Objectives

1. Demonstrate the maneuvers required for the basic treatment of ill and injured children, including oxygen administration, monitoring, and basic airway maneuvers.
2. Demonstrate orotracheal intubation using a manikin model.
3. Demonstrate placement of an intraosseous needle in a manikin or other model and describe the landmarks for intraosseous needle placement in a child.
4. Describe the indications and technique for needle thoracostomy.
5. Describe indications and technique for pericardiocentesis.

Chapter Outline

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**Section 2: Cervical Spine Stabilization**

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13.1 Cardioversion and Defibrillation
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**Section 14: Vascular Access**

14.1 Peripheral Venous Catheter Placement
14.2 External Jugular Vein
Introduction

Chapter addresses the performance of several key emergency procedures. The individual practitioner must determine the extent to which each of these procedures is likely to be required in his or her practice, but all physicians who care for children with serious illnesses and/or injuries must possess, in addition to cognitive skills, the requisite procedural skills. All procedures should be performed with universal precautions.

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Section 1: Pediatric Length-Based Resuscitation Tape

1.1 Pediatric Length-Based Resuscitation Tape
Length-based resuscitation tape permits the rapid determination of size-dependent resuscitation parameters, such as drug doses, endotracheal tube (ETT) sizes, mask sizes, and vital signs, which potentially speeds resuscitation efforts and reduces the likelihood of a medical error. The tape is placed at one end of the patient, and the other end of the patient aligns with a color-coded block corresponding to the patient’s length-based resuscitation parameters. There might be two sets of blocks, one of which corresponds to tube sizes, vital signs, etc., and the other of which indicates drug dosing. Many systems include books with color-coded pages that provide even more information. Some length-based resuscitation systems will have corresponding color-coded bags or carts that contain the actual resuscitation devices (eg, tracheal tubes and laryngoscope) and drugs (pre-calculated unit doses).

Technique
1. Align the end of the tape to the patient. Alternatively, if the tape is secured to the gurney, adjust the patient’s position to align with one end of the tape.
2. Identify the inferior end of the patient using the heels, not the toes (Figure 26.1).
3. If the child is larger than the tape (>36 kg), proceed as in the case of an adult.

4. Verbalize the color or letter block (on the edge of the tape) and the weight estimate determined by the tape so that this information can be recorded.
5. Use the appropriate color or letter block to identify appropriate drug doses and equipment sizes (Figure 26.2).

Section 2: Cervical Spine Stabilization

2.1 Cervical Spine Stabilization
Indications
Although cervical spine injuries are relatively rare in children, patients who have sustained significant blunt trauma (eg, falls from heights, automobile-pedestrian crashes, moderate to severe motor vehicle crashes, diving injuries) and those who sustain direct injury to the neck (blunt or penetrating) are at risk, and the cervical spine should be protected before complete evaluation.
Likewise, children and adolescents with symptoms of cervical cord dysfunction after trauma (e.g., numbness and/or tingling or weakness in an extremity) should be appropriately stabilized pending further evaluation, even if the symptoms are transient. Finally, patients who have significant alterations in mental status and who might have been injured should also be stabilized until they can be thoroughly evaluated.

**Equipment**

- Appropriately sized rigid cervical collar ([Figure 26.3](#))
- Long spine stabilization board
- Lateral spacing blocks or similar devices
- Straps or tape

**Required for Infants and Young Children:**

- Specially designed long spine stabilization board with cutout or indentation to accommodate the occiput or
- Pad placed on the spine board and extending from the child’s shoulders to his or her feet

*This equipment can be obtained as part of a kit specially designed for this purpose.*

**Technique**

1. Ensure that adequate personnel are available to assist.

2. Stabilize the patient’s head in place by holding the head and keeping the neck in a neutral position ([Figure 26.4A](#)).

3. Determine the proper size for the cervical collar. The ideally sized collar extends from the top of the shoulders to the bottom of the chin, leaving the neck in a neutral position. A collar that is too tall hyperextends the neck, whereas one that is too short allows for unwanted neck flexion. Both hyperextension and flexion can be disastrous in the face of a cervical spine injury and, therefore, should be avoided.

4. Some cervical collars require assembly before use. If necessary, assemble the collar.

5. Open the cervical collar and carefully slide the rear portion behind the neck while an assistant maintains inline stabilization of the patient’s head and neck.

6. Bring the front of the collar into position and then attach the front and back portions together using the adhesive straps. The collar should fit snugly but not constrict the airway or restrict blood flow to the skin ([Figure 26.4B](#)).

7. Ensure that the head remains in a neutral position.

8. Secure the patient to a long spine board. If the patient is seated, a short spine board or extrication vest should be secured to the patient to stabilize the head and trunk as a unit. Then place a long spine board beside the patient and, keeping the knees and hips bent, pivot and lower the patient onto the long board. Lower the knees to the board. If the patient is supine, log-roll the patient onto his or her side, maintaining inline stabilization of the neck. Place the long board on edge behind the patient and roll the patient and the board as a unit back into a supine position ([Figure 26.4C](#)).

9. Secure the patient to the spine board. Place soft lateral spacing devices on either side of the patient’s head. Heavy objects such as sandbags should be avoided because they can place undue lateral pressure on the spine if the board is inadvertently tilted ([Figure 26.4D](#)).

10. Using tape or commercial straps, first secure the forehead, then the chin, shoulders, and pelvis to the board ([Figure 26.4E](#)).
This can cause the child’s neck to be flexed when he or she is placed in a supine position on a flat surface. This problem can be corrected in two ways. Special spine boards designed with indentations or cutouts to accommodate the head can be used. Alternatively, a pad can be placed over the spine board before the patient is secured to it. The child should then be placed on the board such that his or her shoulders and body are on the pad but the head and neck are not. Elevation of the torso allows the neck to remain in a neutral position. Some recommend that clinically stable, very young infants be stabilized in a car seat (Figure 26.5).

Complications and Pitfalls
The major risk associated with cervical spine stabilization is unintentional injury to the spinal cord. Excessive movement of the patient’s neck must be avoided because such movement might convert a stable cervical spine fracture not involving the spinal cord into a cord injury.
Section 2: Cervical Spine Stabilization

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In some cases, attempted stabilization of struggling patients might place them at risk of injury. In such cases, patients can be evaluated without formal stabilization provided that they can remain calm and cooperative during the evaluation. The reasons for the decision not to stabilize should be documented.

Spinal stabilization is an all-or-nothing procedure. All personnel must understand that a cervical collar alone is not adequate protection because it allows a significant amount of neck extension and rotation and does not completely eliminate flexion. The straps and lateral supports are an integral part of the system. Effective lateral supports, also called lateral spacing devices, can be made of many materials, including cardboard, foam, or air-filled bladders. Heavy objects, such as sandbags, should not be used because they can put pressure on the lateral side of the neck when the spine board is tilted to one side. Tilting of the board can occur unintentionally during movement or deliberately in the transport of a pregnant adolescent or to allow the patient to vomit without aspirating.

Stabilization can compromise circulation or the airway. These must be assessed after the patient is stabilized and at frequent intervals thereafter. The stabilized patient with significant nausea and vomiting can aspirate, and treatment with antiemetics and/or nasogastric suction might be necessary. Personnel should carefully log-roll the patient to one side (preferably the left side) to allow him or her to vomit, if necessary. Adolescent females in the latter stages of pregnancy might require transport with the board tilted to the left side to reduce pressure on the inferior vena cava. Stabilization can also make it more difficult to assess other injuries, particularly head and neck injuries. In these cases it is acceptable to remove the restraint devices to examine the patient while assistants maintain inline stabilization.

Finally, it is important that the clinician understand when stabilization can be discontinued. In some cases, cervical restraints can be removed after a clinical examination of the neck. Several studies have demonstrated that patients who do not have neurologic deficits, lack midline cervical spine tenderness, and are

KEY POINTS

Performing Spinal Immobilization
- Ensure clinical cervical spine clearance (without radiographs) in selected patients at low risk.
- Maintain cervical spine stabilization in nonawake patients.
- Ensure proper cervical spine stabilization position for children to avoid flexion.
- Avoid heavy sandbags.

