful.

The *Textbook of Neonatal Resuscitation*, 9th edition, focuses on resuscitation of the newborn infant in a hospital delivery room or an accredited birth center. However, not all neonatal resuscitation takes place in these settings. In this lesson, you will learn about strategies for resuscitating newborn infants outside the delivery room setting and infants who require resuscitation in the parent's postpartum room after the initial transition period. Additional information describing the resuscitation of infants in the neonatal intensive care unit (NICU) after the transition period is provided in Supplemental Lesson 16 ("Resuscitation in the Neonatal Intensive Care Unit").

Case 1: Newborn resuscitation after a home birth

A multiparous pregnant person at 36 weeks' gestation awakens following premature rupture of membranes and experiences the rapid onset of frequent, intense contractions. The nearest hospital is more than a 30-minute drive away and the pregnant person's partner calls 911. The emergency operator advises the partner to increase the temperature in the room by turning the thermostat to 74°F and obtain towels to warm and dry the infant after birth.

The emergency medical service (EMS) is dispatched and arrives at the home just as the infant's head is crowning. The team quickly assembles supplies and equipment from the emergency childbirth kit, including personal protective equipment, warm towels and blankets, a cotton hat, umbilical cord clamps and sterile scissors, a bulb syringe, a stethoscope, a handheld Doppler ultrasound, a small self-inflating bag and neonatal face mask, a portable oxygen source, a pulse oximeter, and a laryngeal mask.

The infant is born with poor tone and does not cry. One member of the EMS team places the infant skin-to-skin on the parent's chest and uses a warm towel to dry and stimulate the infant by gently rubbing the infant's back, but the infant's condition does not improve. The umbilical cord is clamped and cut, and the infant is moved to a covered, flat surface. The EMS provider puts a hat on the infant's head and places the infant's head in the sniffing position. The infant remains limp and apneic. The paramedic begins assisted ventilation with a self-inflating bag and mask, using 21% oxygen, as additional emergency responders arrive. An assistant uses a stethoscope to listen to the infant's heart rate and applies a pulse oximeter sensor on the infant's right hand. Two minutes after birth, the infant's heart rate is 80 beats per minute (bpm) and increasing, but there is no respiratory effort, and the oxygen saturation is below the target range. An assistant connects the self-inflating bag to a portable oxygen source. Three minutes later, the newborn's heart rate is greater than 100 bpm, but the infant still has poor tone, a low oxygen saturation, and irregular, grunting spontaneous respiratory effort. The EMS provider inserts a laryngeal mask and continues ventilation while monitoring the infant's heart rate and oxygen saturation. The infant is wrapped in a warm blanket and prepared for safe transport to the nearest hospital emergency department for further evaluation and treatment.

Are resuscitation techniques different for infants born outside the delivery or birthing room setting?

Although newborn infant resuscitation scenarios encountered outside the delivery or birthing room setting present different challenges, the physiologic principles and basic steps remain the same. **Regardless of the location of birth, ventilation of the lungs is the initial priority for resuscitating the newborn infant.**

Strategies for resuscitating infants born outside the delivery or birthing room

Temperature management

When an infant is born outside the delivery or birthing room environment, without a radiant warmer, maintaining the infant's axillary temperature between 36.5°C and 37.5°C (97.7°F and 99.5°F) may be challenging. Some suggestions for minimizing heat loss include the following:

- Increase the room or ambulance's temperature to 74°F to 77°F by adjusting the room's heat source.
- Dry the infant thoroughly with bath towels, a blanket, or clean clothing. If available in the home, towels may be warmed using a clothes dryer.
- Place a cotton cap on the newborn infant's head.
- Use the parent's body as a heat source. Consider placing the infant skin-to-skin on the parent's chest and covering both infant and parent with a warm blanket. If the infant is preterm or the environment is cold, consider covering the infant with a clean sheet of food-grade plastic wrap or placing the infant's lower body and chest (up to the neck) in a food-grade polyethylene plastic bag, and then covering the infant with a warm blanket.
- Emergency response teams should consider keeping a supply of polyethylene plastic wrap and portable thermal mattresses to help maintain temperature. It is important that the thermal mattress be stored and activated at room temperature. If the mattress is already warm (from being stored in a hot vehicle), it may reach a higher temperature than intended after activation and increase the risk of overheating the newborn infant or causing thermal injury.

Ventilation

Ventilation of the infant's lungs is the single most important and effective step during neonatal resuscitation. Most infants breathe spontaneously after birth, and many of those who do not will begin spontaneous respirations after receiving gentle tactile stimulation.

Drying the newborn infant and rubbing the back and extremities are acceptable methods of stimulation. Some infants born outside the delivery or birthing room setting may require assisted ventilation to inflate their lungs. The NRP recommends that all personnel who may need to resuscitate a newborn outside the delivery or birthing room environment carry an appropriately sized self-inflating bag-and-mask device and portable oxygen source in case assisted ventilation is needed. Similar to the method described in Lesson 4, if the infant's heart rate does not increase rapidly after starting assisted ventilation and the chest is not moving, use the ventilation corrective steps (MR SOPA).

Clearing secretions from the airway

If secretions are obstructing the airway, use a bulb syringe or wipe the mouth and nose with a clean handkerchief or other cloth wrapped around your index finger.

Assessing heart rate

Initially, the infant's heart rate should be assessed by auscultating the chest with a stethoscope. Emergency responders who attend births should also carry a pulse oximeter. An appropriately sized oximeter sensor and sensor cover should be used. If the newborn infant's heart rate cannot be auscultated and pulse oximetry is not functioning, a handheld Doppler ultrasound (used to auscultate the fetal heart rate prior to birth) can be held against the infant's chest to assess the heart rate, or a portable cardiac monitor with appropriate chest leads may be used.

Oxygen management

Outside the delivery or birthing room environment, you may not have access to an oxygen blender. You can administer 21% oxygen by ventilating with a self-inflating bag that is not attached to an oxygen source. If the self-inflating bag is attached directly to a portable oxygen source with 5 to 10 L/min flow during ventilation with a rate of 30 to 60 breaths per minute and peak inflation pressure near 25 cm H_2O, you will be administering approximately 85% to 90% oxygen. If pulse oximetry is available and indicates that the infant's oxygen saturation is outside the target range, you may be able to adjust the oxygen concentration (FIO_2) by incrementally adjusting the flowmeter on the portable oxygen tank between 0 L/min and 10 L/min.

If the newborn infant is breathing and has a heart rate greater than 100 bpm, but the oxygen saturation is below the target range, you can give supplemental oxygen through oxygen tubing, through an oxygen mask, or from the open reservoir (tail) of some self-inflating bags. Adjust the distance between the 100% oxygen flow and the infant's mouth and nose, or adjust the gas flow rate, to maintain the oxygen saturation within the minute-specific target range. Be aware that newborn infants may rapidly become hypothermic if cold and dry gas from a compressed source is directed across their face or body.

Alternative airways

If an alternative airway is needed, this program suggests the use of a laryngeal mask as guided by local protocols and described in Lesson 4. Endotracheal intubation is possible but may be more difficult and less successful for newborn infants outside of the delivery room setting. Insertion of a laryngeal mask does not require additional instruments or visualization of the infant's vocal cords. Laryngeal masks can be inserted by appropriately trained emergency responders with a high rate of first attempt success and have been shown to be an effective alternative to both face mask ventilation and endotracheal intubation. If face mask ventilation is not successful or if prolonged ventilation will be required during emergency medical transport to a hospital, insertion of a laryngeal mask, as guided by local protocols, is suggested.

Similar to the recommendation in Lesson 6, in most circumstances, effective ventilation through an alternative airway is suggested, if feasible, prior to initiating chest compressions. Provide 30 seconds of ventilation through the laryngeal mask, ensure that the chest is moving with ventilation, and reassess the heart rate before beginning chest compressions. The laryngeal mask may improve the efficacy of ventilation and increase the heart rate so that chest compressions are not necessary. Use the most accurate method available for assessing the infant's heart rate (such as a portable cardiac monitor or handheld Doppler ultrasound) to ensure appropriate decision-making and interventions.

Although laryngeal mask insertion is consistent with the general guidelines for nurse and respiratory therapist practice within hospitals, emergency response personnel should check with their state licensing board or regulatory agency regarding laryngeal mask insertion and their professional scope of practice.

Chest compressions

Chest compressions are indicated when the newborn infant's heart rate remains less than 60 bpm after at least 30 seconds of ventilation that inflates the lungs, as evidenced by chest movement with ventilation. If feasible, insertion of a laryngeal mask to improve the effectiveness of ventilation prior to initiating chest compressions is suggested. Regardless of the location of birth, this program recommends using a 3:1 compression-to-ventilation ratio with 120 events per minute (90 compressions + 30 ventilations). Chest compressions should be accompanied by coordinated ventilations using 100% oxygen, as described in Lesson 6.

Vascular access and medications

If the newborn infant's heart rate remains less than 60 bpm after 60 seconds of chest compressions and coordinated ventilations, epinephrine and possibly volume expansion are indicated, as described in Lesson 7. In this case, emergency vascular access is required. Emergency catheterization of the umbilical vein generally is not an option outside the delivery room setting. In such cases, prompt insertion of an intraosseous needle into the flat surface of the tibia just below and medial to the tibial tuberosity (the bony bulge below the kneecap), as described in Lesson 7, is a reasonable alternative. Attempts at inserting a peripheral intravenous catheter are likely to be unsuccessful because of the infant's poor perfusion.

Emergency response personnel should check with their state licensing board or regulatory agency regarding emergency vascular access and medication administration and their professional scope of practice.

Transporting the newborn infant to a medical facility for post-resuscitation care

A newborn infant who requires assisted ventilation for more than 30 to 60 seconds should be transferred to an appropriate medical facility for close monitoring, post-resuscitation care, and evaluation. In addition, any preterm infant or infant who has respiratory distress, persistent central cyanosis, poor tone, poor perfusion, fever, hypothermia, difficulty feeding, or other signs of failing transition or illness should be immediately and safely transported to a medical facility.

What is the American Academy of Pediatrics position on planned home birth?

In 2020, the American Academy of Pediatrics (AAP) Committee on Fetus and Newborn published a Policy Statement, "Providing Care for Infants Born at Home."[1] The statement addressed resuscitation of the newborn infant after home birth, as well as initial care and follow-up. Both the AAP and NRP believe that hospitals and accredited birth centers are the safest settings for birth in the United States because planned home births are associated with a twofold to threefold increase in perinatal mortality. Therefore, the AAP and NRP do not recommend planned home birth; however, the AAP and NRP recognize that pregnant people have the autonomy to choose the location of their infant's birth, and some will choose a home birth. Pregnant people who choose a planned home birth should be fully informed that in the event of an unanticipated emergency, it is unlikely that the personnel, supplies, and equipment necessary to perform a complex neonatal resuscitation will be immediately available in the home environment, and any delay may result in an adverse outcome for the newborn infant.

Case 2: Resuscitation in the postpartum unit

An infant was born at term in the hospital following an uncomplicated pregnancy and labor. The transitional period was uneventful, and the infant stayed with the parent to begin breastfeeding. During breastfeeding, when the infant was approximately 6 hours of age, the parents noticed that the infant was limp, not breathing, and unresponsive. The parents activated the nurse call button and shouted for help, and a nurse from the postpartum unit responded immediately. The nurse turned on the room light, opened the blanket, and found the infant limp and apneic. The nurse placed the infant on a safe, flat surface, provided stimulation by rubbing the infant's back, and placed the infant's head in the sniffing position. The infant did not improve after these maneuvers. To get additional help, the nurse pushed the emergency response button on the wall and began assisted ventilation with the self-inflating bag and mask that were kept in the postpartum room.

The neonatal resuscitation team arrived in the room, received information from the first-responder nurse, and quickly assessed the situation. One team member used a stethoscope to listen to the infant's heart rate and breath sounds. Another team member placed a pulse oximeter sensor on the infant's right hand and portable cardiac monitor leads on the infant's chest. The infant's heart rate was 80 bpm and rising, but the respiratory effort was irregular, and oxygen saturation was low. The FIO_2 was adjusted to achieve an oxygen saturation greater than 90%. The infant soon developed consistent respiratory effort, the heart rate increased above 100 bpm, and assisted ventilation was gradually discontinued. The infant received supplemental oxygen through the open tail reservoir of the self-inflating bag and was transferred to the nursery in a prewarmed incubator for additional evaluation and treatment. A team member stayed with the infant's parents to obtain additional information, provide support, and answer questions. Shortly afterward, the care team conducted a debriefing to evaluate its readiness, teamwork, and communication.

Sudden unexpected postnatal collapse

The infant in the scenario experienced sudden unexpected postnatal collapse (SUPC), which is a clinical entity characterized by a need for resuscitation with assisted ventilation in an apparently healthy term newborn during the first 12 hours after birth. It is one reason why an infant may require resuscitation beyond the immediate transition period. This event can occur during skin-to-skin contact with the parent or during a breastfeeding session. Many newborn infants are in a prone position at the time of the event. Many affected newborn infants will require intensive care, and some will die. The reported incidence of SUPC ranges from 3 to 74 cases per 100,000 live births. The etiology of SUPC is unknown and is likely multifactorial. Most cases are unexplained.

Are resuscitation techniques different for newborn infants after the initial transition period?

Throughout this program, you have learned about resuscitating newborn infants in the delivery or birthing room setting during the transition period immediately after birth. Some infants, however, require resuscitation after this initial transition. Although resuscitation scenarios encountered after the initial transition period present unique challenges, the physiologic principles and basic steps remain the same. **Ventilation of the lungs is the initial priority for resuscitating most newborn infants after the initial transition period.** Once adequate ventilation is ensured, obtain additional information about the infant's history to guide interventions.

Strategies to resuscitate newborn infants after the initial transition period

Temperature management

Maintaining normal body temperature is easier outside the initial transition period because the infant's body is not wet, and the risk of evaporative heat loss is lower. However, thermoregulation is still essential. To prevent hypothermia, resuscitate under a radiant warmer if available, use a hat, and wrap the infant in warm blankets for transport.

Ventilation

A self-inflating bag and mask should be immediately available in every postpartum room and require no compressed air for use. Ensure an open airway by placing the infant's head and neck in the sniffing position. Using the same principles taught in Lesson 4, troubleshoot ineffective ventilation using the ventilation corrective steps (MR SOPA).

Clearing secretions from the airway

If you suspect that secretions are obstructing the airway, use a bulb syringe or wipe the mouth and nose with a clean handkerchief or cloth wrapped around your index finger.

Assessing heart rate

If you are alone when you discover a limp, apneic newborn infant in a postpartum room who does not respond rapidly to gentle tactile stimulation, call for help and begin assisted ventilation without delay. A resuscitation team member who arrives to help will assess the infant's heart rate. Initially, the infant's heart rate should be assessed by auscultating the chest with a stethoscope. If not immediately available in the postpartum room, the emergency resuscitation team should bring a pulse oximeter and cardiac monitor. These monitors should be applied to the infant as soon as possible so the team members have accurate data to inform their decisions.

Alternative airways

If an alternative airway is needed, a laryngeal mask or an endotracheal tube can be used. The laryngeal mask, described in Lesson 4, may be preferable if the infant is being resuscitated in a location that makes positioning for intubation difficult.

Chest compressions

Because most sudden cardiorespiratory events occurring in newborn infants after the initial transition period have an underlying respiratory etiology, this program recommends using a 3:1 compression-to-ventilation ratio with 120 events per minute (90 compressions + 30 ventilations) for newborn infants who require chest compressions during the initial hospitalization. This recommendation may be modified by health care providers who have a reason to suspect a primary cardiac etiology. Based on current guidelines, chest compressions should be accompanied by coordinated ventilations, preferably with an endotracheal tube or a laryngeal mask, with 100% oxygen.

Vascular access and medications

If the infant's heart rate remains less than 60 bpm after 60 seconds of chest compressions and coordinated ventilations, epinephrine and possibly volume expansion are indicated, as described in Lesson 7. In this case, emergency vascular access is required. Emergency catheterization of the umbilical vein may be successful during the first week after birth. Beyond the first week, this is generally not an option. In such cases, prompt insertion of an intraosseous needle into the flat surface of the tibia just below and medial to the tibial tuberosity (the bony bulge below the kneecap), as described in Lesson 7, is a reasonable alternative for emergency vascular access. Attempts at inserting a peripheral intravenous catheter are likely to be unsuccessful because of the infant's poor perfusion.

If an infant is found unresponsive on the postpartum unit, should resuscitation be initiated in the parent's room, or should the infant be carried to the nursery?

When faced with a compromised infant in a parent's room, the decision to "scoop and run" to the nursery may seem like a reasonable approach, but this is not the best choice for several reasons. It is not safe to run down a hallway carrying a compromised newborn infant in your arms.

This puts you and the infant at risk for injury from a fall or a collision with another person, equipment, or a passageway door.

In general, every location where newborn infants receive care should have ready access to the equipment necessary to initiate resuscitation. If there is a designated resuscitation space that is only steps away from every postpartum room, it may be appropriate to carefully move the compromised newborn infant directly to this location for immediate care. In all cases, the optimal solution prioritizes a timely and efficient response and best serves the interests of the infant's health and safety.

- Each hospital should evaluate its readiness for resuscitating newborn infants in locations outside the delivery or birthing room setting.
- Anticipate this potential scenario and develop a plan for how an emergency call will be initiated, how the appropriate team will be assembled, what equipment will be stored in the room, and what equipment will be stored in a nearby location (eg, code cart in the hallway).
- By simulating unusual or uncommon scenarios in different locations, you can make plans to address your system's weaknesses and improve your teamwork.

When should pediatric resuscitation algorithms be used?

There is insufficient evidence to make a universal recommendation that is appropriate for all newborn infants outside the initial transition period. It is unlikely that there is a single post-conceptual age or number of days or weeks after birth when resuscitation following the Pediatric Advanced Life Support (PALS) algorithms,[2] compared with the NRP Algorithm, leads to improved outcomes. The recommendations provided by the NRP are primarily intended to address the resuscitation of newborn infants transitioning from intrauterine to extrauterine life. The recommendations included in the PALS algorithms are intended to address a broader range of acute events, including cardiac arrhythmias, trauma, septic shock, drowning, and toxicological emergencies. The PALS algorithms include therapies and medications such as defibrillation and amiodarone that are not included in the NRP Algorithm. Rather than attempting to identify an age at which NRP or PALS algorithms should be followed, consideration of the etiology of the acute event requiring resuscitation is likely to be more helpful.

Most acute cardiorespiratory events occurring in newborn infants during the hours and days after the initial transition period, and many occurring during the first weeks or months in the NICU, are caused by respiratory failure. Therefore, restoring ventilation using the principles described in the NRP Algorithm still applies. For newborn infants in whom the etiology of their cardiorespiratory arrest is not addressed by the NRP, such as a primary cardiac arrhythmia, septic shock, or an electrolyte disturbance, the treatment approach described in the PALS algorithms may be most appropriate.

The practical implications for training emergency responders and hospital staff outside the delivery room environment must be considered. The leadership in areas where infants may require resuscitation must decide which training is most appropriate for staff based on the needs of the patient population. If the staff within a single unit is trained in both programs, it is essential to develop a plan to determine which resuscitation guidelines are being used and to clearly communicate this plan to the resuscitation team to avoid confusion. These concepts are explored further in Supplemental Lesson 16 ("Resuscitation in the Neonatal Intensive Care Unit").

References

1. Watterberg K; Committee on Fetus and Newborn. Providing care for infants born at home. *Pediatrics.* 2020;145(5):e20200626. doi:10.1542/peds.2020-0626

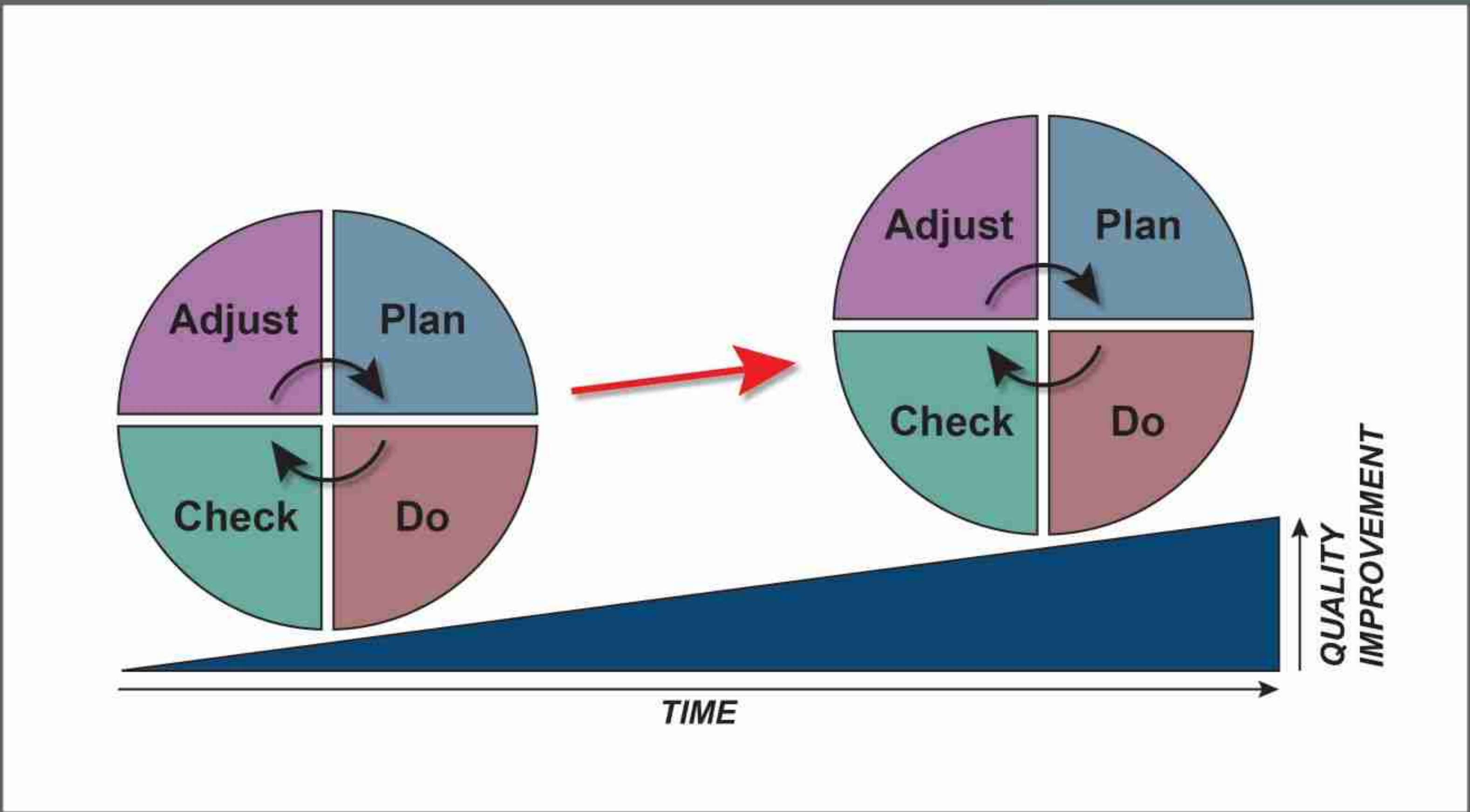
2. Lasa JJ, Dhillon GS, Duff JP, et al. Part 8: Pediatric advanced life support: 2025 American Heart Association and American Academy of Pediatrics guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Pediatrics.* 2025; doi: 10.1542/peds.2025-074351

Supplemental Lesson 14

Bringing Quality Improvement to Your Resuscitation Team

What you will learn

- The rationale for introducing quality improvement (QI) methods into the birth setting
- Basic QI principles
- Potential QI projects for neonatal resuscitation teams



Key Points

1. In health care, multifaceted tasks such as neonatal resuscitation benefit from the application of quality improvement principles.
2. Quality improvement can address multiple aspects of neonatal resuscitation practice and outcomes.
3. A multidisciplinary team is a key component of effective quality improvement.
4. Project aims should be specific, measurable, achievable, realistic, and timely.
5. A balancing measure seeks to ensure that the quality improvement project is not leading to unintended adverse consequences.
6. Data collection and reporting can identify gaps and allow tracking of neonatal resuscitation performance.
7. As the team tracks data and develops ideas for changes to result in improvement, a common method of testing change is the 4-phase Plan-Do-Check-Adjust (PDCA) cycle.

Case: A quality improvement project to reduce hypothermia in preterm newborn infants

A staff member who collects data for your hospital's participation in a statewide collaborative notices that several recent preterm infants had hypothermia when they were admitted to your neonatal intensive care unit (NICU). The staff member brings this to the attention of the nurse manager and medical director. The team reviews data from the past 12 months and finds that the average temperature among the 20 infants born before 32 weeks' gestation was 35.9°C. Because admission hypothermia is associated with adverse outcomes for preterm infants, a multidisciplinary quality improvement (QI) team is formed to address this problem. The team includes a neonatologist, neonatal nurse practitioner, NICU nurse, pediatric hospitalist, and respiratory therapist. The team also invites the hospital's QI specialist to participate.

Upon further review of the data, the team found that 40% of the preterm infants had an admission temperature below 36.5°C, meeting the definition of hypothermia. The team develops the following aim statement: We will decrease the rate of admission hypothermia in preterm infants whose gestational age is less than 32 weeks from 40% to 20% during the next 12 months. A data collection form is created to track the implemented changes and their impact on the frequency of hypothermia. While reviewing its unit's practices, the QI team finds that thermoregulation practices vary according to the provider attending each birth. The team reviews the literature and decides to standardize care by implementing a combination of interventions, including using polyethylene plastic wrap, a chemical warming mattress, and a cotton hat. Two nurses attend each preterm birth in the hospital. The team decides that one of these nurses will be designated to be in charge of thermoregulation. This nurse will prepare the supplies, turn on the radiant warmer, place the temperature sensor, and monitor the steps of thermoregulation during resuscitation to ensure that the infant remains covered with plastic wrap.

The QI team meets monthly and reviews its data. The team posts a chart showing admission temperatures for all preterm newborns in a location where NICU staff can see it daily. After 3 months, the team finds that the average admission temperature has increased and there appears to be a trend toward a reduced rate of admission hypothermia. Looking more closely, they find that the improvement is noticeable for vaginal births but not cesarean births. Two representatives from the labor and delivery staff are invited to join the QI team. Over the next month, the QI team hosts educational huddles during which the risk of admission hypothermia is discussed with the operating room staff. The team implements a process to increase the operating room temperature before preterm cesarean births. There is a steady improvement in admission temperatures, the team's aim is achieved, and the team focuses on strategies to sustain the improvement.

The role of QI in neonatal resuscitation

A newborn infant who requires resuscitation or stabilization after birth relies on well-trained health care providers. This textbook reviews the cognitive and technical skills necessary to become proficient in neonatal resuscitation. Participating in simulation and debriefing enhances the communication, leadership, and behavioral skills that are necessary for effective teamwork. Ultimately, health care providers' performance and patient outcomes also depend on the system in which the patients receive their care. This includes the physical environment, policies, and culture of the health care setting. Quality improvement in health care aims to address these underlying aspects of care.

In health care, multifaceted tasks benefit from the application of QI principles. Several aspects of neonatal resuscitation make it a particularly good area on which teams can focus their QI efforts.

- Neonatal resuscitation is a complex process that may require infrequently used supplies and equipment.
- Teams with varying composition often assemble to work together with little advance notice.

- Practice is guided by an algorithm.
- There are measurable data that are relevant for processes in care and important patient outcomes.

This lesson gives an overview of basic QI principles as they relate to training and practice in neonatal resuscitation.

Identifying and describing the problem

Begin your neonatal resuscitation QI project by identifying a problem and describing the process that needs to be improved. You can identify problems in your neonatal resuscitation process by surveying parents in your nursery or NICU, asking your staff about things that cause them dissatisfaction, reviewing patient safety reports or patient complaints, and/or auditing charts and comparing your patient outcomes with those from published reports or established collaborations. Observe a series of neonatal resuscitations from a parent's point of view. Are there processes or activities that you would find confusing, upsetting, or frustrating? Next, observe resuscitations from a staff member's point of view. Are there processes or activities that are inefficient or distract staff members from important tasks?

Once you identify a potential problem, ask yourself a series of questions to further describe the problem. Following are some examples:

- What is the problem that we need to solve?
- Who are the people affected by this problem?
- During patient care, when does this problem happen?

Now that you have created a list of potential problems, you need to prioritize them. Additional questions will help you judge the importance of potential QI projects.

- Is the problem an urgent patient safety issue?
- Do you have the experience and resources to solve a complex problem, or do you need to start with a small project to improve the likelihood of success?
- Do you have access to the data needed to determine whether your project is successful?

Assembling a team to solve the problem

A multidisciplinary team is a key component of health care QI, and this is particularly true for problems identified in delivery room care. While a specific process that needs improvement may be the target of a project that directly involves only 1 or 2 roles, other members of the delivery room team may provide helpful insights. A core QI team may include a physician/advanced practice provider, nurse, respiratory therapist, labor and delivery nurse, and patient advocate. Administrators, educators, lactation consultants, parents, and hospital-based QI experts can also be important members of a team. Specific projects may benefit from recruitment of other roles to the team. For example, a project aiming to improve management of the operating room environment or deferred umbilical cord clamping would benefit from other members of the obstetric team. A project that aims to ensure that the correct neonatal care providers are called to a birth would benefit from involving unit clerks.

There are formal training programs and a broad literature based on the science and practice of QI. Many hospitals have clinicians and/or administrators with a substantial background in QI who can provide valuable expertise even if they are not clinically involved in the birth.

Developing a specific aim

Next, develop a clearly stated and specific aim. The Institute of Medicine (IOM) has outlined 6 broad aims for health care improvement that can be used to help teams identify their own specific aims.[1] The IOM suggests that care should be

- **Safe:** Patients should not be injured by the care that is intended to help them.
- **Effective:** The care provided should be guided by scientific evidence.
- **Patient-Centered:** Decisions should be focused on the patient's best interest and goals.
- **Timely:** Care should be provided when it is needed and without delay.
- **Efficient:** Avoid wasting patient and staff time. Avoid wasting limited resources.
- **Equitable:** All patients deserve high-quality care, and we should work to eliminate disparities between racial, ethnic, and gender groups.

Your goal is to describe exactly what you hope to accomplish with this project. An acronym that has been used as a guide for developing a good aim is SMART. This acronym stands for Specific, Measurable, Achievable, Realistic, and Timely. It is based on principles outlined by the Model for Improvement from the Institute for Healthcare Improvement (Table 14-1).

Prioritizing your potential changes

Once your target for QI has been identified and a specific aim has been described, the team can identify potential practice changes using evidence from published literature, interventions from similar QI projects at your own institution, practices in other local hospitals, and guidelines or toolkits developed by multicenter collaborative QI organizations. The team also can brainstorm about the specific circumstances in the local setting that have made it difficult to achieve the best outcomes for the targeted problem. This planning will help to inform the strategies in initiating and sustaining the project.

Table 14-1. Steps for Developing SMART Aims

Step	Description
Specific	Have a precise goal. Example: *We will reduce the number of preterm newborn infants < 32 weeks' gestational age who have hypothermia upon admission to the NICU from 40% to 20%.*
Measurable	Have a clear, understandable measurement that will make it possible to recognize an improvement. Example: . . . *defined as admission temperature < 36.5°C.*
Achievable	Have actionable items that can be used to achieve the goal, such as evidence-based practices that have been shown to be effective. Example: . . . *using a bundle of preventive measures, including plastic wrap, chemical warming mattresses, cotton hats, and increasing ambient temperature.*
Realistic	Have appropriate resources, such as staff involvement, training, and equipment. Example: . . . *with plans for simulation training for all staff to implement strategies.*
Timely	Have a timeline that is realistic yet creates a sense of urgency for the project. Example: . . . *within a time frame of 1 year.*
Final SMART Aim	*We will reduce the number of preterm newborn infants < 32 weeks' gestational age with hypothermia upon admission to the NICU from 40% to 20%, defined as admission temperature < 36.5°C, using a bundle of preventive measures, including plastic wrap, chemical warming mattresses, cotton hats, and increasing ambient temperature, with plans for simulation training for all staff to implement strategies, within a time frame of 1 year.*

Data for QI in neonatal resuscitation

Being able to track data efficiently and accurately is an important aspect of QI. Depending on the targets of a project, some data may already be collected as part of clinical care, while other elements may be collected specifically for a project. In many situations, measures that describe a particular process in patient care, rather than the outcome of care, require additional data collection.

- For example, in a project to improve thermoregulation for preterm infants, admission temperature may be routinely collected, but whether a thermal mattress was used in the birth setting may not be systematically evaluated.
- Another key process measure may be the actual ambient temperature of the operating room during a cesarean birth.

An important feature of data for QI is the use of balancing measures. A balancing measure seeks to ensure that the QI project is not leading to unintended adverse consequences. For a project to reduce hypothermia, a balancing measure could be newborn infants who have hyperthermia upon admission to the NICU.

Tracking the improvement process

It is important to systematically follow the data collected through the improvement process. **Run charts and control charts** are common ways to track QI data.

A run chart is a simple method of visualizing change over time. It can help you identify trends and determine if the changes you made are leading to improvements. On the chart, the horizontal (x) axis represents time periods or cases in order, and the process or outcome being measured is plotted on the vertical (y) axis. Individual values are connected by a line.

- A run chart can be constructed relatively easily using a spreadsheet program, online tools, or even by hand.
- Two horizontal lines may be added to the chart. One line shows the mean (average) or median (middle) value of the process or outcome you are measuring during the monitoring period. The other line shows the goal or target chosen by your team for your SMART aim.
- For example, in a project tracking thermal management for preterm infants, admission hypothermia would be the primary measurement being tracked (Figure 14.1). Baseline data prior to starting the QI project are necessary to have a sense of the goal, direction, and scale of change. Annotations can be made on the chart to show key time points when new processes were implemented.