Figure 26.5 Very young, clinically stable infants can be stabilized in a car seat.
able to voluntarily move their necks without experiencing significant pain are unlikely to have sustained a fracture of the cervical spine, provided that the patient has a normal level of consciousness, does not have a second injury causing significant pain (eg, a long bone fracture), and is not intoxicated. Although the mechanism of injury is not a part of these rules, experience suggests that well-restrained patients involved in low-speed motor vehicle crashes are at even lower risk of cervical spine injury. These rules should be cautiously applied to pediatric patients; however, few very young children have been studied, and more conservative evaluation of these patients is recommended.

Unfortunately, the standard three-view series of radiographs of the cervical spine is only 93% to 95% sensitive for the presence of a cervical spine fracture. Conscious patients should undergo a thorough examination of the cervical spine after radiographs have demonstrated no fractures. Computed tomography provides superior images but at the cost of increased radiation exposure. Unconscious patients with normal cervical spine radiographs should remain stabilized unless stabilization is compromising clinical care or causing injury. Likewise, children with neurologic symptoms should remain stabilized even if their radiographs or computed tomography results are normal. Initially, it can be difficult or impossible to distinguish patients with occult cervical spine fractures from those who have spinal cord injury without radiographic abnormality.

Children placed on standard spine boards will likely have their necks in moderate flexion. Lateral cervical spine radiographs taken in this position frequently show C2-3 pseudosubluxation (Figure 26.6A, B). This malalignment can be difficult to distinguish from a true subluxation or fracture injury. Absence of prevertebral soft tissue widening, a history of relatively benign trauma, lack of neck pain in an awake patient without other distracting injuries, and alignment of the anterior cortical margins of the spinous processes of C1, C2, and C3 all suggest (but do not guarantee) that this is a pseudosubluxation and not a true subluxation. It would be preferable to stabilize children properly to avoid cervical spine flexion, which reduces the risk of spinal cord injury and the artifact pseudosubluxation on initial lateral cervical spine radiographs.

Figure 26.6 Two examples of C2-3 pseudosubluxation. Note that the neck is flexed forward.
Section 3: Monitoring

Monitoring of physiologic parameters is an essential component of modern emergency care. Advances in technology have made it possible to measure several key physiologic indicators in a noninvasive manner. There are seven essential monitoring devices in current use. These are electrocardiographic (ECG) monitoring, impedance pneumographic monitoring, blood pressure monitoring, pulse oximetry, exhaled carbon dioxide detection, temperature, and the stethoscope. Measurement of temperature and auscultation are commonly used by most health care professionals; these techniques will not be described in this chapter.

3.1 ECG Monitoring

ECG monitors detect and display the electrical activity produced by the cardiac conducting system. This monitor allows emergency personnel to detect changes in cardiac rhythm. Because these devices measure the difference in electrical potential between two electrodes, several electrodes are required. The standard monitor has three sensing leads. The two upper leads are intended to be placed on the left and right arms, respectively, but in practice are usually placed on the left and right sides of the upper torso. Likewise, the lower left lead is intended for placement on the left leg but might be placed on the lower left side of the abdomen. Some monitors have a fourth lead for the right lower extremity, which is placed on the right leg or on the right side of the lower abdomen. In many cases, the electrodes are labeled so that they can be properly placed. In other cases, they are color-coded. Proper lead placement is important, and each practitioner should learn the configuration used in his or her institution (Figure 26.7).

THE BOTTOM LINE

- Optimal cervical spine stabilization requires special positioning for children.
- Children are at lower risk for cervical spine fracture and spinal cord injury compared with adults, but this does not permit clinicians to ignore this risk.

Equipment

- ECG monitor
- Electrodes
- Alcohol pads

Technique

1. Ensure that the monitor is functioning properly and that the electrode pads are not damaged. New electrode pads must be used for each patient to prevent the spread of infection and to ensure that the adhesive substance can make adequate contact with the patient’s skin.
2. Select the sites for electrode placement and cleanse the patient’s skin with alcohol to improve contact.
3. Allow the alcohol to dry and then attach the electrodes.
4. Turn on the monitor.
5. Most monitors have different lead configurations (using different pairs of leads), which will give a different waveform. Select one. Often lead II is selected (Figure 26.8).
6. Set the monitor alarms.
Critical Procedures

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Critical Procedures

26-10

Complications and Pitfalls

ECG monitoring is generally safe. There are, however, a few complications that should be noted. On some monitors, the alarms must be activated before they will function. Failure to activate these alarms can result in a serious dysrhythmia going unrecognized. It is also vital that the staff correctly interpret the data received from the monitor. Apparent dysrhythmias should be checked in a second lead configuration, and the staff must ensure that the electrodes are properly positioned and that the problem is not related to patient movement.

3.2 Impedance Pneumatography

The impedance pneumatograph uses the ECG electrodes to measure the motion of the chest wall as a surrogate marker for respiratory effort, which is displayed as a waveform (or square waveform) on the monitor (Figure 26.8).6

Equipment and Technique

Uses the same leads as the ECG monitor.

Complications and Pitfalls

Like ECG monitoring, impedance pneumatography is subject to artifact caused by patient movement and lead placement problems. However, the most important potential pitfall in the use of impedance pneumatography lies in the understanding that it is measuring chest wall movement, not air flow. Intermittent auscultation is required to ensure that the ventilation is indeed adequate.

3.3 Blood Pressure Monitors

Most health care professionals were previously taught to measure blood pressure by auscultation. The modern oscillometric methods that are used by monitoring devices replace the sound of blood flowing with a measurement of the oscillations in the arterial wall.5,6

Equipment

- Properly sized blood pressure cuff (The appropriately sized cuff should cover approximately two-thirds of the upper arm length and should completely encircle the arm. It should fit snugly but not constrict the arm, as this can affect the result. If in doubt, select a larger cuff rather than a smaller one.)
- Blood pressure monitoring device

Technique

1. Place the cuff on the patient’s upper arm (or thigh).
2. Attach the cuff to the monitoring device.
3. Set the frequency of measurement and set the alarms.

Complications and Pitfalls

Like all monitors, blood pressure monitors are affected by patient movement. Likewise,
improperly sized cuffs and air leaks can affect the accuracy of the result. A key issue in the measurement of blood pressure is the understanding that the presence of shock is not determined or ruled out by any specific blood pressure value. This is particularly true in early (compensated) shock. A patient with a normal or near normal blood pressure can exhibit shock symptoms.

3.4 Pulse Oximetry
The pulse oximeter uses two different wavelengths of light to transcutaneously measure the degree to which the patient’s hemoglobin molecules are bound to oxygen. The result is expressed as the percentage of oxygen saturated hemoglobin (Figure 26.8). Normally, 97% to 100% of available binding sites are saturated. In hypoxic states, when the \(P_{O_2}\) is less than 70 mm Hg, the pulse oximeter will display an oxygen saturation value of 90% or less.\(^7\)\(^8\)

There are many types of pulse oximeters available. Technological advances have made these devices small and portable.

**Equipment**
- Pulse oximeter
- Pulse oximeter probe
- Alcohol pads

**Technique**
1. Choose a location for the placement of the pulse oximeter probe. The site must allow the light waves to pass through the skin to the receiver probe (Figure 26.9). Fingers, toes, and ear lobes are often used for this purpose. In infants and very young children, the side of the hand or foot can be used.
2. Clean the skin at the site if necessary.
3. Apply the probe, making certain that the transmitting and receiving portions are well aligned.
4. Connect the probe to the monitor and confirm that the heart rate measured by the device correlates with the patient’s actual heart rate.

**Complications and Pitfalls**
Like all monitoring devices, the pulse oximeter is subject to erroneous readings caused by patient movement. Likewise, the sending and receiving sections of the probe must be relatively well aligned for the device to function effectively. There are rare case reports of falsely elevated pulse oximeter readings caused by ambient light. It is, therefore, important to ensure that the receiving section of the probe is not exposed.

Pulse oximetry is based on the light absorption characteristics of hemoglobin A (ie, normal adult hemoglobin). It is inaccurate in the presence of carboxyhemoglobin and methemoglobin. It is fairly accurate for fetal hemoglobin and most other hemoglobinopathies.

Pulse oximetry can be falsely elevated by the presence of carboxyhemoglobin (ie, the pulse oximeter reads 100% when the true oxygen saturation is lower). When carbon monoxide poisoning is suspected, a blood sample for co-oximetry or a carboxyhemoglobin level should be tested. An arterial or venous blood gas measurement will similarly be misleading because it will show a high \(P_{O_2}\) and high calculated oxygen saturation, although it might correctly demonstrate a metabolic acidosis. Most blood gas analyzers do not automatically run
The pulse oximeter does not measure the patient's hemoglobin concentration, so the patient's oxygen-carrying capacity cannot be fully assessed. A patient with an oxygen saturation of 95% and hemoglobin concentration of 6 mg/dL has a lower oxygen content than a patient with an oxygen saturation of 90% and a hemoglobin concentration of 14 mg/dL.

Finally, the pulse oximeter gives no information regarding the \( \text{PaCO}_2 \) and, therefore, no information about the adequacy of ventilation. It is possible for a child receiving supplemental oxygen to be well oxygenated and yet be hypoventilating.

### 3.5 Exhaled Carbon Dioxide Monitors

Capnometry devices measure and, in some cases, quantify the exhaled carbon dioxide.\(^9\,10\)

After endotracheal intubation, capnography is used to confirm that the tube is located in the trachea; later it is used to ensure the tube remains properly located. Carbon dioxide detectors are small plastic devices that are inserted into the ventilation circuit closest to the ETT (Figure 26.10). These devices change color as carbon dioxide flows through the device. The color change visible with each respiration indicates the presence of carbon dioxide, confirming endotracheal intubation. End-tidal carbon dioxide (ETCO\(_2\)) monitors quantify the degree of exhaled carbon dioxide. A sensor is inserted into the ventilation circuit closest to the ETT. The sensor is then connected by wires to an ETCO\(_2\) monitor to follow or track ventilation (gas exchange) because the ETCO\(_2\) measurement (numeric display on the monitor) usually approximates the arterial \( \text{Paco}_2 \) (except in instances described below). An arterial blood gas analysis will reveal a high \( \text{Po}_2 \) (especially if the patient is receiving supplemental oxygen), and the calculated oxygen saturation will be falsely high (usually 100%, despite the lower oxygen saturation measured by pulse oximetry, which is a discrepancy that should lead to this diagnosis). In addition, the patient's blood will appear to be chocolate brown in color (if the methemoglobin percentage is high enough), and the patient will appear to be dusky or pale (often described as ashen gray). In other instances where there is doubt as to the accuracy of the pulse oximeter reading, co-oximetry should be obtained.

Note that methemoglobinemia pulse oximetry measurements are low, but they should be lower. This is less misleading than in carbon monoxide poisoning, where the pulse oximetry measurements are usually 99% to 100%. In addition, although methemoglobinemia patients are dusky, pale, or grayish, carbon monoxide–poisoned patients are pink and can appear to be well oxygenated. Table 26-1 describes the pulse oximetry, arterial blood gas, and co-oximetry differences among normal hemoglobin, carboxyhemoglobin, and methemoglobin.

![Using the carbon dioxide detector.](image)
Table 26-1 Oximetry Measurement Method Differences in Patients With Carbon Monoxide Poisoning and Methemoglobinemia

<table>
<thead>
<tr>
<th></th>
<th>Normal Hemoglobin</th>
<th>Carboxyhemoglobin 20%</th>
<th>Methemoglobin 20%</th>
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</thead>
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<tr>
<td><strong>Room Air (Normal Lungs)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH (ABG)</td>
<td>7.4</td>
<td>&lt;7.4</td>
<td>&lt;7.4</td>
</tr>
<tr>
<td>$P_{O_2}$ (ABG), mm Hg</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Calculated oxygen saturation (ABG), %</td>
<td>99</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>Color of blood (ABG)</td>
<td>Red</td>
<td>Red</td>
<td>Brown</td>
</tr>
<tr>
<td>Pulse oximetry oxygen saturation, %</td>
<td>99</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Co-oximetry oxygen saturation, %</td>
<td>99</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Clinical color</td>
<td>Pink</td>
<td>Pink</td>
<td>Dusky/gray</td>
</tr>
</tbody>
</table>

|                     |                   |                        |                   |
| **Supplemental Oxygen 50% $F_{O_2}$ (Normal Lungs)** |                   |                        |                   |
| pH (ABG)            | 7.4               | <7.4                   | <7.4              |
| $P_{O_2}$ (ABG), mm Hg | 350              | 350                    | 350               |
| Calculated oxygen saturation (ABG), % | 100              | 100                    | 100               |
| Color of blood (ABG) | Red               | Red                    | Brown             |
| Pulse oximetry oxygen saturation, % | 100              | 100                    | 90                |
| Co-oximetry oxygen saturation, % | 100              | 80                     | 80                |
| Clinical color      | Pink/red          | Pink/red               | Dusky/gray        |

**Abbreviations:** ABG, arterial blood gas; $F_{O_2}$, fraction of inspired oxygen.

gas analysis should be performed to confirm the accuracy of the ETCO$_2$ measurement.

New carbon dioxide detectors intended for use in the spontaneously breathing patient are becoming more available and can become an essential monitoring tool for patients undergoing procedural sedation and those who require continuous monitoring of their ventilation.

**Complications and Pitfalls**

The following conditions can result in capnometry measurements that are lower than the arterial P$_{CO_2}$. This occurs because capnometry requires the carbon dioxide to be exhaled for the device to detect or measure it. In conditions of reduced pulmonary blood flow or poor air exchange, exhaled P$_{CO_2}$ will be lower than the arterial P$_{CO_2}$. For example,

- Low cardiac output, severe hypotension, cardiac arrest (false readings)
- Severe airway obstruction (increases dead space)
- Severe parenchymal lung disease (increases dead space)

**Section 4: Oxygen Administration**

Supplemental oxygen is indicated for the treatment of documented hypoxemia. Although oxy-
gen is used liberally for other indications, there is scant evidence to support this practice. There are, however, several oxygen delivery devices, and each has its own indications and limitations.

**Equipment**
- Oxygen source (e.g., hospital gas system, oxygen cylinder)
- Oxygen delivery device (e.g., nasal cannula, mask, oxygen hood)

### 4.1 Nasal Cannula
This simple device consists of soft rubber tubing fitted with two small prongs, or nipples, intended to direct oxygen into the patient’s nares or at least enrich the oxygen concentration around the nares (Figure 26.11). These devices are available in a variety of sizes and have the advantage of being better tolerated than face masks. They have several disadvantages. Obviously, they are less useful in children with nasal obstruction. Likewise, less oxygen is delivered in the child who is crying excessively or mouth breathing. Finally, oxygen flow rates higher than 2 to 4 L/min are uncomfortable and might be poorly tolerated. Some children will have oxygen requirements that cannot be met by nasal cannula.

**Technique**
1. Choose the correct size for the patient.
2. Insert the nasal prongs into the anterior nares.
3. Drape the tubing behind the ears.
4. Consider securing the tubing to the patient’s face with tape.
5. Connect the distal end of the tubing to the oxygen source.

### 4.2 Oxygen Masks
Oxygen masks are clear plastic masks that fit over the mouth and nose (Figure 26.12). They provide more oxygen than a nasal cannula because they create a more closed system. With oxygen flow rates of 6 or more L/min, the patient will receive a fraction of inspired oxygen ($F_{\text{io}2}$) of 30% to 60%. These masks have exhalation ports and, depending on how well the mask fits, there might be spaces along the sides of the mask. These areas allow the patient to “entrain” room air with each breath and, therefore, dilute the inspired oxygen. Face masks are poorly tolerated by some children.