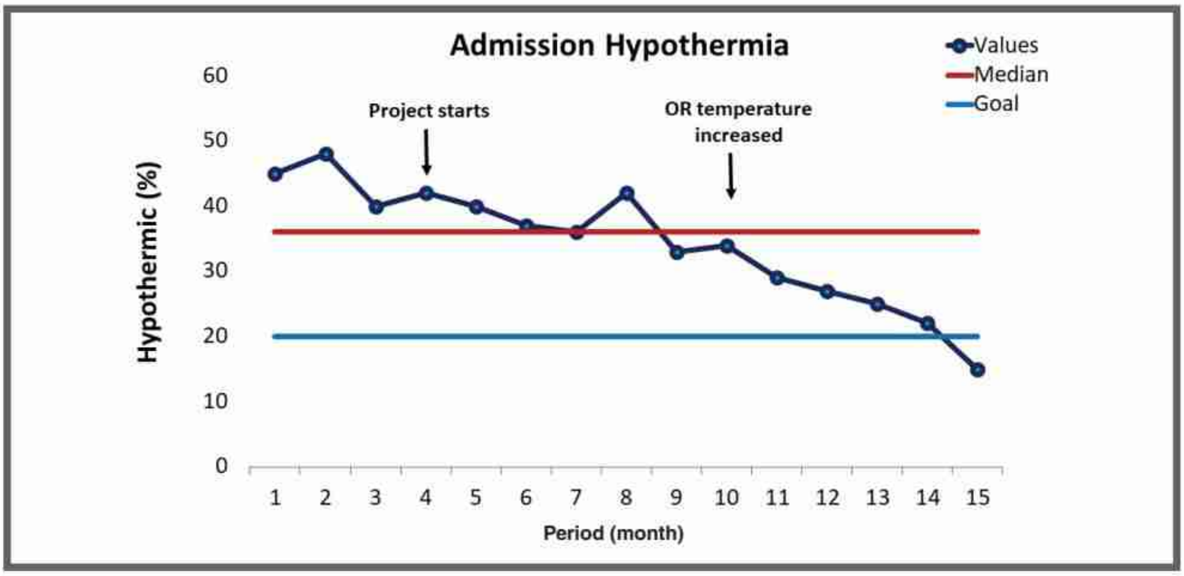


Figure 14.1. A sample run chart illustrating admission hypothermia over time. The plotted values represent the percentage of preterm infants admitted with hypothermia each month. The project goal and the median (middle) value during the entire monitoring period are shown with horizontal lines. Important process changes are annotated on the chart. OR, operating room.

Rules have been published to help you determine if the trends visualized on the run chart represent chance (random) variation or can be attributed to the practice changes you made. If you are interested in learning more about these rules, see the Additional Resources section at the end of this lesson.

A limitation of a run chart is that it may not be able to provide assurance that the observed trend is stable ("in control") or changing. To get a better sense of whether the process being measured is in control, QI teams use **control charts** (also called statistical process control charts or SPC charts).

- A control chart is a version of the run chart that includes additional horizontal lines called **upper and lower control limits**. These control limits are determined from historical data.
- If the variation in the outcome being measured is contained within the 2 control limits, it is stable and not changing more than what can be explained by chance variation.
- The upper and lower control limits are calculated by spreadsheet programs or QI software.
- Calculating control limits requires the collection of some baseline data. Frequently, at least 15 to 20 points are recommended.
- Once the process has changed and your measured outcome shows a sustained improvement beyond what can be explained by chance variation, the QI team may choose to recalculate the control limits.

An example of a control chart for the data collected during the thermal management project is shown in Figure 14.2.

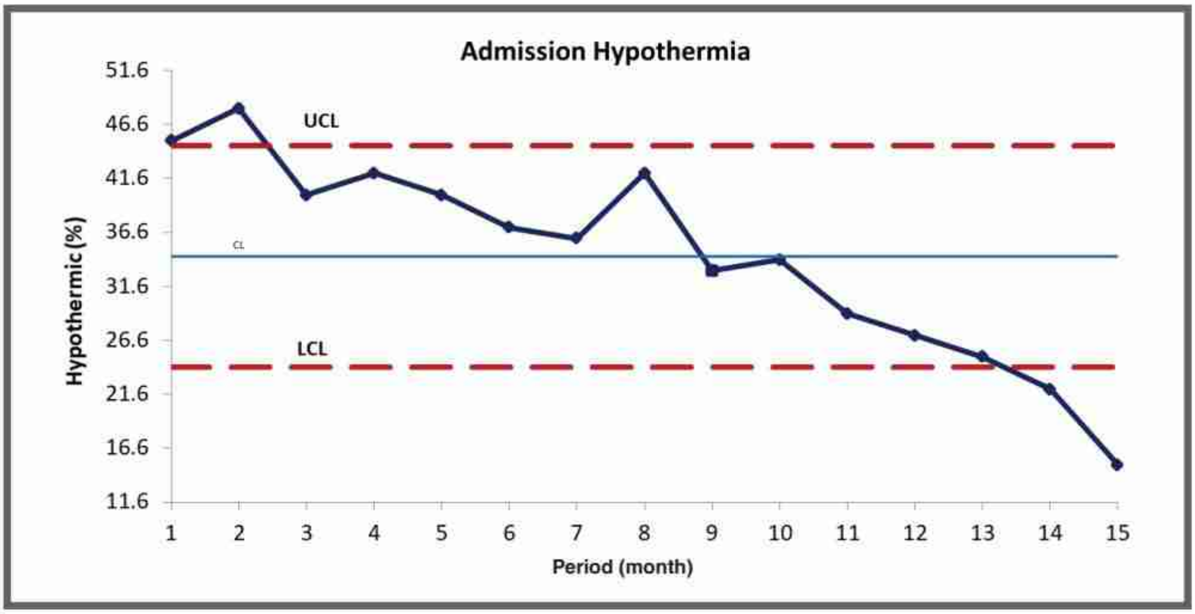


Figure 14.2. A sample control chart illustrating upper control limits (UCL) and lower control limits (LCL). After period 15, the team may choose to recalculate the control limits.

Plotting data over time and using control charts will prevent the QI team from overreacting to outliers. These are situations where an unusual outcome occurred for reasons not directly related to the QI project. Reacting too quickly to an undesirable outcome may lead to an inability to discern the true result of a QI intervention. It may be helpful to recruit a colleague to the team who has experience with software for QI. This person does not necessarily need to be directly involved with the perinatal/neonatal setting to provide their expertise to complement the clinical expertise of the other team members.

Cycles of improvement

As the team tracks data and develops ideas for changes to improve processes, a common method of testing change is the 4-phase Plan-Do-Check-Adjust (PDCA) cycle.[2] The **Plan** phase involves the team's efforts to review the relevant best practices in the context of the local setting and develop an initial set of changes designed to improve the situation. The **Do** phase involves the implementation of selected changes in processes, systems, or education. The **Check** phase includes tracking and reviewing data after the practice changes are implemented to determine if the goal has been achieved. In addition to reviewing the process or outcome in question, explore what you have learned from implementing the changes. Ask why improvement was observed or not observed. The **Adjust** phase involves taking action on what you have learned from this cycle, informing others of the results, implementing the tested changes widely and sustaining them if successful, or incorporating what you learned from this cycle into new changes that will inform the **Plan** phase of the next improvement cycle.

There is a difference between a research project and a QI project

A research project seeks to answer the question of whether a specific intervention leads to a better outcome. This often involves randomizing a patient to the study intervention or to a control intervention. In contrast, QI projects use existing evidence or best practices and seek to implement them for the appropriate patients more frequently, systematically, and efficiently. Usually, there is no randomization and no informed consent, as the interventions are already presumed to be beneficial to the patient. Quality improvement projects can be written into reports for the purpose of informing others to learn how to implement changes in their setting.

Potential projects for QI in neonatal resuscitation

The previous lessons have ended with lists of potential QI opportunities. These and other potential projects are listed in Table 14-2.

Table 14-2. Potential Quality Improvement Opportunities in the Birth Setting

Having the appropriate team members at the time of birth
Increasing the proportion of newborn infants with deferred cord clamping for at least 60 seconds
Having all of the ventilation corrective steps performed prior to alternative airway insertion
Decreasing delivery room intubation for preterm infants by improving continuous positive airway pressure (CPAP) and face mask ventilation
Having the target oxygen saturation in range at 5 minutes of age for preterm infants
Providing 100% oxygen when initiating chest compressions

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Additional Resources

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Supplemental Lesson 15

Resuscitation and Stabilization of Newborn Infants With Congenital Heart Disease

What you will learn

- How the transition from fetal to neonatal circulation may differ in newborn infants with congenital heart disease (CHD)
- How to anticipate which infants with CHD are at high risk of experiencing cardiorespiratory instability in the immediate newborn period
- How to prepare for the birth of an infant with CHD
- How to modify or adapt the pre-resuscitation team briefing and Neonatal Resuscitation Program® (NRP®) Algorithm for newborn infants with specific CHDs

Key Points

1. When preparing for the birth of an infant with antenatally diagnosed congenital heart disease (CHD), include the 6 cardiac-specific pre-delivery questions in your pre-resuscitation team briefing.
   i. Do we anticipate this infant will be **unstable or have cardiorespiratory failure** immediately after birth?
   ii. Are there any **additional features to consider** for this CHD that increase the risk of cardiorespiratory failure or other complications immediately after birth?
   iii. Does this CHD require any modification to the **heart rate targets** included on the NRP Algorithm?
   iv. Does this CHD require any modifications to the **oxygen saturation targets** included on the NRP Algorithm? Is careful titration of oxygen concentration (FIO_2) required?
   v. Is this CHD expected to cause problems with **systemic blood flow and perfusion**?
   vi. What additional **equipment, medications, and personnel** are needed?
2. Most newborn infants with CHD will be vigorous after birth. If resuscitation is required, it is not likely to be the result of the underlying cardiac defect. Except for those with a few specific critical congenital heart diseases (CCHDs), infants with CHD who are not vigorous immediately after birth should be treated using the same steps of neonatal resuscitation described in this program and summarized on the NRP Algorithm.
3. Based on the anatomy and blood flow pattern, newborn infants with specific CCHDs will require modifications to the steps of neonatal resuscitation and the Target Oxygen Saturation Table.
4. Supplemental oxygen should be given to newborn infants with CHD to maintain their pre-ductal oxygen saturation within a target range that is specified before birth based on their expected anatomy and physiology.
5. Fetal echocardiography is helpful but cannot accurately predict if the amount of atrial mixing is sufficient to support newborn infants with certain CCHDs.

6 If a newborn infant with a CCHD is not responding to the recommended steps of stabilization, contact your cardiology consultant for additional expertise, implement steps to minimize oxygen consumption and maximize cardiac output, and prepare for emergent transfer to a location or facility with the resources to provide additional cardiac interventions.

Case 1: Prenatally diagnosed hypoplastic left heart syndrome

Your team is called to attend a birth at 36 weeks' gestation. You ask the obstetric provider the 4 standard pre-birth questions to assess perinatal risk factors and determine who should attend the birth. Pregnancy has been complicated by the prenatal diagnosis of hypoplastic left heart syndrome (HLHS) with good atrial level mixing and good ventricular function. Labor was induced because of worsening pre-eclampsia. The amniotic fluid is clear, and deferred cord clamping is planned. On entering the room, you introduce the team to the parents. You complete a pre-resuscitation team briefing, review the 6 additional cardiac-specific questions, and prepare your supplies and equipment. You confirm that the newborn infant is expected to have HLHS without additional features increasing the risk for severe cardiorespiratory compromise immediately after birth. Based on this information, the team decides there is no need to modify the heart rate targets in the NRP Algorithm and that oxygen will be given judiciously to achieve a target pre-ductal oxygen saturation of 75% to 85% by approximately 10 minutes after birth. There is no reason to anticipate poor systemic blood flow or perfusion. The team leader assigns one team member to insert an umbilical vein catheter shortly after birth, and a second team member will order a prostaglandin E (PGE) infusion to maintain the patency of the ductus arteriosus. In addition, you discuss the signs of a restrictive atrial communication or poor ventricular function and how your team will respond.

At the time of birth, the newborn infant is vigorous with good tone and a strong cry. The obstetrician places the infant on the parent's abdomen and begins the initial steps of newborn care. After 60 seconds, the cord is clamped and cut, and the infant is held skin-to-skin by the parent while a team member assesses the infant's breathing, tone, and color. At 3 minutes, the infant has labored breathing and is brought to the radiant warmer for further evaluation. You position the infant's airway, secure a pulse oximeter sensor on the infant's right hand, and attach cardiac monitor leads to the infant's chest. Listening with a stethoscope, you determine that the infant has equal breath sounds, and the heart rate is 140 beats per minute (bpm). At 4 minutes, the pre-ductal oxygen saturation (SpO_2) is 60%, and the infant continues to have retractions, so a T-piece and resuscitation mask are used to administer continuous positive airway pressure (CPAP). The oxygen concentration (FiO_2) is adjusted to reach the target of 75% to 85%. By 10 minutes, the infant remains tachypneic, but the SpO_2 is 80% and the FiO_2 has been decreased to 21%. You update the parents and transfer the infant to the neonatal intensive care unit (NICU) to place an umbilical vein catheter, start a PGE drip, obtain additional diagnostic studies, and continue your post-resuscitation care. Shortly afterward, your team conducts a debriefing to discuss preparation, teamwork, and communication.

Congenital heart disease (CHD)

An infant with congenital heart disease (CHD) is born in the United States every 15 minutes, making it the most common severe congenital anomaly. Most fetuses with CHD remain in stable condition throughout pregnancy, and most newborn infants with CHD will be vigorous at the time of birth. For most newborn infants with CHD, the need for resuscitation after birth is not a direct result of the underlying cardiac defect. In most cases, the steps of resuscitation and stabilization described in this program and summarized on the NRP Algorithm can be followed without modifications. Similar to infants without CHD, ventilation of the newborn infant's lungs is usually the single most important and most effective step in neonatal resuscitation.

Of the 40,000 infants with CHD born in the United States each year, 1 in 4 has critical congenital heart disease (CCHD). The structural defects or rhythm abnormalities can disrupt the normal pulmonary and systemic blood flow and require intervention immediately after birth. For these infants, establishing cardiorespiratory stability after birth requires the usual steps of neonatal resuscitation described in this program, some modifications to the NRP Algorithm and Target Oxygen Saturation guidelines, and additional interventions to maintain appropriate pulmonary and systemic blood flow. Without timely implementation of these interventions, perfusion and oxygenation remain inadequate and the newborn infant's condition may rapidly worsen. Understanding and preparing for these infants can minimize the duration of cardiorespiratory instability and may improve their outcome. There are limited data on long-term outcomes of specialized delivery room management of prenatally diagnosed CHD.

Prenatal detection of fetal CHD has improved over the past few decades, mainly due to advancements in fetal imaging, involvement of fetal cardiologists in prenatal care, and expansion of maternal-fetal medicine programs. In utero diagnosis of CHD, particularly CCHD, allows for closer maternal-fetal monitoring and specialized care, including customized delivery planning. Fetal echocardiography findings have been used to create risk stratification models to assign levels of risk for cardiorespiratory failure at birth and standardize resuscitation. Recognizing which infants with CCHD are at high risk of experiencing cardiorespiratory failure immediately after birth permits the resuscitation team to anticipate and prepare for additional interventions. While fetal echocardiography is helpful, certain CCHDs may not be detected and antenatal predictions of cardiorespiratory stability after birth may not be accurate.

A comprehensive review of neonatal cardiology is beyond the scope of this lesson and not all CHDs are included. The clinical management suggested in this lesson is based on the underlying physiology and expert opinion. CHDs are often complex and may include multiple structural anomalies. Based on the interaction of these anomalies, newborn infants with a similar diagnosis may differ in their expected postnatal physiology. Their care plan should be individualized in consultation with a pediatric cardiologist.

Fetal circulation with CHD

As described in Lesson 1, highly oxygenated blood returning from the placenta typically bypasses the fetal lungs and shunts through the open foramen ovale and ductus arteriosus to reach the carotid and coronary arteries. For most CHDs, this circulation pattern allows the fetus to remain in stable condition throughout gestation before transitioning to neonatal circulation after birth. Even for fetuses with CCHD, the placenta and fetal shunt pathways will preserve both oxygenation and systemic circulation. There are specific CCHDs, such as significant rhythm abnormalities, structural defects with valve regurgitation, or cardiomyopathies, in which the fetus cannot maintain cardiac function. In these cases, the fetus will develop signs of hydrops fetalis, which may increase the risk of both fetal and neonatal mortality.

Healthy newborn infants without CHD undergoing normal transition usually take several minutes to increase their blood oxygen saturation level from approximately 60%, which is the normal intrauterine state, to more than 90%, which is the eventual state of air-breathing healthy term infants. After transition, newborn infants with certain types of CHD may not achieve an oxygen saturation above 75% to 85% because of their unique physiology. For infants with specific CHDs, it is reasonable to use a modified pre-ductal oxygen saturation target of 75% to 85% by approximately 10 minutes after birth. The goal is to avoid severe hypoxemia but also avoid unnecessary oxygen exposure that can disrupt the balance between pulmonary and systemic blood flow. It is important to note that this modified oxygen saturation target is not required for all newborn infants with CHD, and teams must review the details of the infant's specific CHD lesion and anticipated physiology when determining the appropriate oxygen saturation target.