### 4.3 Nonrebreathing Masks
When a child requires an even higher concentration of oxygen, this can often be provided by a nonrebreathing mask (Figure 26.13). These devices are simple face masks with two important modifications. First, the exhalation ports have one-way valves so that the patient cannot inhale...
3. Connect the distal end of the tubing to the oxygen source.
4. The oxygen flow should be at least 6 L/min.
5. The reservoir bag might need to be unfolded and manipulated to inflate.

### 4.4 Oxygen Hoods

Oxygen hoods can deliver relatively high concentrations of oxygen without the discomfort sometimes associated with a face mask. They are generally used only in young infants because older children can easily remove them.

**Technique**

1. Assemble the hood (if necessary).
2. Ensure that the patient is in the supine position.
3. Place the hood over the patient’s head.
4. Connect the device to the oxygen source.
5. Monitor the patient’s oxygen saturation.

### Complications and Pitfalls

The most significant potential complication of emergency oxygen therapy lies in its misuse. Oxygen therapy is indicated for hypoxemia, not respiratory failure. To benefit from oxygen therapy, the patient must have adequate ventilatory effort. The patient with inadequate ventilatory effort might require oxygen therapy but will also require assisted ventilation. Another common error is the use of a self-inflating ventilation bag (discussed later) to deliver blow-by oxygen. This type of ventilation device has a one-way valve that prevents the delivery of oxygen to the mask unless the bag is squeezed (regardless of the oxygen flow rate into the tail of the device). Hospital oxygen delivery systems rarely fail, but oxygen tanks have a limited capacity. This capacity must be taken into consideration when planning treatment.

### Section 5: Suction

The airway can easily become occluded by secretions or foreign material, such as emesis or blood clots. The ability to clear these obstructions using the appropriate suction apparatus is criti-
Critical Procedures

Tracheal suction catheters of various sizes from 5/6 Fr to 14 Fr (Figure 26.16)

5.1 Suction

Indications and Equipment

1. Tonsillar tip suction tips—for the removal of solid materials, such as vomitus or blood clots, from the hypopharynx. Most stiff suction tips have several small holes at the tip that will not permit suctioning of solid debris. To suction solid material, a stiff suction tip with a large end hole must be used.

2. Nasogastric or orogastric tubes—for the removal of gastric secretions and air from the stomach. If not contraindicated, a nasogastric suction device should be placed in every intubated patient.

3. Tracheal suction catheters—these devices are used in combination with a saline wash to remove secretions and mucus from ETTs or tracheostomy tubes.

Contraindications

1. Avoid deep tonsillar tip suction in awake or lightly sedated patients to prevent gagging, emesis, or laryngospasm.

2. Avoid nasogastric tubes in cases of facial or cranial trauma (use the oral route instead).

3. Use caution when placing orogastric tubes in patients with suspected laryngeal, penetrating neck, or esophageal injury.

4. Avoid vigorous suctioning with tracheal suction catheters in patients with fresh surgical tracheostomies.

Equipment

- Tonsillar tip (stiff) adult- and pediatric-sized suction catheters (Most of these have several small holes at the tip. Some have a single large hole at the tip.) (Figure 26.14)

- Nasogastric or orogastric tubes of various sizes from 10 to 16 Fr, with connectors to suction tubing (Figure 26.15)
**Complications and Pitfalls**

1. If the suction device becomes completely occluded, then suctioning will fail. Whenever possible, use the adult Yankauer suction tip to avoid clogging the suction apparatus with large particles of debris or blood clots. A second stand-by suction apparatus is strongly encouraged. Ideally, this device should be a rigid-tipped suction device for the suctioning of larger debris. Also remember that the suction tubing can be used directly without the Yankauer tip if the tip becomes clogged with debris.

2. To function effectively, nasogastric or orogastric tubes must extend into the stomach. These tubes should be measured before placement.

3. Nasogastric or orogastric tubes can be unintentionally inserted into the trachea. Always check placement with auscultation immediately after placement.

4. Tracheal suctioning can produce significant hypoxemia. The patient should receive supplemental oxygen before the procedure begins and then be monitored throughout the procedure. The procedure should be limited to 15 seconds.

5. Tracheal suctioning can produce vagally mediated cardiovascular alterations and should be used judiciously with careful monitoring in the unstable patient.

6. All suctioning techniques can produce mucosal irritation. Overly vigorous suctioning, suctioning using very high suction pressure, and excessively frequent suctioning should be avoided.

**Section 6: Opening the Airway**

Under the right (or wrong) circumstances, difficulties in intubation and ventilation can occur in almost any patient. Some patients have anatomical features or other limitations that should be recognized as potential impediments to effective airway management before the administration of neuromuscular blocking agents. Although some children require immediate

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**Technique**

**Oral suctioning with tonsillar tip:**

1. Connect suction apparatus to wall suction or portable suction pump and adjust to medium, continuous pressure (not to exceed 300 mm Hg). If suctioning vomitus, the suction strength will need to be increased to high and a stiff suction tip with a larger hole will be necessary.

2. Preoxygenate patients by increasing oxygen delivery or manually ventilating them.

3. Open the mouth manually and sweep the suction tip across the oropharynx, under direct visualization.

4. Limit suctioning to 10 seconds per attempt or less, depending on the patient’s condition.

5. Reoxygenate the patient manually between attempts.

**Tracheal suctioning with ETT or tracheostomy tube:**

1. Connect suction apparatus to wall suction, adjust to low, continuous pressure (not to exceed 100 mm Hg).

2. Preoxygenate the patient by increasing oxygen delivery or manually providing ventilatory support to the patient.

3. Apply sterile gloves and open sterile suction setup.

4. Advance the sterile catheter beyond the distal tip of the ETT or tracheostomy tube without applying suction.

5. When the catheter can no longer be easily advanced, withdraw the catheter in a rotating manner while intermittent vacuum pressure is applied.

6. Limit vacuum suction time to 10 to 15 seconds.

7. Reoxygenate the patient manually immediately after suctioning.

8. Suctioning can be repeated as necessary. To loosen mucous plugs, inject 1 to 2 mL of sterile saline into the ETT between attempts.

9. After airway suctioning, the catheter can be used to suction oropharyngeal secretions.
Airway management, when time permits, it is prudent for the physician to perform a brief evaluation of the airway in an attempt to identify the presence of a “difficult airway.” This assessment can afford the physician an opportunity to use an alternative method of airway management and to avoid potential disaster. The assessment of the difficult airway is discussed thoroughly in Chapter 2, The Pediatric Airway in Health and Disease. Potential rescue airway devices are discussed later in this chapter.

The initial step for most children requiring urgent airway intervention will be a basic maneuver designed to relieve the airway obstruction that inevitably accompanies loss of tone in the upper airway. The two techniques that are commonly used are the chin-lift maneuver and the jaw-thrust maneuver.

6.1 Chin-Lift Maneuver

Indications
The chin-lift maneuver is indicated in children who have a depressed level of consciousness with concomitant upper airway obstruction and who have not sustained any trauma.15,16

Contraindications
Because this technique involves movement of the neck, it should not be performed in children who have sustained trauma, even if radiographs do not demonstrate a cervical spine fracture.

Technique
1. Verify unresponsiveness.
2. Place one hand on the forehead and the other on the mandible just lateral to the chin.
3. Gently depress the forehead with one hand to extend the neck while simultaneously lifting the chin anteriorly with the other. Classically, this technique is performed by placing the fingers of the dominant hand beneath the patient’s chin and then lifting the chin anteriorly and caudally. In some cases, it might be necessary to firmly grasp the chin and/or skin or to use the lip or teeth to gain the appropriate mechanical advantage. If the latter technique is used, care must be exercised to ensure that the patient is indeed unconscious and unable to bite the rescuer. Hyperextension of the neck should be avoided in infants and young children (Figure 26.17).

4. Confirm adequate ventilation by looking for chest wall rise, by feeling for exhaled air, and by auscultation.

Figure 26.17 The chin-lift maneuver should be used to place the airway in a neutral position.

Complications and Pitfalls
The chin-lift maneuver can cause or exacerbate cervical spine injury and should not be used in those who have sustained trauma. Hyperextension of the neck in infants and young children can cause, rather than relieve, airway obstruction.

6.2 Jaw-Thrust Maneuver

Indications
The jaw-thrust maneuver is indicated when the movement of the patient’s neck is impossible or imprudent (Figure 26.18).15,16

Contraindications
There are no contraindications to this technique; however, it might be ineffective in children with significant mandibular injuries.

Technique
1. Without moving the neck, place both hands at the mandibular angle and push the mandible anteriorly. This is commonly done by using the maxilla/zygoma or forehead region for leverage.
2. Confirm adequate ventilation by looking for chest wall rise, by feeling for exhaled air, and by auscultation.
Indications
Oropharyngeal airways are indicated for relieving upper airway obstruction, serving as a “bite block” to protect the ETT, and facilitating oral and pharyngeal suctioning.

Contraindications
Oropharyngeal airways should not be used in conscious or semiconscious patients (including lightly sedated or anesthetized patients) who have intact protective airway reflexes. When used in these patients, oropharyngeal airways can cause gagging, vomiting, or catastrophic laryngospasm or bronchospasm. Nasopharyngeal airways are generally better tolerated in awake or semiconscious patients. Do not use either type of airway in cases of suspected foreign body aspiration.

Equipment
- Properly sized oral airway (available in sizes 55 to 90 mm)—to estimate size, place the airway on the patient’s cheek. With the flange at the level of the lips, the distal pharyngeal tip should be at the angle of the mandible (Figure 26.20).

Technique
1. Select the appropriately sized oropharyngeal airway.
2. Suction the oral cavity if indicated.
3. Open the mouth and place a tongue blade at the base of the tongue.
4. Depress and pull the tongue forward with the tongue blade, lifting it off the posterior pharyngeal wall.
5. Insert the airway, leaving 1 to 2 cm protruding beyond the incisors.

Complications and Pitfalls
Movement of the neck should be avoided.

Section 7: Airway Adjuncts
Oropharyngeal airways and nasopharyngeal airways provide a mechanical stent that relieves soft tissue obstruction from the mouth to the glottis (oral airway) or from the nasal opening to the glottis (nasal airway). They can be used in intubated and nonintubated patients. These airways are important in overcoming proximal airway obstruction for effective spontaneous and bag-mask-assisted ventilations.11

7.1 Oropharyngeal Airways
Oropharyngeal airways are rigid, semicircular tubes (or sometimes H-shaped in cross-section) with a central lumen (Figure 26.19). They can be used in intubated and nonintubated patients. In intubated patients, they serve to protect the ETT from being crushed between the patient’s upper and lower jaws.

Figure 26.18 The jaw-thrust maneuver should be used in a child with possible spinal injury.

Figure 26.19 Different sizes of oropharyngeal airways.

Figure 26.20 An oropharyngeal airway should be placed next to the face, with the flange at the level of the central incisors and the bite block segment parallel to the hard palate.
6. To complete the insertion, perform a jaw-thrust maneuver with the fingers until the flange is even with the lips.
7. Relax the jaw thrust.
8. Check that the tongue and lips are not caught between the teeth and the airway.

Alternative Technique
1. Select the appropriately sized oropharyngeal airway.
2. Suction the oral cavity if indicated.
3. Open the mouth and insert the oral airway such that the curved portion of the device depresses the tongue.
4. Rotate the airway 180° into position, leaving 1 to 2 cm protruding beyond the incisors.
5. To complete the insertion, perform a jaw-thrust maneuver with the fingers until the flange is even with the lips.
6. Relax the jaw thrust.
7. Check that the tongue and the lips are not caught between the teeth and the airway.

Complications and Pitfalls
The oropharyngeal airway must be appropriately sized to function properly. An oral airway that is too large can obstruct the airway and might stimulate potentially lethal laryngospasm and/or bronchospasm. Conversely, an oral airway that is too small will push the tongue base posteriorly into the pharynx, worsening the airway obstruction (Figure 26.21).

7.2 Nasopharyngeal Airways
A nasopharyngeal airway is a soft rubber or plastic tube that provides a mechanical stent to relieve soft tissue obstruction from the nares to the glottis (Figure 26.22).11

Indications
Nasopharyngeal airways can be used in awake or lightly sedated patients when airway obstruction is not relieved with an oropharyngeal airway alone (eg, large adenoids, swollen tonsillar tissues) and in patients with trismus when placement of an oral airway device is difficult or impossible (eg, status epilepticus).
**Contraindications**

The following are contraindications to nasopharyngeal airway placement:

1. Trauma with suspected nasal or basilar skull trauma or midface fractures
2. Coagulopathy (epistaxis)
3. Prior history of nasal facial surgery (eg, cleft palate repair)
4. Adenoid hypertrophy
5. Suspected foreign body aspiration

**Equipment**

- Properly sized nasal airway (available in sizes 16 Fr through 34 Fr)—to estimate size, place the nasopharyngeal airway at the tip of the nose. A properly sized tube will extend to the tragus of the patient’s ear (Figure 26.23). A shortened ETT can also be used as a nasal airway.

**Figure 26.23** The nasopharyngeal airway should be placed next to the face and measured from the tip of the nose to the tragus of the ear.

**Technique**

1. Select an appropriately sized nasopharyngeal airway.
2. Suction the nares if indicated.
3. Lubricate the airway with water-soluble lubricant.
4. Hold the tube between the thumb and the first two fingers of the dominant hand and insert it into the nostril with the bevel facing the patient’s nasal septum.
5. On the right:
   a. Pass the tube along the floor of the nasal passage “downward” (ie, do not aim it upward) toward the posterior pharynx using slow, gentle, steady pressure.
   b. If resistance is felt in the posterior nasopharynx, a gentle anterior-posterior, back-and-forth motion of the nasal airway a few millimeters in each direction or a gentle rotation in a clockwise or counterclockwise direction while advancing will help in passing the tube.
   c. If continued resistance is felt, remove the tube and attempt placement in the opposite nostril. Consider the need for a smaller tube.
6. On the left:
   a. Insert the tube with the bevel toward the septum. The nasopharyngeal airway will be pointed upward and resistance will be felt at 1 to 2 cm.
   b. Rotate the airway 180° into position with the flange resting against the base of the nostril (Figure 26.24).

**Figure 26.24** For the left nostril, the nasopharyngeal airway should be initially inserted with the curvature upward until resistance is felt (approximately 2 cm), then the device should be rotated 180° and advanced until the flange is against the outside of the nostril.

**Complications and Pitfalls**

The nasal airway must be appropriately sized to function properly.

**Section 8: Bag-Mask Ventilation**

Because resistance to gas flow through a tube increases to the fourth power as the lumen becomes smaller, infants and children have higher baseline airway resistance than adults. They also experience substantially greater increases in resistance with the same amount of airway narrowing (edema, obstruction). Furthermore, the respiratory...
muscles (intercostals and diaphragm) of infants and children have fewer fatigue-resistant fibers than adults and thus tire (fail) more rapidly.