Cardiac-specific questions to add to your pre-resuscitation team briefing

Except for specific CCHDs, the underlying cardiac disorder usually does not cause cardiorespiratory failure immediately after birth. Common problems that interfere with fetal-to-neonatal transition should be considered in a newborn infant with CHD who requires resuscitation after birth. The steps of resuscitation and stabilization described in this program and summarized on the NRP Algorithm should be followed. Reviewing a series of CHD-specific pre-delivery questions as a team provides a shared understanding and better preparation for anticipated problems.

When your team is called to attend the birth of an infant with prenatally diagnosed CHD, add these 6 questions to your pre-resuscitation team briefing.

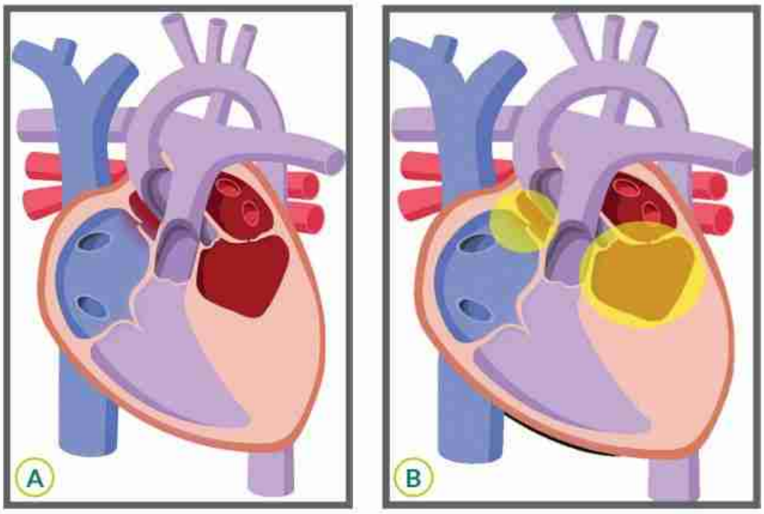
1. Do we anticipate that this infant will be **unstable or have cardiorespiratory failure** immediately after birth?
2. Are there any **additional features to consider** for this CHD that increase the risk of cardiorespiratory failure or other complications immediately after birth? Examples include a restrictive atrial septum (RAS), hydrops fetalis, an arrhythmia, or other associated anomalies.
3. Does this CHD require any modification to the **heart rate targets** included on the NRP Algorithm?
4. Does this CHD require any modifications to the **oxygen saturation targets** included on the NRP Algorithm? Is careful titration of oxygen concentration (FIO_2) required?
5. Is this CHD expected to cause problems with **systemic blood flow and perfusion**?
6. What additional **equipment, medications, and personnel** are needed?

Delivery room interventions for specific CCHDs

Hypoplastic left heart syndrome (HLHS)

Hypoplastic left heart syndrome (HLHS) describes a spectrum of CHD in which the left heart structures are underdeveloped, including a hypoplastic (small and underdeveloped) left ventricle, atresia or stenosis of the mitral and aortic valves, and a small aortic arch (Figure 15.1).

The cardiorespiratory stability of newborn infants with HLHS depends largely on an open pathway through the atrial septum. Because of the underdeveloped mitral valve and left ventricle, the newborn infant's left atrium is unable to empty. Blood flow into the infant's aorta and systemic circulation depends on an open connection through the atrial septum, such as an atrial septal defect (ASD) or a patent foramen ovale (PFO). This allows blood from the left atrium to empty into the right atrium and right ventricle. Ultimately, blood reaches the aorta and systemic circulation by flowing from the right ventricle through the patent ductus arteriosus (PDA). In some infants with HLHS and an intact atrial septum (IAS) or RAS, high pressure in the left atrium in utero may have caused damage to the lung parenchyma or lymphatic channels. Therefore, the postnatal



A
Hypoplastic left heart syndrome.

B
Anatomic features of HLHS influencing stability in the delivery room are highlighted in yellow. These include the size of the atrial septal defect, left ventricle, and left ventricle outflow tract.

Figure 15.1. Anatomy of hypoplastic left heart syndrome (HLHS).

stability of infants with HLHS depends on the size of the atrial septal opening, right ventricular function, and patency of the ductus arteriosus.

HLHS with an unrestrictive opening of the atrial septum

Newborn infants with an unrestrictive ASD or PFO are unlikely to require resuscitation after birth as a direct result of HLHS. In most instances, right ventricular function is normal and the ductus arteriosus is open. The stabilization and resuscitation of these neonates should follow the typical steps described in the remainder of this program, including the initial steps of newborn care, and a focus on providing effective ventilation if the newborn infant is not breathing or the heart rate is less than 100 bpm by 1 minute after birth. Supplemental oxygen should be used judiciously to achieve a pre-ductal SpO_2 equal to 75% to 85% by approximately 10 minutes after birth or the range recommended by the cardiologist. Once the infant's oxygen saturation approaches the target range, the FiO_2 should be decreased to maintain the pre-ductal oxygen saturation within this target range. For CHD with single ventricle circulation, such as HLHS, excessive oxygen can cause vasodilation in the pulmonary circulation, diverting more blood flow to the lungs and less to the remainder of the body, disrupting the balance between the systemic and pulmonary blood flow. In addition, although unlikely to occur immediately after birth, excessive administration of supplemental oxygen can theoretically initiate closure of the PDA.

Shortly after birth, a PGE infusion should be initiated to maintain the PDA, which is required for systemic circulation. The usual dose range for continuous intravenous infusion of PGE is 0.005 to 0.03 mcg/kg/min but may vary based on the infant's response and institutional guidelines. Common side effects associated with a PGE infusion include apnea, fever, skin flushing, and hypotension.

Caution: Fetal echocardiography cannot accurately predict whether the ASD or PFO will be sufficient to provide unrestricted flow and adequate mixing after birth. If the newborn infant's pre-ductal SpO_2 remains $< 70\%$ by 10 minutes after birth despite use of supplemental oxygen or the infant has signs of low cardiac output such as decreased peripheral perfusion, there may be poor right ventricular function or a closing ductus arteriosus or the atrial communication may be restrictive. Consider the following management steps.

HLHS with a restrictive atrial septum (RAS) or an intact atrial septum (IAS)

Newborn infants with a prenatal diagnosis of HLHS and a RAS or an IAS **are anticipated to have signs of cardiorespiratory failure shortly after birth**. The initial management should follow the neonatal resuscitation steps described in the remainder of this program. Supplemental oxygen should be used judiciously to achieve a pre-ductal SpO_2 equal to 75% to 85% by approximately 10 minutes after birth or the range recommended by the cardiologist. Once the infant's oxygen saturation approaches the target range, the FiO_2 should be decreased to avoid exceeding this target range. The resuscitation team should be prepared to insert an umbilical vein catheter and start a PGE infusion to maintain the patency of the ductus arteriosus and systemic blood flow.

However, these steps may not be sufficient to stabilize a newborn infant with HLHS and RAS or IAS. It is important to have an established plan to rapidly escalate care if there are signs of cardiorespiratory failure, including a pre-ductal SpO_2 of less than 70% by 10 minutes after birth despite using 100% oxygen or decreased peripheral perfusion.

To minimize oxygen consumption and maximize cardiac output, consider these steps:

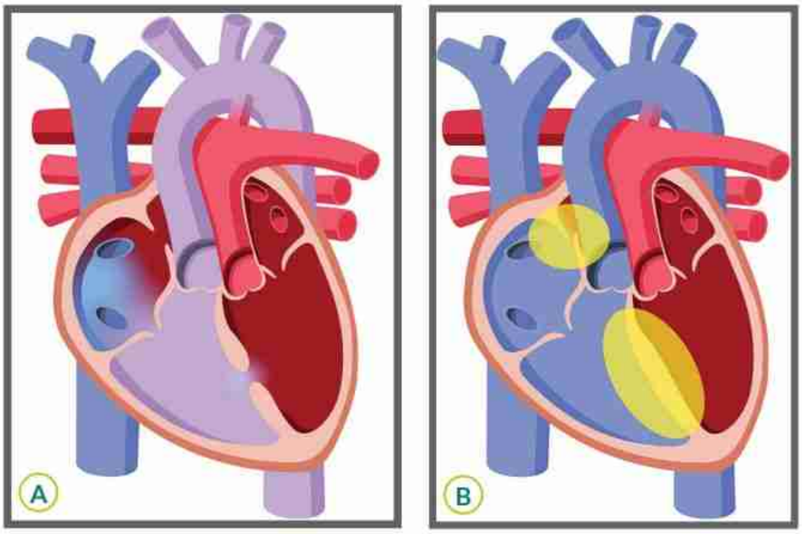
- Intubate the infant.
- Use supplemental oxygen to maintain pre-ductal SpO_2 equal to 75% to 85%.
- Sedate and paralyze the infant using appropriate medications.
- Immediately contact your cardiology consultant for additional expertise.
- Prepare to emergently transfer the infant to the location or facility with the resources to open the atrial septum with a catheter (balloon atrial septostomy) or surgical procedure (atrial septoplasty).

HLHS pre-delivery questions

1. What is the heart lesion?
   - HLHS
2. Are there any additional features to consider for this CHD that will increase the risk of cardiorespiratory failure or other complications immediately after birth?
   - Discuss the degree of opening in the atrial septum, the presence of hydrops, arrhythmia, or other associated anomalies
3. Does this CHD require any modification to the heart rate targets included on the NRP Algorithm?
   - No.
4. Does this CHD require any modifications to the oxygen saturation targets included on the NRP Algorithm? Is careful titration of FIO_2 required?
   - Yes, the modified target pre-ductal oxygen saturation is 75% to 85% by approximately 10 minutes after birth or as recommended by the cardiologist. Yes, careful titration is required.
5. Is this CHD expected to cause problems with systemic blood flow or perfusion?
   - Yes, if the atrial septum is restrictive or intact, it can compromise systemic blood flow and perfusion.
6. What additional equipment, medications, or personnel are needed?
   - Vascular access (peripheral intravenous [PIV] or umbilical vein catheter [UVC]) and PGE. Notify cardiology and the critical care unit following institutional guidelines. In case of a restrictive or an intact atrial septum, emergent intervention to open the atrial septum may be needed.

Dextro-Transposition of the great arteries (d-TGA)

Transposition of the great arteries (d-TGA) describes a CHD in which the aortic arch originates from the anatomic right ventricle, and the pulmonary artery originates from the anatomic left ventricle. Because blood is oxygenated by the placenta in utero, this CHD is generally well tolerated by the fetus. After birth, the deoxygenated blood returning from the body enters the right atrium and right ventricle where it is pumped to the aorta and returned to the body without passing through the lungs. At the same time, oxygenated blood returning from the lungs enters the left atrium and left ventricle, where it is pumped to the pulmonary artery and returns to the lungs without going to the rest of the body. In d-TGA, the pulmonary and systemic circulation are separated and operate in parallel to each other instead of being connected in series (Figure 15.2).



A
Transposition of great arteries (d-TGA).

B
Anatomic features of d-TGA that influence stability in the delivery room are highlighted in yellow. These features include the size of atrial septal opening and absence of a ventricular septal defect.

Figure 15.2. Anatomy of transposition of the great arteries (d-TGA).

After birth, the cardiorespiratory stability of newborns with d-TGA is dependent on an open pathway through the atrial septum, such as an ASD or a PFO. This pathway allows mixing of the pulmonary and systemic circulations. Although some mixing can occur through the PDA, atrial level mixing is crucial for maintaining cardiorespiratory stability. The atrial communication allows oxygenated blood from the left atrium to cross into the right atrium and right ventricle where it will be pumped through the aorta and reach the systemic circulation. Some of the blood exiting the right ventricle will be shunted across the ductus arteriosus to the lungs to receive oxygen. Some infants may have d-TGA with a ventricular septal defect (VSD). Although a VSD in combination with d-TGA creates additional shunting and provides some stability, it does not guarantee that the newborn infant will be in stable condition in the delivery room or during the immediate newborn period.

Because the ductus arteriosus supports pulmonary blood flow, the resuscitation team should be prepared to insert a UVC and start a PGE infusion shortly after birth.

d-TGA with an unrestrictive opening of the atrial septum

Newborn infants with an unrestrictive ASD or PFO are unlikely to require resuscitation after birth as a direct result of the cardiac lesion. The stabilization and resuscitation of these infants should follow the typical steps described in the remainder of this program, including deferred cord clamping, the initial steps of newborn care, and a focus on providing effective ventilation if the newborn infant is not breathing or the heart rate is less than 100 bpm by 1 minute after birth. If there is adequate mixing at the atrial level, the newborn infant will likely be stable, well-perfused, and only mildly cyanotic. Supplemental oxygen should be used judiciously to achieve a pre-ductal SpO_2 of 75% to 85% by approximately 10 minutes after birth or the range recommended by the cardiologist. Once the infant's oxygen saturation approaches the target range, the FiO_2 should be decreased to avoid exceeding the target. A PGE infusion should be initiated shortly after birth to maintain the PDA. The dose and timing of PGE initiation depend on institutional practice.

Caution: Fetal echocardiography cannot accurately predict whether the ASD or PFO will be sufficient to provide unrestricted flow and adequate mixing after birth. If the newborn infant's pre-ductal SpO_2 remains < 70% by 10 minutes after birth despite using 100% oxygen or the infant has signs of low cardiac output such as decreased peripheral perfusion, the atrial communication may be restrictive. Consider the following management steps.

d-TGA with a restrictive atrial septum (RAS) or an intact atrial septum (IAS)

Newborn infants with a prenatal diagnosis of d-TGA and a RAS or IAS **are anticipated to have signs of cardiorespiratory failure shortly after birth**. The initial management should follow the neonatal resuscitation steps described in the remainder of this program; however, these steps may not be sufficient to achieve cardiorespiratory stability. It is important to have an established plan to rapidly escalate care if there are signs of cardiorespiratory failure, including a pre-ductal SpO_2 < 70% by 10 minutes after birth despite using 100% oxygen or decreased peripheral perfusion.

To minimize oxygen consumption and maximize cardiac output, consider these steps:

- Intubate the infant.
- Use supplemental oxygen to maintain pre-ductal SpO_2 at 75% to 85%.
- Sedate and paralyze the infant using appropriate medications.
- Initiate a PGE infusion.
- Immediately contact your cardiology consultant for additional expertise.
- Prepare to emergently transfer the infant to the location or facility with the resources to open the atrial septum with a catheter (balloon atrial septostomy).

Persistent pulmonary hypertension may also be present in a newborn infant with d-TGA. Persistent cyanosis with oxygen saturation < 70% in the upper extremities, with higher oxygen saturation in the lower extremities, suggests reversed flow in the ductus arteriosus. In this situation, inhaled nitric oxide can be used to decrease the pulmonary vascular resistance and improve oxygenation. Consult with a cardiologist to determine if use of inhaled nitric oxide should be considered while preparing the infant for transfer.

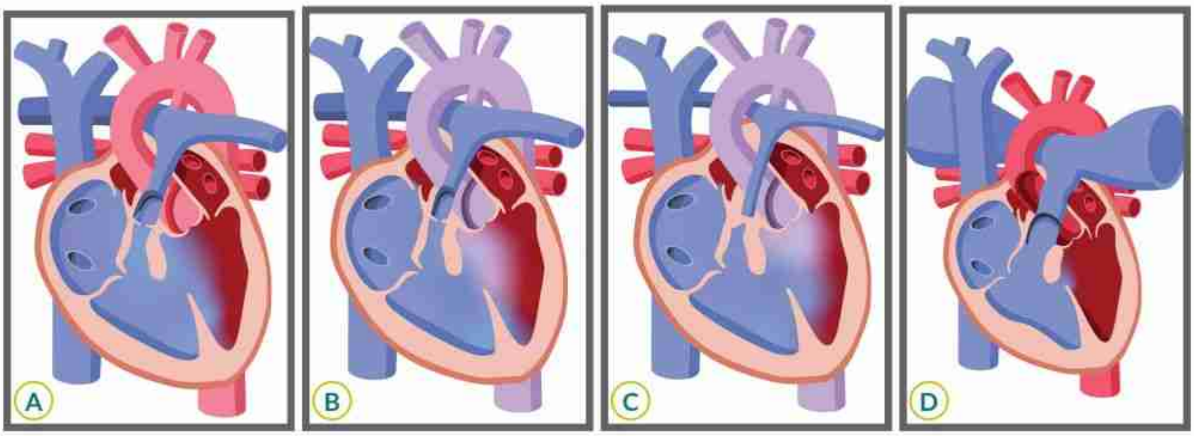
d-TGA pre-delivery questions

1. What is the heart lesion?
   - d-TGA
2. Are there any additional features to consider for this CHD that will increase the risk of cardiorespiratory failure or other complications immediately after birth?
   - The size of the atrial septum defect impacts stability at the time of delivery.
3. Does this CHD require any modification to the heart rate targets included on the NRP Algorithm?
   - No.
4. Does this CHD require any modifications to the oxygen saturation targets included on the NRP Algorithm? Is careful titration of F_{IO_2} required?
   - Yes, the modified target oxygen saturation is 75% to 85% by approximately 10 minutes after birth or as recommended by the cardiologist. Yes, careful titration is required.
5. Is this CHD expected to cause problems with systemic blood flow or perfusion?
   - No, although some infants with d-TGA may have associated anomalies that cause problems in systemic blood flow. In addition, excessive supplemental oxygen administration may disrupt the balance between pulmonary and systemic blood flow, resulting in decreased systemic perfusion.
6. What additional equipment, medications, or personnel are needed?
   - Vascular access (PIV or UVC) and PGE. Notify cardiology and the critical care unit following institutional guidelines. In case of a restrictive or an intact atrial septum, emergent intervention to open the atrial septum may be needed.