These characteristics, combined with the rarity of cardiac disease in pediatric patients, account for the fact that most episodes of cardiac arrest in children are secondary events after (primary) respiratory failure and arrest. In adults, cardiac arrest is usually a primary process resulting from ischemia. This is perhaps the most fundamental difference in terms of resuscitation between pediatric and adult patients. For this reason, bag-mask ventilation (BMV) is a crucial skill in managing pediatric arrests. In addition, although emergent endotracheal intubation will be performed in the ED by physicians, BMV serves as the initial method to maintain ventilation and the method of choice if endotracheal intubation is unsuccessful. Many types of health care professionals (nurses, respiratory therapists, physician assistants) might be called on to perform BMV in a pediatric resuscitation.17,18

8.1 Bag-Mask Ventilation

Indications
Indications for BMV include all circumstances in which assisted or controlled ventilation is required. The list of potential causes is long and involves a diversity of mechanisms, such as neurologic causes (diffuse axonal injury, herniation syndromes), infectious causes (sepsis, meningitis), upper airway causes (anaphylaxis, thermal injury), and lower airway causes (pneumonia, asthma, pulmonary contusion), among many others. There are few contraindications to this procedure. Relative contraindications include conditions that make performing effective BMV extremely difficult or impossible, such as severe facial or mandibular injuries or complete upper airway obstruction from a foreign body. If the patient has a known pneumothorax, BMV should only be performed for a brief period before decompression of the affected hemithorax is performed to avoid precipitating a tension pneumothorax. The two absolute contraindications to BMV are meconium in a depressed newly born infant and known diaphragmatic hernia, which both require immediate endotracheal intubation.

Equipment
- Manual resuscitator (self-inflating or gas inflated)
- Appropriately sized masks

The most important difference in BMV setups is determined by the type of resuscitation bag used, that is, a self-inflating bag (manual resuscitator) vs a standard anesthesia bag (also known as the Rusch bag). As the name implies, a self-inflating bag is designed to reinflate automatically after being compressed and released during BMV. Although this might make the procedure somewhat easier to perform, rapid reexpansion of the bag with each ventilation allows entrainment of ambient air, even when an oxygen reservoir is used, thereby decreasing the concentration of oxygen delivered to the patient. This disadvantage is also an advantage. Because self-inflating bags are not dependent on an external gas source, they will continue to function even when the oxygen tank is depleted. This allows the patient to receive ventilation, albeit with room air, until the oxygen tank can be replaced (Figure 26.25).

Figure 26.25 A self-inflating bag.

By contrast, an anesthesia bag will inflate only if there is sufficient oxygen inflow, a closed system is maintained (good mask seal), and the adjustable pressure leak valve is set appropriately (Figure 26.26). Although these requirements make BMV more complicated, failure of the bag to reexpand provides a valuable indication that a significant problem exists and must be corrected. Such problems (eg, depletion of an oxygen tank or a poor mask seal) do not prevent reexpansion of a self-inflating resuscitation bag and might therefore go undetected.
Basic airway management is especially relevant in the ED because BMV circuits with self-inflating bags are used by out-of-hospital and emergency personnel far more commonly than anesthesia bag circuits. For this reason, only the use of self-inflating bag circuits is described here.

**Technique**

As with most aspects of pediatric advanced life support, performing BMV in an infant or child begins with the ABCs (airway, breathing, circulation). First, determine whether the child requires BMV using the “look, listen, and feel” method if necessary. Look at the chest wall for any respiratory effort and/or signs of respiratory distress (belly breathing, retractions). Listen, with one ear close to the child’s nose and mouth, for any air movement. Feel, with one cheek close to the child’s nose and mouth, for any air movement. These steps might not be necessary, as with a child in cardiac arrest, but they can be useful in many circumstances. This aspect of the assessment should take at most only a few seconds.

If the child is not moving adequate air, position the head and neck so that the upper airway is most likely to be patent. This is generally best accomplished by flexing the neck slightly and rotating the head upward in a “sniffing position” (Figure 26.27). For patients with no risk of neck trauma, use the chin-lift maneuver to open the airway. For trauma patients, use the jaw-thrust maneuver to reduce neck movement. If necessary, place a small pad under the patient’s head to produce neck flexion. This will not usually be required with young infants because they have a relatively large occiput, which causes neck flexion whenever they are supine on a firm, flat surface. In infants it might be necessary to place a small towel under the shoulders to level the plane of the airway.

If the patient continues to have inadequate respirations after appropriate airway maneuvers, BMV should be started.

First, the smallest mask that completely covers the nose and mouth should be selected. A mask that is too large will compress the eyes, causing injury and/or bradycardia. A mask that is too small will make it impossible to establish and maintain an adequate mask seal on the face. The mask should be measured from the bridge of the nose to the cleft of the chin.

Next, a bag that is appropriately sized for the patient should be selected. It is always possible to ventilate with a bag that is too large—and never possible with one that is too small.

A change to a better size bag or mask can be made, even during the procedure, if this seems...
Airway management is crucial for all resuscitations. The physician should not make the mistake of using improperly sized equipment. The mask should be applied to the face with the nondominant hand while the head and neck are positioned optimally to maintain airway patency. The index finger and thumb gently compress the mask onto the face (C-grip), and the 3rd, 4th, and 5th fingers are placed on the angle of the jaw, forming an “E.” The entire hand placement for BMV is called the EC clamp. The fingers on the jaw should pull the patient’s chin into the mask, creating a good mask seal. The resuscitation bag should be compressed with the dominant hand at an age-appropriate rate (Figure 26.28). It is helpful to control the rate and volume by saying, “Squeeze, release, release.” Squeeze the bag just until chest rise is initiated and then release.

It might be preferable to use a two-person technique in which one person uses both hands to apply the mask using the EC clamp and the other person compresses the bag. If two individuals perform BMV, the more experienced person should generally apply the mask and maintain the airway while the other person compresses the resuscitation bag. Optionally, an available assistant can apply cricoid pressure (Sellick maneuver), taking care not to use excessive force that can cause airway obstruction.

The patient should be carefully monitored at all times while performing BMV. The bag should be compressed so that the patient’s chest excursions approximate a normal deep inspiration. Once chest rise is visible, enough volume has been delivered to the patient, so the bag should be slowly released. Less than this will not provide an adequate tidal volume; more will cause air entry into the stomach, increasing the risk of vomiting and aspiration. The heart rate and, if available, pulse oximetry and/or capnometry should be monitored to ensure that the procedure is being properly performed. Bradycardia, hypoxia, and hypercapnia are all possible indications of poor technique.

Complications and Pitfalls
The most common serious complication that occurs with BMV is aspiration pneumonitis. Patients who require BMV often have diminished or absent protective airway reflexes and, in the out-of-hospital and ED settings, a full stomach. Unlike endotracheal intubation, BMV does not provide protection against aspiration of gastric contents into the lungs. The risk of this complication can be reduced by minimizing air entry into the stomach. This is best accomplished by providing ventilatory support to the patient with an appropriate tidal volume (ie, monitoring chest excursions) and can also be aided by applying cricoid pressure, although the use of cricoid pressure can increase airway resistance and consequently decrease the efficiency of BMV ventilation. The other serious complication associated with BMV (or any other method of positive pressure ventilation) is barotrauma, resulting in a pneumothorax and, potentially, a pneumomediastinum.

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tension pneumothorax. The likelihood of this complication can be reduced by carefully monitoring chest wall excursions to avoid administering excessive tidal volumes. Finally, minor and generally self-limited complications include eye injury due to compression with the mask, facial nerve neurapraxia caused by excessive pressure on the mask, and allergic reactions resulting from contact with the materials used to manufacture the mask.

Section 9: Management of Upper Airway Foreign Bodies With Magill Forceps

Treatment of the patient with a foreign object occluding, or partially obstructing, the upper airway is dependent on several factors. If the child is awake and has evidence of partial airway obstruction (eg, stridor), then the best course of action will almost certainly be to administer high-flow oxygen or a helium-oxygen mixture, allow the patient to find a comfortable position, and transport the child to a location where the object can be removed by those with the most expertise under controlled circumstances. On the other hand, the child with impending respiratory failure or complete airway obstruction must be treated immediately.

Dependent on age, such children should be treated with back blows and chest thrusts for infants (<12 months of age) or the Heimlich maneuver or abdominal thrusts for children (>1 year of age). When these techniques have failed and the patient has lost consciousness, the next step in the treatment algorithm is attempted removal of the object using direct laryngoscopy and Magill (or other) forceps.