Tetralogy of Fallot (TOF)

Tetralogy of Fallot (TOF) is a CHD consisting of 4 structural defects, including the following:

1. Right ventricular outflow tract (RVOT) and pulmonary valve obstruction
2. Ventricular septal defect (VSD)
3. Overriding of the aorta that straddles the VSD
4. Right ventricular hypertrophy



A
TOF with mild pulmonary stenosis.

B
TOF with severe pulmonary stenosis.

C
TOF with pulmonary atresia.

D
TOF with absent pulmonary valve.

Figure 15.3. Anatomy of tetralogy of Fallot (TOF) variants.

The clinical presentation of newborn infants with TOF, and degree of cyanosis after birth, varies depending on the degree of outflow obstruction across the RVOT and pulmonary valve (Figure 15.3 and Table 15-1). Newborn infants with an open RVOT and only mild pulmonary valve stenosis are anticipated to have near-normal SpO_2. They are unlikely to require resuscitation after birth as a direct result of TOF, and the team can follow the routine steps of newborn care described in this program. In consultation with a cardiologist, they will be monitored until the ductus arteriosus closes.

With severe RVOT or pulmonary valve obstruction, deoxygenated blood returning from the body crosses from the right ventricle to the left ventricle through a large VSD, bypasses the lungs, and flows into the systemic circulation without receiving oxygen. Even with a severe outflow obstruction, most newborn infants are vigorous after birth and are unlikely to require resuscitation as a direct result of TOF. It is appropriate to follow the steps of neonatal stabilization and resuscitation described in the remainder of this program. These newborn infants usually do not have significant cyanosis immediately after birth because the ductus arteriosus is open. The modified pre-ductal target SpO_2 is 75% to 85% by approximately 10 minutes after birth or as recommended by the cardiologist. If severe outflow obstruction is predicted, a PGE infusion will be administered shortly after birth.

Three subtypes of TOF require special consideration.

1. **TOF with pulmonary valve atresia.** Without an open pulmonary valve, the only source of pulmonary blood flow is through the PDA. The modified pre-ductal target SpO_2 is 75% to 85% by approximately 10 minutes after birth or as recommended by the cardiologist. Postnatal management includes prompt initiation of a PGE infusion.

Table 15-1. **Tetralogy of Fallot (TOF)–Related Causes of Cardiorespiratory Failure at Birth**

Obstruction of Blood Flow Entering the Pulmonary Vasculature				
Variation of Pulmonary Valve Obstruction		Pre-ductal SpO_2 After Birth*	Postnatal Management	Persistent SpO_2 < 70% Despite Standard Care
TOF with mild pulmonary valve stenosis	Minimal obstruction from RV to PA	Near normal	PGE not usually required	• Consider non–TOF-related causes • Start PGE • Consider intubation, sedation, neuromuscular blockade
TOF with severe pulmonary valve stenosis	Significant obstruction from RV to PA	75%-85%	PGE required	
TOF with pulmonary valve atresia	Complete obstruction from RV to PA	75%-85%	PGE required	
TOF with pulmonary valve atresia and MAPCAs (rare condition)	Complete obstruction from RV to PA. Pulmonary blood flow from collateral vessels	Near normal	Case-by-case management; PGE usually not required	
Compression of airway				
TOF with absent pulmonary valve (rare condition)	No restriction to blood flow from RV to PA. Dilated pulmonary arteries may compress the airway.	Near normal	Consider prone positioning PGE not required	• Consider non–TOF-related causes • Consider intubation, sedation, neuromuscular blockade

Abbreviations: MAPCAs, major aorto-pulmonary collaterals; PA, pulmonary artery; PGE, prostaglandin; RV, right ventricle.

*This represents the modified target pre-ductal oxygen saturation (SpO_2) following the initial transition phase (approximately 10 minutes after birth). This target may be adjusted by the cardiologist based on the individual infant's anticipated physiology.

2. **TOF with pulmonary valve atresia and major aorto-pulmonary collaterals (MAPCAs).** In very rare cases of TOF with pulmonary valve atresia, there is no ductus arteriosus and either absent or severely hypoplastic pulmonary arteries. Pulmonary blood flow is supplied by bronchial collateral arteries originating from the aorta. These vessels allow a significant amount of blood to enter the lungs. This rare condition requires close involvement with a cardiologist since management will be on a case-by-case basis. The SpO_2 is anticipated to be near normal, and no modification is required in the target oxygen saturation. **Usually, a PGE infusion is not needed.**

3. **TOF with absent pulmonary valve.** TOF with an absent (or dysplastic) pulmonary valve is a rare CCHD. In this defect, the degree of RVOT and pulmonary valve obstruction is usually mild. In addition, there is no ductus arteriosus. Abnormal pulmonary valve development causes a ring-like stenotic outlet of the right ventricle without valve leaflets, which allows severe regurgitation (backflow) of blood from

the pulmonary artery into the right ventricle. This leads to very dilated pulmonary arteries and potentially poor function of the right ventricle. The dilated pulmonary arteries can press on the distal trachea or a proximal bronchus, causing airway compression and obstruction. After birth, these infants may present with respiratory failure due to airway compression, air trapping, or congenital lobar emphysema. Unlike TOF with severe pulmonary valve obstruction, the respiratory failure and low SpO_2 are due to mechanical airway compression and lung disease rather than decreased pulmonary blood flow. Resuscitation and stabilization for these infants may include prone positioning to pull the pulmonary arteries off the trachea and bronchi. In severe instances, intubation, sedation, and pharmacologic paralysis may be needed, while the resuscitation team is cautious not to overventilate and cause a pneumothorax. No modification in the target SpO_2 is required because of the CHD, and PGE usually is not required.

TOF pre-delivery questions

1. What is the heart lesion?
   - Tetralogy of Fallot and its variants
2. Are there any additional features to consider for this CHD that will increase the risk of cardiorespiratory failure or other complications immediately after birth?
   - Yes, based on the variant of TOF. The degree of cyanosis after birth depends on the degree of obstruction across the pulmonary valve. TOF with absent pulmonary valve can result in airway obstruction.
3. Does this CHD require any modification to the heart rate targets included on the NRP Algorithm?
   - No.
4. Does this CHD require any modifications to the oxygen saturation targets included on the NRP Algorithm? Is careful titration of FiO_2 required?
   - The answer depends on the TOF variant. With mild pulmonary valve obstruction or TOF with MAPCAs, SpO_2 may be normal. With significant pulmonary valve obstruction, the modified pre-ductal target SpO_2 will be 75% to 85% by approximately 10 minutes after birth or as recommended by the cardiologist.
5. Is this CHD expected to cause problems with systemic blood flow or perfusion?
   - No.
6. What additional equipment, medications, or personnel are needed?
   - Depending on the TOF variant, a PGE infusion may be required. Notify cardiology and the critical care unit following institutional guidelines.

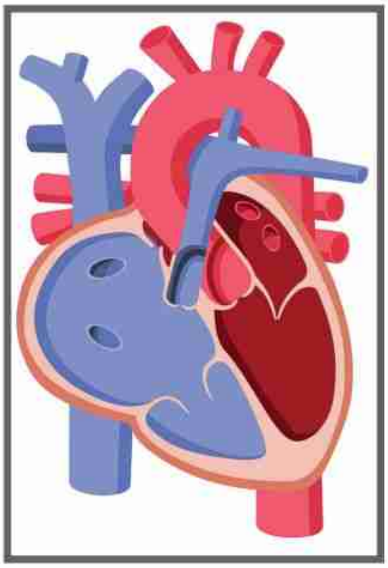


Figure 15.4. Anatomy of Ebstein anomaly.

Ebstein anomaly

Ebstein anomaly is a CCHD with an abnormal tricuspid valve leading to tricuspid valve regurgitation, right atrial dilation, right ventricular dilation with possible dysfunction, and cardiomegaly (Figure 15.4). There may be left ventricle dysfunction due to right ventricle compression or an abnormal myocardium. Ventricular dysfunction may lead to fetal hydrops. Because of the severe tricuspid regurgitation, there usually is a lack of flow into the pulmonary artery, resulting in "functional" pulmonary atresia. This results in reversed flow from the aorta into the pulmonary artery through the ductus arteriosus. If pulmonary valve insufficiency develops, the fetus may experience a circular shunt of blood leading to a "steal" of blood flow from the systemic circulation, resulting in low cardiac output, fetal hydrops, and death. The dilated right atrium may also lead to arrhythmias including atrial flutter, Wolff-Parkinson-White syndrome, and supraventricular tachycardia (SVT). Finally, the massive degree of cardiomegaly may result in compression hypoplasia of the fetal lungs.

Immediately after birth, infants with Ebstein anomaly can have a variable presentation with signs ranging from no instability to profound hypoxia and/or poor perfusion. Follow the steps of neonatal stabilization and resuscitation described in this program. Additional interventions should be considered if the infant's condition remains unstable despite these steps. As described in Lesson 10, if fetal hydrops occurs, the newborn infant may have severe cardiorespiratory failure and require higher peak inflation pressures during assisted ventilation. If pleural effusions or ascites are present, thoracentesis or paracentesis may be required to achieve effective ventilation. For cardiac dysfunction, the choice of inotrope should take into consideration the low threshold for tachyarrhythmias associated with Ebstein anomaly.

As described earlier, circular shunt is a unique and dangerous phenomenon where blood travels through the heart in a circular path, "stealing" from the systemic circulation. A PGE infusion is not recommended if there is a concern for circular shunt with an open ductus arteriosus and pulmonary valve insufficiency. Consultation with a cardiologist is advised.

Ebstein pre-delivery questions

1. What is the heart lesion?
   - Ebstein anomaly
2. Are there any additional features to consider for this CHD that will increase the risk of cardiorespiratory failure or other complications immediately after birth?
   - Not all newborn infants with Ebstein anomaly will be unstable after birth. Each case of Ebstein anomaly is unique, depending on the severity of tricuspid valve regurgitation, right ventricle and left ventricle dysfunction, the presence of anomalies in other valves, and the presence of arrhythmia or hydrops.
3. Does this CHD require any modification to the heart rate targets included on the NRP Algorithm?
   - Ebstein anomaly can have associated tachyarrhythmias including SVT or atrial flutter.
4. Does this CHD require any modifications to the oxygen saturation targets included on the NRP Algorithm? Is careful titration of FIO_2 required?
   - Depending on the severity of the Ebstein anomaly, the modified pre-ductal target SPO_2 will be 75% to 85% by approximately 10 minutes after birth or as recommended by the cardiologist. Supplemental oxygen may be given.
5. Is this CHD expected to cause problems with systemic blood flow or perfusion?
   - Depending on the degree of ventricular dysfunction and associated abnormalities, systemic blood flow and perfusion may be decreased.
6. What additional equipment, medications, or personnel are needed?
   - Depending on prenatal findings, a wide range of additional resources may be needed, including supplies to perform thoracentesis or paracentesis and secure vascular access; medications such as inotropes, adenosine, and inhaled nitric oxide; and equipment to perform cardioversion. Notify cardiology and the critical care unit following institutional guidelines.

Total anomalous pulmonary venous return (TAPVR)

In total anomalous pulmonary venous return (TAPVR), none of the 4 pulmonary veins drain into the left atrium, thus disrupting the normal

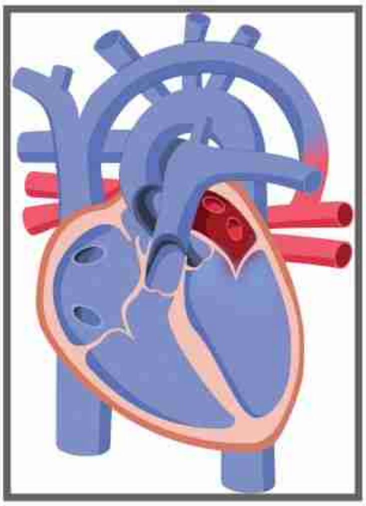


Figure 15.5. Anatomy of TAPVR.

delivery of oxygenated blood from the lungs to the left side of the heart and body. Instead, the pulmonary veins drain directly into the right atrium or reach the right atrium through the superior vena cava, hepatic veins, inferior vena cava, or coronary sinus. These malpositioned pulmonary veins may be narrowed or obstructed and interfere with blood leaving the lungs, causing pulmonary venous congestion (Figure 15.5). Before birth, TAPVR with pulmonary vein obstruction is not likely to cause fetal distress because the placenta is the source of oxygenated blood and little blood flows through the fetal pulmonary veins. TAPVR is difficult to identify by prenatal ultrasound and is less likely to be diagnosed before birth. After birth, despite adequate lung recruitment and ventilation, newborn infants with TAPVR and pulmonary vein obstruction may develop rapid and progressive respiratory failure that is unresponsive to typical treatment strategies. Because of venous obstruction, interventions that increase pulmonary blood flow frequently worsen the infant's distress. Stabilization after birth may require immediate surgical intervention and extracorporeal membrane oxygenation (ECMO).

TAPVR pre-delivery questions

1. What is the heart lesion?
   - TAPVR with or without pulmonary vein obstruction
2. Are there any additional features to consider for this CHD that will increase the risk of cardiorespiratory failure or other complications immediately after birth?
   - Yes, identify if the pulmonary veins are obstructed. Newborn infants with obstructed pulmonary veins are more likely to develop cardiorespiratory failure shortly after birth.
3. Does this CHD require any modification to the heart rate targets included on the NRP Algorithm?
   - No.
4. Does this CHD require any modifications to the oxygen saturation targets included on the NRP Algorithm? Is careful titration of FIO_2 required?
   - No; however, newborn infants with TAPVR are expected to have difficulty with oxygenation.
5. Is this CHD expected to cause problems with systemic blood flow or perfusion?
   - No.
6. What additional equipment, medications, or personnel are needed?
   - Prepare to secure vascular access (PIV or UVC). Notify cardiology and the critical care unit following institutional guidelines.

Congenital heart block (CHB)

Fetal congenital heart block (CHB) can be the result of underlying fetal CHD or secondary to transplacental passage of SSA autoimmune antibodies from a pregnant person with systemic lupus erythematosus or Sjögren syndrome. If heart function is normal, the fetus usually can tolerate heart rates as low as 55 bpm. However, if CCHD is also present or if there is cardiac dysfunction due to cardiomyopathy, CHB can result in the development of fetal hydrops.

Immediate management after birth depends on the presence of cardiac dysfunction and signs of fetal hydrops. If the newborn infant with CHB appears well perfused after birth, the steps of neonatal resuscitation and stabilization described in this program, and summarized on the NRP Algorithm, can be followed with a modification in the heart rate thresholds for interventions. The key modifications of the NRP Algorithm occur at points where heart rate targets are used as decision points for interventions such as assisted ventilation, intubation, chest compressions, or epinephrine administration. Instead of using the heart rate targets described on the NRP Algorithm, make decisions based on your assessment of the newborn infant's breathing, perfusion, and hemodynamic stability. If a newborn infant with CHB has a heart rate < 100 bpm but is crying and well perfused, assisted ventilation is not required. Similarly, a newborn infant with a heart rate < 60 bpm who is breathing, has good tone, and is well perfused does not require chest compressions or epinephrine administration. Unless there is an associated CCHD, the target oxygen saturation described on the NRP Algorithm does not need to be modified. If an infant with CHB is becoming unstable, this will manifest as hemodynamic instability with indicators of poor perfusion, cyanosis, apnea/gasping, and decreased tone.

Without any signs of cardiac dysfunction, management of CHB after immediate stabilization will depend on institutional guidelines. If there are signs of cardiac dysfunction, such as the presence of hydrops or poor perfusion, resuscitation and stabilization steps should include intubation, sedation, and neuromuscular blockade to minimize oxygen consumption. In consultation with a cardiologist, epinephrine or isoproterenol may be used as a temporizing measure to increase the infant's heart rate. Transfer to a location or facility with additional cardiology resources may be indicated.

CHB pre-delivery questions

1. What is the heart lesion?
   - CHB
2. Are there any additional features to consider for this CHD that will increase the risk of cardiorespiratory failure or other complications immediately after birth?
   - If the ventricular rate is < 50 bpm or there are other structural heart defects, the risk of fetal hydrops is increased.

3. Does this CHD require any modification to the heart rate targets included on the NRP Algorithm?
   - Yes.
4. Does this CHD require any modifications to the oxygen saturation targets included on the NRP Algorithm? Is careful titration of FIO_2 required?
   - No.
5. Is this CHD expected to cause problems with systemic blood flow or perfusion?
   - Possibly.
6. What additional equipment, medications, or personnel are needed?
   - Prepare equipment to continuously monitor the infant's heart rate and, if possible, record the tracing. Supplies to secure vascular access (PIV or UVC) and medications to increase the heart rate such as a continuous infusion of epinephrine or isoproterenol may be required. Notify cardiology and the critical care unit following institutional guidelines.

Fetal tachyarrhythmias

Fetal tachyarrhythmias (fast heart rates) are usually primary conditions but they can be associated with underlying CHD such as the Ebstein anomaly. The fetus usually will tolerate intermittent tachyarrhythmias if their heart function is normal. Persistent tachyarrhythmias, particularly at high rates, frequently result in cardiac dysfunction that may lead to fetal hydrops. Immediately after birth, the steps of neonatal resuscitation and stabilization described in this program and summarized on the NRP Algorithm can be followed. In the absence of cardiac dysfunction, management after initial stabilization depends on institutional guidelines.

If the arrhythmia is accompanied by cardiac dysfunction, additional steps to minimize oxygen consumption including assisted ventilation, intubation, and sedation should be considered. Electrical cardioversion should be considered in the presence of tachyarrhythmia with cardiac dysfunction. Consultation with a cardiologist, as needed, is advised. Depending on the resources available at your institution, transfer to a location or facility with additional cardiology resources may be indicated.

Tachyarrhythmia pre-delivery questions

1. What is the heart lesion?
   - SVT
2. Are there any additional features to consider for this CHD that will increase the risk of cardiorespiratory failure or other complications immediately after birth?

- Assess if there has been prolonged fetal SVT, other structural heart disease, or fetal hydrops.

3. Does this CHD require any modification to the heart rate targets included on the NRP Algorithm?
   - No.
4. Does this CHD require any modifications to the oxygen saturation targets included on the NRP Algorithm? Is careful titration of F_{IO_2} required?
   - No.
5. Is this CHD expected to cause problems with systemic blood flow or perfusion?
   - Possibly. While most newborn infants are stable with a heart rate > 220 bpm, they are at risk of having inadequate cardiac output with decreased systemic blood flow and perfusion.
6. What additional equipment, medications, or personnel are needed?
   - Prepare equipment and supplies to secure vascular access (PIV or UVC), administer adenosine, and perform cardioversion. Notify cardiology and the critical care unit following institutional guidelines.

Additional information on the evaluation and management of arrhythmias can be found in Supplemental Lesson 16 ("Resuscitation in the Neonatal Intensive Care Unit").

Case 2: A newborn infant with unanticipated CCHD

Your resuscitation team is called to the delivery room to see a cyanotic newborn infant with respiratory distress. The full-term infant is 15 minutes old and has increased work of breathing and a low S_{PO_2}. The pregnancy was complicated by uncontrolled type 1 diabetes. Labor was induced because of macrosomia. After birth, the infant was vigorous, deferred cord clamping was performed, and the infant was placed skin-to-skin on the parent's chest. Shortly afterward, the infant was noted to be breathing fast and had central cyanosis. The infant was brought to the radiant warmer, a pulse oximeter sensor was applied on the right wrist, and the S_{PO_2} was 60% at 8 minutes. Supplemental oxygen was increased to 100% but the S_{PO_2} did not improve, and the labor and delivery team called for assistance.

On arrival, your team finds the labor and delivery staff providing assisted ventilation with a T-piece and resuscitation face mask. The infant's heart rate is 150 bpm but the S_{PO_2} remains at 60% despite the use of 100% oxygen. The infant's chest is moving, and breath sounds are audible on both sides. There is no sign of airway obstruction or pneumothorax.

Chest leads are applied and attached to an electronic cardiac monitor. Because of persistently low SpO_2, a member of the team intubates the infant but there is no improvement. The endotracheal tube is secured, the parents are quickly updated, and the infant is transferred to the NICU for further evaluation and treatment. A chest radiograph shows the endotracheal tube in the appropriate location, and there is no pneumothorax or effusion. Given the lack of improvement, there is concern for possible undiagnosed CHD. Cardiology is consulted, a UVC is inserted, a PGE infusion is started, and an echocardiogram is ordered. The echocardiogram confirms the diagnosis of d-TGA with a RAS; the PGE infusion is continued; and arrangements are made for emergent transfer to a pediatric cardiothoracic specialty center.

When to consider undiagnosed CHD

Prenatal diagnosis of CHD depends on the ultrasound timing, technique, and equipment. During fetal anatomy scans, a routine 4-chamber view misses over 50% of CHDs. Prenatally undiagnosed CHD can present immediately after birth to 6 months of age. Neonatal resuscitation providers should have a high index of suspicion for undiagnosed CCHD in a newborn infant who does not improve after the usual steps of neonatal stabilization and resuscitation described in this program.

Cardiac lesions that place the infant at high risk of having cardiorespiratory failure immediately after birth include HLHS with restrictive atrial-level communication, d-TGA with intact or restrictive atrial-level communication, TOF with absent pulmonary valve, moderate-to-severe Ebstein anomaly, TAPVR with obstruction, and arrythmias (Table 15-2). These lesions can result in hypoxia, cardiovascular collapse, or both. Early recognition and timely intervention can influence the outcome for this patient population.

Summary

After birth, the stabilization and resuscitation of newborn infants with prenatally diagnosed CHD requires a significant amount of preparation. Most newborn infants with CHD are vigorous after birth. If they are not vigorous, it is usually not directly related to their CHD, and they should be treated using the same steps of neonatal resuscitation described in this program and summarized on the NRP Algorithm. On reviewing the cardiac-specific pre-delivery questions, the resuscitation team can anticipate whether the newborn infant with CHD is at increased risk of experiencing cardiorespiratory failure after birth; if any modifications to the NRP Algorithm are indicated; and if additional equipment, supplies, or resources may be needed. For some infants with CCHD, modifications will be made to the target oxygen saturation. In these cases, supplemental oxygen should be used to maintain the pre-ductal oxygen saturation within a pre-specified target range that is determined on the basis of the anticipated anatomy and physiology. Newborn infants

Table 15-2. **Congenital Heart Disease at High Risk for Instability in the Delivery Room**

Congenital Heart Disease	Low Oxygen Saturation	Abnormal Heart Rate	Decreased Systemic Perfusion	Stabilization Steps to Consider
HLHS with RAS or IAS	Yes	No	Yes	Intubate, sedate and paralyze, PGE infusion, emergent cardiology intervention.
d-TGA with RAS or IAS	Yes	No	Yes, severe hypoxemia from poor mixing may reduce systemic perfusion.	Intubate, sedate and paralyze, PGE infusion, emergent cardiology intervention.
TOF with absent pulmonary valve	Possible respiratory failure due to airway compressions	No	No	Prone position, intubation, sedate and paralyze.
Ebstein	Possible depending on severity	Possible tachyarrhythmias	Possible depending on severity	Multiple potential interventions required.
TAPVR with obstruction	Not immediately but respiratory failure may develop soon after birth	No	No	Vascular access.
Tachyarrhythmia with heart failure	No	Yes	Yes	Vascular access, rate control (adenosine or cardioversion).
Heart block with heart failure	No	Yes	Yes	Vascular access, rate control (epinephrine or isoproterenol).

Abbreviations: d-TGA, transposition of the great arteries; HLHS, hypoplastic left heart syndrome; IAS, intact atrial septum; RAS, restrictive atrial septum; TAPVR, total anomalous pulmonary venous return; TOF, Tetralogy of Fallot.

with CCHD who are not responding to the recommended stabilization plan may require additional steps, including minimizing oxygen consumption, maximizing cardiac output, and preparing for emergent transfer to a location or facility with the resources to provide additional cardiac interventions.

Focus on Teamwork

Stabilizing and resuscitating a newborn infant with CHD highlights several opportunities for effective teams to use the Neonatal Resuscitation Program® (NRP®) Key Behavioral Skills.

Behavior	Example
Use available information. Anticipate and plan.	Review the cardiac-specific pre-delivery questions to identify risk factors for instability in the delivery room, determine if modifications to the NRP Algorithm are required, and/or determine if additional equipment, supplies, or personnel will be needed.
Know your environment.	Know how to access and operate a defibrillator for cardioversion. Know how to obtain additional supplies and medications such as a UVC and adenosine.
Communicate effectively.	Ensure that the members of the resuscitation team are aware of planned modifications to the NRP Algorithm.
Call for additional help when needed.	Know how to emergently access additional expertise from a cardiology consultant. Know how to emergently transfer an unstable infant with CHD to a location or facility with additional cardiology resources.

Supplemental Lesson

16

Resuscitation in the Neonatal Intensive Care Unit

What you will learn

- The unique aspects of resuscitation in the neonatal intensive care unit (NICU)
- Common causes of clinical decompensation among infants in the NICU
- Basic emergency management of arrhythmias in the NICU
- Considerations for cardiopulmonary arrest prevention and post-resuscitative care in the NICU
- When to consider using pediatric resuscitation algorithms and guidelines

Key Points

1. Effective ventilation of the lungs is the initial priority for resuscitating most infants in the neonatal intensive care unit (NICU).

2. Many infants who require resuscitation in the NICU have completed the initial physiologic transition to neonatal circulation, may already be receiving respiratory support, and already have intravascular access.

3. Many infants who experience clinical decompensation in the NICU have underlying health conditions that need to be considered during the resuscitation and post-resuscitation care.

4. When administering chest compressions to infants in the NICU, it may be reasonable to coordinate ventilations and compressions and use the same ventilation-to-compression ratio that is recommended by the Neonatal Resuscitation Program® (NRP®) for resuscitations performed in the birth setting. If a primary cardiac etiology for cardiopulmonary arrest is suspected, the ventilation-to-compression ratios recommended in the Pediatric Advanced Life Support (PALS) program may be considered.

5. There is currently insufficient evidence to make a single, definitive recommendation that is appropriate for all infants in the NICU regarding the appropriate time to transition from using the NRP Algorithm to the Pediatric Advanced Life Support (PALS) algorithms. Rather than attempting to identify an age at which the PALS algorithms should be used, consideration of the etiology of the acute event requiring resuscitation is likely to be more helpful.

6. Pericardial tamponade should be considered in any acute unexpected decompensation in an infant with an umbilical vein catheter (UVC) or a peripherally inserted central catheter (PICC) in place.

7. Infants with a tachyarrhythmia and no pulse are treated following the PALS Cardiac Arrest Algorithm. Activate your emergency response system and start high-quality chest compressions without delay. If the cardiac monitor shows ventricular tachycardia or ventricular fibrillation, defibrillation is indicated.

8. The most common metabolic cause of arrhythmia in the NICU is severe hyperkalemia.

9. Although the resources in the NICU may be different from those in the birth setting, the NRP key behavioral skills are applicable to resuscitations performed in the NICU.

10. A NICU-specific code response plan that includes early recognition, teamwork training, debriefing, and a focus on quality improvement is important to optimize the team's response.

Case 1: A preterm infant with a sudden clinical deterioration

An infant born at 25 weeks' gestation is now 4 days old with severe respiratory failure. The infant is receiving support with conventional mechanical ventilation and has received 2 doses of surfactant. The infant suddenly becomes bradycardic with a heart rate of 50 beats per minute (bpm) and the oxygen saturation (SpO_2) rapidly decreases to 40%. The bedside continuous electronic capnography (end-tidal carbon dioxide) monitor alarms and shows a flat tracing. Using the DOPE mnemonic, the bedside nurse rapidly confirms that the ventilator is cycling, evaluates the position and patency of the endotracheal tube, confirms that an unintended extubation has occurred, and calls for additional help. The tube-securing device is removed, and the nurse begins manual ventilation with a resuscitation face mask and T-piece resuscitator. As additional team members arrive, they are rapidly briefed and assess the situation. One team member brings the unit's emergency cart and video laryngoscope to the room while another uses a stethoscope to listen to the infant's breath sounds. Initially, the infant's heart rate does not improve, and the chest is not rising. After the mask is adjusted, the head is repositioned, and the mouth and nose are suctioned, the chest begins to rise with each assisted breath. Within 30 seconds of starting effective face mask ventilation, the infant's heart rate increases and oxygen saturation gradually improves. Members of the resuscitation team perform a rapid procedural time-out, confirm the treatment plan, assign tasks, and prepare to insert a new endotracheal tube. The tube is successfully inserted on the first attempt and placement is confirmed by capnography. Over the next several minutes, the infant's condition continues to improve and the oxygen concentration is adjusted to meet the institutional target. After the event, a team member contacts the infant's parents to update them, provide support, and answer questions. Shortly afterward, the team members conduct a debriefing to evaluate their preparation, teamwork, and communication.

Case 2: An infant with bronchopulmonary dysplasia

An infant who was born at 24 weeks' gestation is now 18 weeks old (42 weeks' post-menstrual age). The infant has been in the NICU since birth and has developed severe bronchopulmonary dysplasia (BPD) with tracheobronchomalacia and pulmonary hypertension. The infant has been intubated and receiving respiratory support with a ventilator since birth. The infant has frequent episodes of oxygen desaturation and bradycardia secondary to airway collapse and obstruction. The infant is receiving multiple medications and continuous tube feedings. One evening, a nurse responds to an alarm in the room and finds the infant cyanotic and apneic. The infant's oxygen saturation is 60% and the heart rate is 50 bpm. The bedside continuous electronic capnography (end-tidal carbon dioxide) monitor shows progressively increasing end-tidal carbon dioxide. The nurse increases the oxygen concentration (FIO_2) on the ventilator, confirms the position of the endotracheal tube and the connection to the ventilator, ensures the ventilator is cycling appropriately, and calls for additional help. A team member assists with suctioning the endotracheal tube and begins to hand ventilate the infant with a T-piece resuscitator. Additional staff, including a respiratory therapist, arrive in the room. They quickly receive information from the bedside nurse and assess the situation. One team member uses a stethoscope to listen to the infant's breath sounds. Another team member brings the unit's code cart to the room. Their rapid assessment determines that the endotracheal tube is inserted correctly, and it is not obstructed by secretions. The respiratory therapist notices that the infant's breath sounds are significantly decreased bilaterally and suggests increasing the peak inflation pressure (PIP) and using a longer inflation time to overcome the suspected distal airway collapse. As these ventilation corrective steps are performed, team members prepare to perform chest compressions and secure emergency vascular access. After approximately 60 seconds of ventilation with higher pressure and a longer inflation time, the infant's heart rate and oxygen saturation begin to improve. Over the next several minutes, the infant's condition continues to improve. A short time later, the infant is placed back on the ventilator and a comprehensive assessment is performed by the medical team. Afterward, a team member contacts the infant's parents to update them, provide support, and answer questions. Soon thereafter, the team members conduct a debriefing to evaluate their preparation, teamwork, and communication.

Unique aspects of resuscitation in the NICU

The *Textbook of Neonatal Resuscitation*, 9th edition, focuses on stabilization and resuscitation of the newborn infant immediately after birth. Infants in the NICU are also at risk of clinical decompensation. They may experience acute respiratory compromise and cardiopulmonary arrest. *Acute respiratory compromise* is the term used to describe an event with absent, agonal, or inadequate respirations leading to emergency assisted ventilation. *Cardiopulmonary arrest* is the term used to describe an event in which chest compressions and/or defibrillation is performed. **Acute respiratory compromise leading to cardiopulmonary arrest is the most common reason that infants receive chest compressions in the NICU.** Studies report that approximately 1% to 2% of all infants admitted to NICUs receive chest compressions. This suggests that chest compressions are administered 10 times more frequently in the NICU compared with the birth setting.

There are many potential causes of acute respiratory compromise and cardiopulmonary arrest in the NICU. Many infants who require resuscitation have completed the initial physiologic transition to neonatal circulation, may already be receiving respiratory support, and already have intravascular access. Some are receiving multiple medications including vasoactive infusions. Knowledge of the infant's medical history is critical to target interventions that address the cause of the clinical decompensation. For example, an infant with a peripherally inserted central catheter (PICC) is at risk of pericardial effusion leading to pericardial tamponade and infection leading to septic shock. An infant with severe BPD or congenital diaphragmatic hernia is at risk for a pulmonary hypertensive crisis. Infants with certain congenital heart diseases may develop shock if their ductus arteriosus closes or a surgically created shunt becomes occluded.

Health care providers working in the NICU must be prepared to perform complex resuscitations that require a well-coordinated response that focuses on identifying the underlying etiology, providing effective ventilation, performing high-quality chest compressions, administering appropriate medications, and performing critical procedures while maintaining optimal team dynamics. In this lesson, you will learn strategies to address clinical decompensation, acute respiratory compromise, and cardiopulmonary arrests in the NICU.

Should I use NRP or PALS for resuscitation in the NICU?

The recommendations provided throughout the *Textbook of Neonatal Resuscitation* are primarily intended to address the resuscitation of newborn infants transitioning from intrauterine to extrauterine life. However, portions of the NRP Algorithm are also applicable to infants in the NICU who have completed transition and require resuscitation after birth. In the NICU, most clinical decompensations are caused by acute respiratory events. Therefore, restoring ventilation using the principles outlined in the remainder of this program is appropriate for many infants in the NICU. Once adequate ventilatory support is established, the NICU team should evaluate the potential underlying cause of the event. For NICU patients with problems not addressed by the NRP, such as cardiac arrhythmias or electrolyte disturbance, the steps outlined in the PALS curriculum may be appropriate.