9.1 Management of Upper Airway Foreign Bodies With Magill Forceps

Equipment
- Laryngoscope
- Magill forceps (Figure 26.29) (If Magill forceps are not available, other forceps or clamps can be substituted. In fact, it is wise to have a variety of tools available, including suction devices and gynecologic tenacula so that oddly shaped or slippery objects can be grasped.)
- Equipment for airway management, including ETTs
- Equipment for surgical airway

Technique
1. Open the mouth and insert the laryngoscope as described for endotracheal intubation.
2. Using the light from the laryngoscope, attempt to visualize the foreign object.
3. If the object cannot be seen, have an assistant administer abdominal thrusts in an attempt to bring the object into view.
4. Once the object is visualized, grasp it with the forceps and remove it from the upper airway. Some objects can be difficult to grasp. In such cases, consider a different tool or a suction device (Figure 26.30).
5. If the patient does not begin breathing spontaneously, proceed with appropriate airway management.
6. If the object cannot be visualized or removed, the clinician has further options:
   a. Attempt to pass an ETT and, in so doing, force the object further into the airway so that it enters one mainstem bronchus, leaving the other open.
   b. Perform a surgical airway, bypassing the occlusion, or
   c. Perform repeated basic maneuvers to dislodge a foreign body in the esophagus or one below the level of the vocal cords.
Critical Procedures

Complications and Pitfalls
This technique should generally be reserved for unconscious patients with complete airway obstruction. Attempted removal of objects in awake patients with partial airway obstruction can dislodge the object and cause complete occlusion of the airway. Blind attempts to grasp objects can damage the vocal cords and cause bleeding, which makes further efforts to visualize objects more difficult.

Section 10: Emergent Intubation
There is perhaps no procedure more important in pediatric resuscitation than endotracheal intubation. For the child who is not adequately breathing, the most immediate priority is always establishing a stable airway, and the definitive method of accomplishing this is endotracheal intubation. The methods involved with performing this procedure can be broadly divided into two categories depending on the clinical circumstances: emergent and nonemergent (elective). Although the goal in both situations is the same (successful insertion of a tube into the trachea), the challenges that the clinician will confront differ substantially. Elective intubations, such as those for scheduled procedures in the operating room, are performed in patients who are hemodynamically stable, have an empty stomach, and have previously been evaluated for any potential airway problems.

With emergent intubations, which are most commonly performed in the ED and out-of-hospital settings, patients are usually acutely ill and often rapidly deteriorating. They must always be presumed to have a full stomach, putting them at much greater risk for vomiting and aspiration of stomach contents. The clinician is rarely afforded a prior opportunity to carefully assess the patient's airway anatomy to identify possible impediments to intubation. Many clinicians who perform emergent intubations in adult patients with great confidence and expertise become extremely anxious when the same procedure must be performed in a child.

Although there are important differences between adults and children that must be understood when performing this procedure, the similarities far outnumber the differences. Some of the most problematic characteristics of adults are rarely if ever present in children (morbid obesity, beards, arthritic cervical vertebrae, false teeth). With proper training and experience, emergency personnel can develop a high level of skill and proficiency in performing this procedure, using the same careful, systematic approach used for other complex emergency procedures.

10.1 Endotracheal Intubation
Indications
Indications for this procedure are similar to those for BMV. As such, the list of potential indications for emergent endotracheal intubation in children is a long one, encompassing virtually all causes of acute respiratory compromise that affect the pediatric population. However, it is useful to consider how the indications and contraindications for these two procedures differ to better understand the unique aspects of endotracheal intubation.

For example, unlike BMV, which delivers positive pressure ventilation to the entire upper airway, endotracheal intubation also protects the airway so that entry of secretions and stomach contents into the lungs is minimized. This is one reason why tracheal succioning is indicated and BMV is contraindicated for the treatment of the depressed, newly born infant after meconium delivery—the presence of a properly positioned ETT prevents further soilage of the lungs.

Another major difference between BMV and endotracheal intubation is that an ETT
delivers air only to the lungs, whereas BMV almost always causes air entry into the lungs and the stomach. This is why patients with respiratory distress resulting from a diaphragmatic hernia should undergo immediate endotracheal intubation and should not receive BMV. If the stomach herniates into the chest cavity, a “ball valve” effect can occur, allowing air to enter but not escape. As the stomach progressively expands and displaces the lung, respiratory distress worsens, and the patient can develop tension physiology (similar to a tension pneumothorax). Bag-mask ventilation, which forces more air down the esophagus and into the stomach, exacerbates this effect. In children requiring ventilatory support for other reasons, excessive air entry into the stomach increases the likelihood of vomiting and aspiration and can impede expansion of the chest wall.

Thus, although BMV can be effectively used as a temporizing measure, emergent endotracheal intubation is indicated for any child requiring assisted or controlled ventilation for a more prolonged period. In addition, emergent intubation is indicated for airway protection (eg, depressed mental status) and to provide direct access to the trachea to facilitate pulmonary hygiene and clearance of secretions.

**Equipment**

In children younger than 8 years, the narrowest point along the trachea is not at the vocal cords (as with adults) but at the cricoid ring. With adults, the largest ETT that can pass through the cords is still small relative to the subglottic diameter of the trachea. For this reason, a balloon (cuff) is needed to fill the surrounding space. This prevents a large air leak (air flowing out into the hypopharynx instead of into the lungs), which would significantly limit effective administration of positive pressure ventilation. By contrast, a properly sized tube for a younger child will pass through the cords and then wedge in position at the cricoid ring, preventing any significant air leak without the use of a cuff. For this reason, uncuffed ETTs are generally used in emergency settings for younger patients (usually 8 years and younger) (Figure 26.31). However, cuffed tubes might be appropriate even for children younger than 8 years if high inspiratory pressures are required, as with a patient who has greatly diminished lung compliance (eg, a near-drowning). With higher pressures, a large air leak will often occur despite having an uncuffed tube that fits properly. Use of a cuffed tube in such situations should only be a temporizing measure because excessive pressure on the wall of the trachea for prolonged periods can lead to the development of subglottic stenosis.

Another important decision regarding equipment when performing an emergent endotracheal intubation involves choosing a laryngoscope blade (Figure 26.32). For both children and adults, selecting the correct laryngoscope blade involves asking whether a straight or curved blade should be used and which size is right for the patient. With adults, curved (Macintosh) laryngoscope blades are preferred by most clinicians because these blades are comparatively easy to use. Except in rare cases, visualization of the vocal cords is readily accomplished by simply inserting the blade tip into the vallecula and pulling upward on the laryngoscope handle. This approach causes tension in the hyoepiglottic ligament, which in turn retracts the epiglottis and thereby reveals the cords. Use of a straight blade for an adult is generally reserved for the patient who is anticipated to have an especially difficult airway or when laryngoscopy with a curved blade has failed.

Conversely, a curved laryngoscope blade is not recommended for use in children younger than 8 years because of two important characteristics of the immature airway: greatly increased laxity of the hyoepiglottic ligament and a relatively large, floppy epiglottis. In these younger patients, inserting the tip of a curved
Critical Procedures

10.2 Rapid Sequence Intubation

Rapid sequence intubation (RSI, also known as rapid sequence induction) is the process of administering a sedative and muscle relaxant (inducing pharmacologic flaccid paralysis) to facilitate the process of endotracheal intubation. There are three major advantages of RSI as follows:

- Rapid sequence intubation creates a controlled clinical environment to facilitate endotracheal intubation in pediatric patients who are frightened, anxious, and uncooperative. It also provides rapid onset of unconsciousness and muscle relaxation.
- The combination of anesthetic agents and neuromuscular blockade used in RSI decreases the stimulation of potentially harmful autonomic reflexes associated with endotracheal intubation and their associated adverse effects (e.g., elevated intracranial pressure, hypertension, bradycardia).
- Rapid sequence intubation with optional cricoid pressure minimizes risks for pulmonary aspiration during intubation. The effectiveness of RSI depends on the rapid intravenous administration of two drugs—an anesthetic and a neuromuscular blocking agent administered sequentially.21,22

Indications

Rapid sequence intubation is indicated for most patients who will undergo emergent endotracheal intubation.