Some of the important differences between the NRP and PALS are described in Table 16-1. A key difference is the initial focus on

Table 16-1. Comparison of NRP and PALS

	Neonatal	Pediatric
Focus	Resuscitation and stabilization of newborn infants at birth	Life support for infants and children outside the newborn period with a wide range of acute events
Sequence of events	Airway, Breathing, Circulation	Circulation, Airway, Breathing
Indications for chest compressions	Heart rate remains less than 60 bpm despite 30 seconds of adequate ventilation	Heart rate is less than 60 bpm and/or there is no palpable central pulse
Compression-to-ventilation ratio and coordination of compressions with ventilations	3:1 ratio with 90 compressions and 30 breaths per minute Ventilation through an alternative airway recommended prior to initiating chest compressions Coordinate compressions and ventilations regardless of ventilation interface	Face mask ventilation: • One rescuer: 30:2 • Two rescuers: 15:2 • Coordinate compressions and ventilations Ventilation through endotracheal tube: • 100-120 continuous compressions per minute • 1 breath every 2-3 seconds (20-30 breaths/min) • No coordination between compressions and ventilations
Relevant algorithms	Neonatal Resuscitation Program Algorithm	• Pediatric Cardiac Arrest Algorithm • Pediatric Bradycardia with a Pulse Algorithm • Pediatric Tachycardia with a Pulse Algorithm
Drugs and other therapies	Epinephrine Normal saline Emergency O-neg blood	Drug classes • Antiarrhythmic • Vasopressors • Inotropes • Pulmonary vasodilators • Sedation/reversal agents Defibrillation, cardioversion, transcutaneous pacing, vagal maneuvers
Vascular access	UVC or IO	PIV, IO, central line
Post-resuscitation temperature management	Newborns with an estimated gestational age at birth of 36 weeks or more with evolving moderate-to-severe HIE should be offered therapeutic hypothermia under clearly defined protocols	For infants and children between 24 hours of age and 18 years of age who remain comatose after in-hospital cardiac arrest, it is reasonable to use either TTM of 32°C-34°C followed by TTM of 36°C-37.5°C or only TTM of 36°C-37.5°C

Abbreviations: HIE, hypoxic-ischemic encephalopathy; IO, intraosseous; PIV, peripheral intravenous; TTM, targeted temperature management; UVC, umbilical vein catheter.

establishing ventilation in NRP, while PALS focuses on initiating chest compressions. Once chest compressions are started, the programs also differ in the compression-to-ventilation ratio and the coordination of ventilation with compressions. The PALS algorithms address a broader range of acute events and include therapies and medications that are not included in NRP.

When administering chest compressions to infants in the NICU, it may be reasonable to coordinate ventilations and compressions and use the same ventilation-to-compression ratio recommended by NRP for resuscitations performed in the birth setting. If a primary cardiac etiology for cardiopulmonary arrest is suspected, the ventilation-to-compression ratios recommended in the PALS program may also be considered.

There is currently insufficient evidence to make a single, definitive recommendation that is appropriate for all infants in the NICU regarding the appropriate time to transition from using the NRP Algorithm to the PALS algorithms. It is unlikely that there is a single post-conceptual age or time after birth when resuscitation following pediatric guidelines leads to improved outcomes. Rather than attempting to identify an age at which the PALS algorithms should be used, consideration of the etiology of the acute event requiring resuscitation is likely to be more helpful. Therefore, it is up to health care teams to develop local guidelines that determine which algorithms will be used. When making this decision, it is important to consider the pathophysiology leading to the acute event, local resources, and the health care teams' training.

In some NICUs, staff are trained using both the NRP and PALS curricula. However, the practical implications for training staff using both programs must be considered. If the staff within a single unit are trained with both programs, it is essential to develop a plan to determine which resuscitation algorithms are being used and to clearly communicate this plan with the resuscitation team to avoid potential confusion.

Acute respiratory compromise in the NICU

Acute respiratory compromise events frequently become apparent with oxygen desaturations and bradycardia. There are many reasons for these events including severe apnea seen in prematurity, sepsis, or seizures. They can also be due to a displaced or an obstructed endotracheal tube, equipment failure, or acute changes in respiratory pathophysiology such as a pneumothorax, severe atelectasis, mucous plugging, and pulmonary hemorrhage (Table 16-2). If initial corrective measures are not sufficient to resolve the acute event, the patient's status can deteriorate to a cardiopulmonary arrest. Studies show that acute respiratory compromise is the most common etiology leading to a cardiopulmonary arrest in the NICU.

Table 16-2. Causes of Acute Respiratory Compromise in the NICU

Category	Representative examples
Mechanical	Displaced or obstructed endotracheal tube, tracheostomy tube, or noninvasive interface; disconnected ventilator circuit; equipment malfunction
Upper airway	Obstruction from tongue, abnormal pharyngeal tone, secretions, laryngomalacia, laryngospasm, vocal cord paralysis, or a mass
Lower airway	Obstruction from secretions, subglottic stenosis, trachea-bronchomalacia, tracheal stenosis, vascular rings, bronchospasm
Parenchymal lung disease	Atelectasis Pneumonia Pulmonary hemorrhage Air leak syndromes Pulmonary edema Pulmonary hypoplasia–associated syndromes (congenital diaphragmatic hernia, congenital pulmonary airway malformations) Congenital disorders of the lung (lymphangiectasia, surfactant deficiency, alveolar capillary dysplasia, acinar dysplasia, interstitial lung disease)
Disordered control of breathing	Apnea of prematurity Seizure Medications Phrenic nerve injury Hypotonia syndromes Infections Intracranial pathology

Management of acute respiratory compromise in the NICU

The first step to managing the care of an infant with acute respiratory compromise in the NICU is to provide effective ventilation. This may include applying the ventilation corrective steps (MR SOPA) described in Lesson 4 for infants receiving mask ventilation. In the NICU, many infants who experience an acute respiratory decompensation requiring an intervention are already receiving respiratory support. If an infant's condition acutely worsens while receiving respiratory support, the previously described **DOPE** mnemonic can be used to rule out a reversible cause (Table 16-3).

If the heart rate has not declined significantly, it might be appropriate to perform some of the steps such as ensuring adequate nasal interface or endotracheal tube positioning and equipment function while continuing support from the continuous positive airway pressure (CPAP) device or ventilator. If the device is functioning, it may be necessary to increase the oxygen concentration (FiO_2). However, if the heart rate is decreasing rapidly or is below 100 bpm, assisted ventilation with a resuscitation bag or T-piece resuscitator may be necessary while further evaluation is completed. If an unintended extubation has occurred, initiate face mask ventilation until the tube can be replaced.

Table 16-3. The DOPE Mnemonic

Displaced	CPAP masks/prongs, ETT, or tracheostomy tube can become displaced. • If CPAP is used, ensure the interface is properly placed and auscultate the lungs. • If intubated, auscultate for breath sounds bilaterally and over the stomach, assess ETT depth, use CO_2 detection (capnography or colorimetric CO_2 detector), consider direct visualization with laryngoscopy. Review ventilator waveforms and loops. Consider a chest radiograph.
Obstructed	Obstruction may be due to secretions, blood, a mass, or an anomaly. Suction the nares, oropharynx, ETT, or tracheostomy tube. Use CO_2 detection.
Pneumothorax, pleural effusion, or pericardial effusion	Diagnosed by unequal breath sounds, transillumination, chest radiography, or point-of-care ultrasound (POCUS)
Equipment failure	Check the CPAP device or ventilator, circuit tubing, and gas connections.

Abbreviations: CO_2, carbon dioxide; CPAP, continuous positive airway pressure; ETT, endotracheal tube.
Adapted from Kleinman ME, Chameides L, Schexnayder SM, et al. Part 14: Pediatric advanced life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation*. 2010;122(18 Suppl):S876–S908.

Ventilation considerations

Infants with underlying lung disease or abdominal distention that impedes optimal lung inflation may require higher PIP and positive end-expiratory pressures (PEEP) than commonly used in the birth setting. Infants with diseases such as pulmonary hypoplasia or congenital diaphragmatic hernia may need lower PIPs because of the risk of developing a pneumothorax when using higher pressures. In infants with established severe BPD, large tidal volumes, long inflation times, and slow rates may be required to achieve adequate ventilation. Communication between team members regarding baseline ventilator settings and interventions that have hastened recovery from previous events is important to inform optimal ventilation strategies.

Some infants in the NICU have congenital or acquired airway diseases that can make both intubation and face mask ventilation challenging. Clearly identifying these infants and prospectively developing a plan is critical to ensuring that the initial response team has a shared mental model of how best to respond. Strategies may include bedside cards or electronic medical record banners that detail the anticipated challenges, what airway maneuvers should be considered or were successful in the past, and ways to rapidly notify other airway experts.

Infants in the NICU may experience a pulmonary hemorrhage. Pulmonary hemorrhage is most frequently seen in preterm infants who experience a sudden change in pulmonary compliance and an increase in pulmonary blood flow. Commonly used initial treatment strategies for pulmonary hemorrhage include suctioning the airway to ensure patency, increasing the ventilator PEEP, and transitioning to a high-frequency oscillating ventilator. If there is cardiovascular instability, consider transfusing red blood cells. Medications such as epinephrine can be instilled into the airway to restrict hemorrhage; however, there is insufficient evidence to recommend any specific intratracheal treatment. Infants with a pulmonary hemorrhage receiving noninvasive ventilation can be difficult to intubate because of bloody airway secretions limiting visualization of the glottis.

If acute respiratory compromise does not resolve with appropriate ventilation through an alternative airway and the heart rate remains less than 60 bpm, chest compressions should be initiated and emergency medications rapidly prepared. If chest compressions, emergency medications, or other procedures are required, you will need additional help. It is likely that more than 4 team members will be needed to continue effective ventilation and compressions, secure vascular access, perform any additional procedures, prepare and administer emergency medications, monitor the passage of time, document events as they occur, and provide support for the infant's family. During resuscitation, the team should continue to assess for other underlying causes of the acute decompensation. If the etiology of the acute decompensation remains unknown, additional studies such as a blood gas test, echocardiography, chest and abdominal radiography, point-of-care ultrasound (POCUS), or subspecialty consultation may be useful.

Cardiovascular compromise

Cardiovascular compromise, encompassing conditions such as shock, pericardial tamponade, and arrhythmias, can occur in the NICU. Cardiovascular compromise can be the result of acute respiratory compromise and can progress to cardiopulmonary arrest. Effective neonatal resuscitation requires prompt recognition and simultaneous management of both respiratory and cardiovascular failure to restore oxygen delivery, stabilize hemodynamics, and prevent end-organ damage. This integrated approach highlights the dynamic interplay between the respiratory and cardiovascular systems in neonates.

Shock

Shock is a condition characterized by inadequate tissue perfusion and oxygen delivery to meet the body's metabolic demands. This state of circulatory failure can arise from various etiologies including hypovolemia, cardiogenic factors, distributive causes, or obstructive reasons (Table 16-4). The pathophysiology of shock involves a cascade of events in which decreased cardiac output and impaired oxygen delivery lead to cellular hypoxia, metabolic acidosis, and subsequent organ dysfunction. Signs of shock in the neonate are illustrated in Figure 16.1.

If untreated, shock can progress rapidly, causing a deterioration in cardiovascular function. This deterioration manifests as bradycardia and hypotension, ultimately compromising myocardial and cerebral perfusion.

Table 16-4. Categories and Risk Factors for Shock in the NICU

Category	Risk Factors
Distributive	Sepsis Necrotizing enterocolitis
Hypovolemic	Massive bleeding Fluid losses (renal or gastrointestinal) Severe dehydration
Cardiogenic	Cardiomyopathy/myocarditis Ductal closure in ductal-dependent congenital heart disease Heart failure
Obstructive	Tension pneumothorax Pericardial tamponade Pulmonary hypertension crisis Persistent pulmonary hypertension of the newborn Coarctation of the aorta Pulmonary vein stenosis

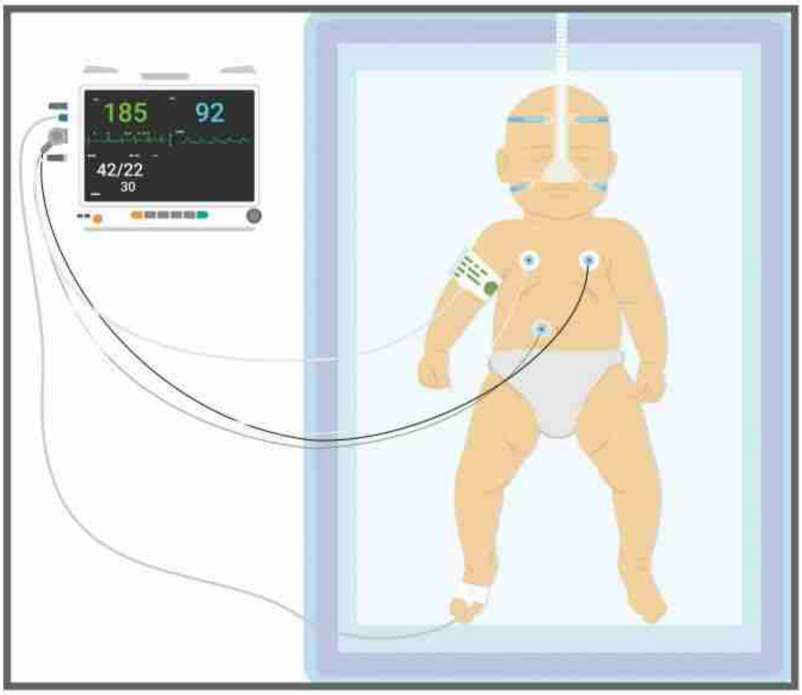


Figure 16.1. Clinical Features of Neonatal Shock
Neonatal shock presents with progressive, multisystem manifestations. Early signs include tachycardia and respiratory distress, followed by hypotension, lethargy, and decreased responsiveness as shock advances. Systemic findings include cardiovascular compromise (weak pulses, hepatomegaly), gastrointestinal dysfunction (feeding intolerance), renal impairment (oliguria or anuria), and skin changes (pallor, mottling, cyanosis, cool extremities, and delayed capillary refill).

Rapid identification and treatment of shock are vital to prevent progression to cardiopulmonary arrest. Interventions to prevent and treat shock include addressing the underlying cause, fluid resuscitation, and support with inotropes or vasoactive medications aimed at restoring adequate perfusion and oxygenation. If available, POCUS or functional echocardiography may be useful to help direct therapies such as volume of fluid administration, choice of inotrope and vasoactive medications, and evaluation for pericardial tamponade. Since sepsis is a common etiology of shock in the NICU, a sepsis evaluation and empiric antibiotic therapy should be considered.

Pericardial effusion and pericardial tamponade

Fluid that collects in the space between the heart and the thin membrane that covers the heart (pericardium) is called a **pericardial effusion**. When excess fluid collects in this space, it exerts pressure on the heart and may prevent it from filling or effectively contracting. When cardiac output is compromised and causes shock from a pericardial effusion, it is called **pericardial tamponade**. Ultimately, pericardial tamponade may cause persistent bradycardia or asystole that does not respond to resuscitative interventions. In the NICU, pericardial tamponade may be a complication related to central venous catheters (UVCs or PICCs), cardiac catheterization, or cardiac surgery.

Symptoms of pericardial tamponade such as tachycardia, narrowing of the pulse pressure, and pulsus paradoxus (a decrease in blood pressure during spontaneous inhalation) can evolve over time. However, pericardial tamponade can also present as acute and sudden cardiac arrest. **Pericardial tamponade should be considered in any acute unexpected decompensation in an infant with a UVC or PICC in place.** Ultrasonographic evaluation with POCUS or echocardiography, if available, can be used to diagnose pericardial tamponade. If a high suspicion of pericardial tamponade exists (either clinically or based on imaging), pericardiocentesis should be performed.

Evacuating a pericardial effusion

The fluid is aspirated by inserting a catheter into the pericardial space. This procedure is called **pericardiocentesis**. Ideally, pericardiocentesis should be performed using sterile technique with appropriate anesthetic for pain management; however, modifications may be required during emergency aspiration of a pericardial tamponade.

1. Take a brief time-out and confirm the location where you plan to aspirate.
2. Identify the insertion site. If ultrasonography is available and time permits, such imaging can identify the ideal entry site and insertion depth. **If ultrasonography is not immediately available, the usual insertion site is just below (0.5 cm-1 cm) the tip of the xiphoid in the midline (Figure 16.2).**

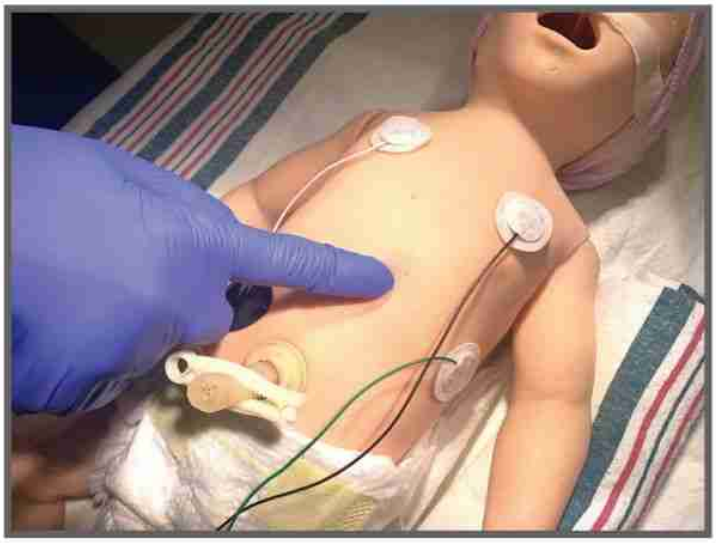


Figure 16.2. Identify the insertion site just below the tip of the xiphoid process in the midline.

3. Prepare the insertion site with topical antiseptic and sterile towels.
4. Prepare a 20- or 24-gauge percutaneous catheter-over-needle device*, an extension set, a 3-way stopcock, and a syringe (10-20 mL).
5. Insert the catheter at a 30- to 40-degree angle to the skin with the needle tip directed toward the infant's left shoulder (Figure 16.3).

*Note: If an appropriate catheter-over-needle device is not available, a small "butterfly" needle may be used. In this case, the syringe and stopcock will be connected to the tubing attached to the needle.

Figure 16.3. Insert the catheter at a 30- to 40-degree angle with the needle tip directed toward the infant's left shoulder.

6 **Advance the needle toward the left shoulder** until fluid fills the catheter. Remove the needle. Connect the extension set, 3-way stopcock, and syringe to the catheter. Open the stopcock to the patient and aspirate the fluid (Figure 16.4).

a. When the syringe is full, the stopcock may be closed to the infant while the syringe is emptied through the open (third) stopcock port.

b. After the syringe is emptied, the stopcock can be reopened to the infant and more fluid may be aspirated until the infant's condition has improved.

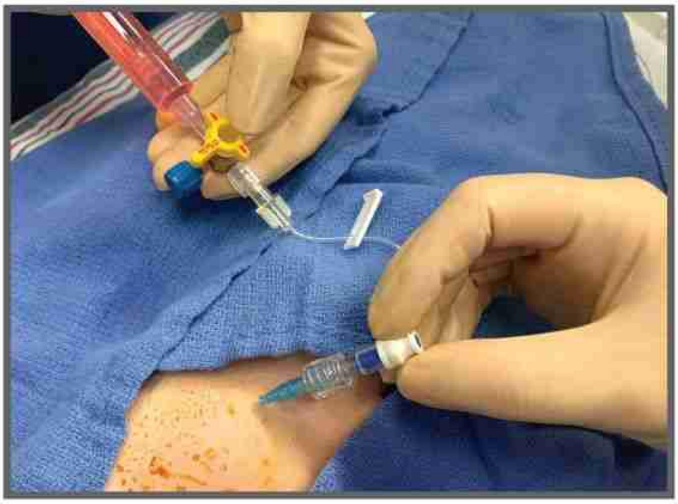


Figure 16.4. Syringe, stopcock, extension set, and catheter assembly used to aspirate a pericardial effusion.

7 Once the infant's condition has stabilized, an echocardiogram may be obtained to document the presence or absence of residual pericardial effusion and cardiac function.

Arrhythmias

Infants in the NICU can have congenital or acquired arrhythmias leading to cardiorespiratory failure (Table 16-5). Arrhythmias are more common in infants with underlying congenital or acquired heart disease. However, electrolyte disturbances such as hyperkalemia can cause life-threatening arrhythmias. UVCs and PICCs with a tip located within the right atrium may cause arrhythmias such as supraventricular tachycardia (SVT). Sinus tachycardia commonly occurs in association with dehydration, pain, agitation, fever, or sepsis. Ventricular arrhythmias and pulseless electrical activity are less common in the NICU, but they may occur and require recognition and rapid intervention.

Table 16-5. Categories and Risk Factors for Arrhythmias in the NICU

Category	Risk Factors
Bradyarrhythmia • Sinus bradycardia • Heart block	Hypoxemia Vagal episode Heart block (congenital or acquired) Medication Hypothermia Hypocalcemia
Tachyarrhythmia • Sinus tachycardia • Atrial flutter • Supraventricular tachycardia • Ventricular tachycardia	Malpositioned central venous catheter Fever Medication Congenital conduction disorder Myocarditis/cardiomyopathy Hyperkalemia
Cardiac arrest rhythms • Asystole • Pulseless electrical activity • Ventricular fibrillation • Pulseless ventricular tachycardia	Hypoxemia Myocardial failure Cardiomyopathy Myocarditis Hyperkalemia

This section provides a basic introduction to the emergency management of arrhythmias in the NICU. This is a complex topic and a comprehensive review of arrhythmia management is beyond the scope of this lesson. Early consultation with a cardiology specialist is recommended to aid in the diagnosis and effective treatment of arrhythmias.

When a tachyarrhythmia (abnormally rapid heart rate) is suspected, perform a rapid initial evaluation including checking for a pulse and looking for signs of poor perfusion or hemodynamic instability. If a pulse is present, complete a preliminary assessment of the infant's cardiac rhythm with a bedside electronic monitor while assessing the infant's blood pressure, oxygen saturation, and mental status. Ensure that the infant has a patent airway, assist breathing, and provide supplemental oxygen as needed. If available, a 12-lead electrocardiogram (ECG) may be helpful. If not already done, secure intravascular access. Early consultation with a cardiology specialist may aid in the diagnosis and effective treatment of tachyarrhythmias.

Infants **with a pulse and narrow QRS complex tachyarrhythmia** may have sinus tachycardia, SVT, or atrial flutter. Sinus tachycardia typically presents with a gradual increase in heart rate ($<$ 220 bpm) and normal-appearing P waves, with a variable RR interval on the ECG. If the infant has sinus tachycardia, identify and treat the underlying cause.

SVT typically presents with the abrupt onset of a very rapid heart rate (> 220 bpm), a narrow QRS complex, absent or abnormal P waves, and no variability in the RR interval. Infants in stable condition with SVT may be treated initially with vagal maneuvers. If SVT persists, intravascular adenosine may be administered. Infants with SVT and signs of hemodynamic instability are treated with adenosine, if intravascular access is present, and synchronized cardioversion if intravascular access is not available or adenosine is ineffective. Atrial flutter can be difficult to distinguish from SVT and follows a similar treatment approach.

The treatment of infants **with a pulse and a wide QRS complex tachyarrhythmia** is based on signs of hemodynamic instability. These infants may have ventricular tachycardia (VT) or an uncommon type of SVT. If their condition is unstable, synchronized cardioversion is indicated. If their condition is stable, consultation with a cardiologist is recommended.

Infants **with a tachyarrhythmia and no pulse** are treated following the PALS Cardiac Arrest Algorithm. They may have pulseless VT or ventricular fibrillation (VF). These rhythms typically have a wide QRS complex. Activate your emergency response system and start high-quality chest compressions without delay. If the monitor shows VT or VF, defibrillation is indicated.

The most common metabolic cause of arrhythmia in the NICU is severe hyperkalemia. When potassium increases, an ECG may show peaked T-waves or widening of the QRS complexes. If untreated, severe hyperkalemia can lead to VF or asystole. Medical treatments used to acutely shift potassium into cells can mitigate the effects of hyperkalemia on the infant's heart. These treatments include intravenous administration of calcium gluconate or calcium chloride, sodium bicarbonate, insulin, and dextrose. Other treatments such as furosemide and inhaled beta agonists may take longer to have an effect. Developing unit-based guidelines for the management of severe hyperkalemia can facilitate timely intervention and avoid progression to VF or asystole.

Although a defibrillator is used for both synchronized cardioversion and defibrillation, these interventions are different and are used for different purposes. **Cardioversion is performed when the infant has a tachyarrhythmia with a palpable pulse, indicating that perfusion is present.** The most common arrhythmia treated in the NICU with cardioversion is SVT. **Defibrillation is only indicated in cases of cardiac arrest caused by VF or pulseless VT** (Table 16-6). In both of these rhythms there is no evidence of perfusion, as evidenced by an absent pulse. Since there is no perfusion in VF or pulseless VT, chest compressions should be performed as soon as the arrhythmia is identified and between shocks whenever defibrillation is indicated. Defibrillation in the NICU is very rarely needed.

Table 16-6. Treatment of Arrhythmias in the NICU

Category	Arrhythmia	Treatment
Tachyarrhythmias	Atrial flutter Supraventricular tachycardia Ventricular tachycardia	Stable: • Vagal maneuvers • Adenosine (0.1-0.2 mg/kg, rapid IV push) Unstable: • Cardioversion (0.5-1 J/kg)
Cardiac arrest rhythms	Ventricular fibrillation Pulseless ventricular tachycardia	Chest compressions Defibrillation (2-4 J/kg)

The safe use of a defibrillator in the NICU for either cardioversion or defibrillation is an important consideration. Familiarity with the defibrillator modes and controls is critical. General principles for the safe use of a defibrillator include the following: (1) frequent practice and education, (2) closed loop communication around the energy dose, choice of cardioversion or defibrillation, and (3) clear communication before delivery of the shock to ensure that all processes are in place to prevent an inadvertent shock to the care providers. If cardioversion is desired, most defibrillators require setting the defibrillator to "sync" mode. Some defibrillators need to be reset into "sync" mode after each cardioversion if a second energy dose is needed.

Medications

Medications, including epinephrine and volume expanders, should be used in the NICU as outlined in Lesson 7. Given the range of etiologies leading to acute respiratory compromise and cardiopulmonary arrest in the NICU, intensive resuscitation may involve many other medications as well. Choices of medications will depend on the identified or presumed underlying etiology of the clinical event. A few examples of such medications include beta-agonists used to treat bronchospasm, antibiotics to treat septic shock, prostaglandin E_1 to treat ductal-dependent cardiogenic shock, and calcium preparations to treat hypocalcemia or hyperkalemia. Institutional policies and knowledge of how staff access these medications are important. Some units will maintain a supply of emergency medications in a dedicated code cart on the unit or in an automated medication management and dispensing system. Others will obtain emergency medications from a unit-based pharmacy. Systems such as bedside code cards, standardized code documentation on electronic or paper forms, and automated drug references should be used to ensure safe medication dosing and support an effective response to emergency events.

NICU resuscitation procedures

Resuscitations in the NICU often require invasive interventions similar to those described in the remainder of this program (Table 16-7). For respiratory distress, endotracheal intubation or laryngeal mask insertion establishes a secure airway for effective ventilation. Needle thoracentesis or chest tube placement is critical for managing a pneumothorax. Additional procedures not commonly performed in the birth setting include pericardiocentesis for treatment of pericardial tamponade, abdominal paracentesis for decompression of severe ascites or pneumoperitoneum, and synchronized cardioversion or defibrillation for unstable cardiac arrhythmias.

Vascular access

Many infants who experience a clinical decompensation in the NICU already have venous access that may include a peripheral intravenous (IV) catheter, UVC, or PICC. Some smaller PICCs (≤ 1.9F) can be damaged with rapid pushes of fluids or medications; thus, additional IV access may be needed during a resuscitation. If no IV access is in place at the time of the event, emergency catheterization of the umbilical vein may be feasible during the first week after birth. Beyond the first week, umbilical catheterization is generally not an option. Because of the poor perfusion during cardiopulmonary resuscitation, establishment of rapid peripheral IV access may be unsuccessful. Therefore, insertion of an intraosseous needle, as described in Lesson 7, is an effective alternative for emergency vascular access.

Point-of-care ultrasound (POCUS)

Point-of-care ultrasound (POCUS) is increasingly used during neonatal resuscitation to enhance clinical decision-making and performance of procedures. POCUS may allow real-time visualization of cardiac function, fluid status, lung aeration, and central catheter tip location. With appropriate training, incorporation of POCUS into clinical care

Table 16-7. NICU Resuscitation Procedures

Category	Procedures
Respiratory	Intubation Laryngeal mask Needle thoracentesis Chest tube
Shock	Intraosseous line placement Pericardiocentesis Abdominal paracentesis
Metabolic	Exchange transfusion Dialysis
Cardiac	Cardioversion Defibrillation

may aid in the rapid diagnosis of conditions like pneumothorax, pleural effusion, cardiac dysfunction, hypovolemia, and pericardial tamponade. In addition, POCUS may be used to guide emergency procedures such as insertion of IV catheters, peripheral arterial lines, thoracentesis, pericardiocentesis, and paracentesis.

Post-resuscitation care in the NICU

Many of the principles outlined in Lesson 9 for post-resuscitation care of the newborn infant are also important in the NICU. One major difference is that there is insufficient evidence to recommend for or against therapeutic hypothermia for infants after resuscitation performed outside the immediate transition period. However, evidence suggests that it is important to avoid hyperthermia. Other post-resuscitation considerations are to assess and maintain cardiopulmonary, fluid and electrolyte, and metabolic parameters within normal ranges. Depending on the clinical situation, this may require intensive monitoring and frequent evaluation of laboratory tests. Neuromonitoring with an electroencephalogram may be considered for infants who experience a change in neurologic status after resuscitation.

Focus on Teamwork

Although the resources in the NICU may be different from those in the birth setting, the NRP Key Behavioral Skills are still applicable to resuscitations performed in the NICU. A NICU-specific code response plan that includes early recognition, teamwork training, debriefing, and a focus on quality improvement is important to optimize the team's response. Resuscitation in the NICU highlights several opportunities for effective teams to use the NRP Key Behavioral Skills.

Behavior	Example
Know your environment.	• Know the location of resuscitation equipment in the NICU and how to access it. • Know how to call for help and what subspecialty support is available.
Use available information.	• Evaluate underlying health conditions that contribute to clinical decompensation in the NICU. • Review baseline ventilator settings and interventions that have aided recovery during previous events to inform optimal ventilation strategies.
Anticipate and plan.	• Clearly identify patients with congenital or acquired airway diseases that can lead to difficulty with ventilation or intubation. • Prospectively identify patients at risk for acute decompensation. • Clearly indicate if PALS algorithms or procedures will be followed during resuscitation. • Assign roles and responsibilities to team members. • Perform simulated resuscitations in the NICU to identify systems issues and latent safety threats.

Continued

Behavior	Example
Delegate workload optimally.	• Avoid overcrowding in the NICU room. • Do not duplicate work or use more resources than necessary. • Change task assignments depending on skill sets and current needs. • Do not allow one person to become overloaded with tasks. • Do not allow the team to become fixated on a single task.
Call for additional help when needed.	• Call for speciality support (eg, anesthesia, cardiology) in a timely manner. • Know how to call for additional help.

Quality Improvement Opportunities

Ask yourself the following questions and begin a discussion with your team if you find a difference between the NRP recommendations and what is currently done in your own hospital setting. Consider using the suggested process and outcome measures to guide your data collection, identify areas for improvement, and monitor your improvement efforts to determine whether they are working.

Quality improvement questions

1. Do you have protocols in place to clearly identify infants in the NICU with a difficult airway?
2. Do you have a training program for advanced resuscitation procedures such as chest tube insertion, pericardiocentesis, abdominal paracentesis, and exchange transfusion?
3. Which members of the NICU staff know how to use a defibrillator to perform cardioversion and defibrillation?
4. Does your NICU use NRP, PALS, or a hybrid approach?
5. How often does your NICU perform resuscitation simulations?
6. Do providers regularly perform post-resuscitation debriefings for resuscitation events in the NICU?

Process and outcome measures

1. What percentage of infants in your NICU have a complete and up-to-date emergency medication card/guide at their bedside?
2. What percentage of NICU staff complete defibrillator competency training each year?
3. What percentage of NICU resuscitation team members have demonstrated that they can properly calculate and prepare emergency epinephrine in a simulation setting each year?
4. How often are chest compressions performed in your NICU?

5. How often are post-resuscitation debriefings performed in the NICU?

6. What are the long-term clinical outcomes in neonates resuscitated in the NICU?

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Appendix

Part 5: Neonatal Resuscitation: 2025 American Heart Association and American Academy of Pediatrics Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care

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ABSTRACT: The guidelines in this document from the American Heart Association and the American Academy of Pediatrics focus upon optimal care of the newborn infant, including those who are proceeding to a normal transition from the fluid-filled uterine environment to birth. Newborn infants who are proceeding to normal transition can benefit from deferred cord clamping for at least 60 seconds in most instances, skin-to-skin with their parent soon after birth, and appropriate assistance with thermoregulation. Some newborn infants require assistance during transition, with interventions ranging from warming and tactile stimulation to advanced airway management, assisted ventilation, oxygen therapy, intravascular access, epinephrine, and volume expansion. In this context, individuals, teams, and health care settings that care for newborn infants should be prepared and have access to appropriate training and resources for neonatal resuscitation. The newborn chain of care provides guidance on considerations that may lead to optimal outcomes for newborn infants starting from prenatal care to recovery and follow-up.

Access the full 2025 Guidelines as published in *Pediatrics* at https://doi.org/10.1542/peds.2025-074352.