Contraindications

Rapid sequence intubation should be attempted with caution, if at all, in patients who might have difficult airways. Once the neuromuscular blocking agent has been administered, the patient will be irreversibly paralyzed for at least a few minutes. In addition, RSI should be used with caution in children who have a history or a family history of untoward reactions to anesthetic agents. Although not contraindicated, RSI might be unnecessary in patients who are unconscious.

Equipment

Making sure you have all essential equipment in place can best be aided by the mnemonic SOAP-ME (suction, oxygen, airway equipment, pharmacology, and monitoring equipment). The essential airway equipment is listed in Table 26-2. This equipment must be immediately available and known to be functioning properly before the RSI agents are administered. All equipment must be available in the appropriate size(s) for the patient.

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TABLE 26-2 Airway Equipment for Rapid Sequence Intubation

- Ventilation face masks
- Ventilation bags
- Oropharyngeal airways (with tongue blades)
- Nasopharyngeal airways (with lubrication gel)
- Endotracheal tubes (with syringes for the cuff)
- Stylets
- Laryngoscope handles
- Laryngoscope blades
- Magill forceps

Difficult Airway Equipment
- Laryngeal mask airway
- Combitube (16 years or older)
- Gum elastic bougie (or other airway guide 14 years or older)
- Specialized laryngoscopes
- Lighted stylet

Surgical Airway Equipment
- Transtracheal ventilation equipment

Pharmacologic Agents
Many pharmacologic agents are useful in the performance of RSI. Tables 26-3 through 26-5 provide information about the advantages and disadvantages of each agent. The actual agents used by an individual physician will likely be dictated by availability, institutional policy, familiarity, and clinical advantages and disadvantages of each agent with respect to the clinical requirements of the patient.

KEY POINTS

Performing RSI
- Select patient who will benefit from the procedure.
- Prepare equipment (SOAP-ME).
- Monitor the patient.
- Administer appropriate sedation based on the patient’s clinical status:
  - hypotension—etomidate
  - status asthmaticus—ketamine
  - head injury—thiopental or etomidate
- Administer appropriate neuromuscular blocking agent—succinycholine vs rocuronium.
- Perform endotracheal intubation.
- Perform clinical assessment and use ETCO, monitor or detector to confirm endotracheal intubation.

TABLE 26-3 Sedative Agents

<table>
<thead>
<tr>
<th>Agent</th>
<th>Dose</th>
<th>Onset</th>
<th>Duration</th>
<th>Benefits</th>
<th>Caution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etomidate</td>
<td>0.3 mg/kg</td>
<td>&lt;1 min</td>
<td>10-20 min</td>
<td>Lowers ICP, lowers IOP, supports BP</td>
<td>Myoclonic excitation, vomiting</td>
</tr>
<tr>
<td>Ketamine</td>
<td>1-2 mg/kg</td>
<td>1 min</td>
<td>5 min</td>
<td>Bronchodilator, dissociative amnesia</td>
<td>Increases secretions, increases ICP, possible emergence reactions</td>
</tr>
<tr>
<td>Midazolam</td>
<td>0.1 mg/kg</td>
<td>1-2 min</td>
<td>20-30 min</td>
<td>Reversible, amnestic, anticonvulsant</td>
<td>Apnea, variable dose</td>
</tr>
<tr>
<td>Thiopental</td>
<td>3-5 mg/kg</td>
<td>30-40 s</td>
<td>10-30 min</td>
<td>Lowers ICP</td>
<td>Hypotension, laryngospasm</td>
</tr>
</tbody>
</table>

Abbreviations: BP, blood pressure; ICP, intracranial pressure; IOP, intraocular pressure.
Critical Procedures

Management

The discussion regarding selection of sedatives, neuromuscular blocking agents, and adjunctive agents can be rather involved, but it can be broken down into three basic categories: head injury without hemodynamic compromise, status asthmaticus, and any condition with hemodynamic compromise. By examining the benefits and cautions of each sedative, the following can be determined: etomidate is useful for head injury without hemodynamic compromise; ketamine is useful for status asthmaticus; and etomidate, ketamine, and midazolam are the least likely to compromise blood pressure in the hemodynamically compromised patient. (However, consider that no sedative might be preferable if the degree of hemodynamic compromise is severe.)

The choice of neuromuscular blocking agent comes down to physician preferences for onset time, duration, and adverse effects. When comparing the nondepolarizing neuromuscular blocking agents, rocuronium is the most useful. Succinylcholine (suxamethonium) has the fastest onset and shortest duration. Rocuronium has a slower onset and a longer duration but it has a lower risk of adverse effects.

---

### TABLE 26-4 Neuromuscular Blocking Agents—Succinylcholine (Suxamethonium)

<table>
<thead>
<tr>
<th>Adult Dose</th>
<th>Infant/Child Dose</th>
<th>Onset</th>
<th>Duration</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1.5 mg/kg</td>
<td>1.5-2 mg/kg</td>
<td>30-60 s</td>
<td>3-8 min</td>
<td>Rapid onset, short duration</td>
</tr>
</tbody>
</table>

**Complications of succinylcholine**

- Bradyarrhythmias
- Increased intragastric, intraocular, and intracranial pressure
- Hyperkalemia
- Fasciculation induced musculoskeletal trauma
- Masseter spasm
- Malignant hyperthermia
- Prolonged apnea with pseudocholinesterase deficiency
- Histamine release
- Cardiac arrest

Atropine, 0.01-0.02 mg/kg (minimum, 0.1 mg; maximum, 0.4 mg) (child)—use prior to succinylcholine if younger than 5 years to prevent bradycardia.

### TABLE 26-5 Neuromuscular Blocking Agents—Nondepolarizing Agents

<table>
<thead>
<tr>
<th>Agent</th>
<th>Dose</th>
<th>Onset</th>
<th>Duration</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocuronium</td>
<td>0.6-1 mg/kg</td>
<td>1-3 min</td>
<td>Intermediate, 30-45 min</td>
<td>Tachycardia</td>
</tr>
<tr>
<td>Vecuronium</td>
<td>0.08-0.15 mg/kg or 0.15-0.28 mg/kg (high dose)</td>
<td>2-4 min</td>
<td>Intermediate/long, 25-40 min or 60-120 min (high dose)</td>
<td>Prolonged recovery in obese patients and those with hepatorenal dysfunction</td>
</tr>
<tr>
<td>Atracurium</td>
<td>0.4-0.6 mg/kg</td>
<td>2-3 min</td>
<td>Intermediate, 25-45 min</td>
<td>Histamine release, hypotension, bronchospasm</td>
</tr>
<tr>
<td>Mivacurium</td>
<td>0.15-0.2 mg/kg</td>
<td>2-3 min</td>
<td>Short, 10-20 min</td>
<td>Histamine release</td>
</tr>
</tbody>
</table>

**Adjuvante Medications**

- Atropine, 0.4-0.6 mg (adolescent), to reduce secretions.
- Atropine, 0.01-0.02 mg/kg (minimum, 0.1 mg; maximum, 0.4 mg) (child)—optional use if younger than 5 years to prevent bradycardia.
- Lidocaine (lignocaine), 1.5 mg/kg intravenously—can be beneficial in head trauma patients to reduce intracranial pressure.
### TABLE 26-6  Rapid Sequence Intubation Drugs, Doses (mg), Sizes, and Distances

<table>
<thead>
<tr>
<th>Age</th>
<th>2 m</th>
<th>6 m</th>
<th>1 y</th>
<th>3 y</th>
<th>5 y</th>
<th>7 y</th>
<th>9 y</th>
<th>11 y</th>
<th>12 y</th>
<th>14 y</th>
<th>16 y</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average weight, kg</td>
<td>5</td>
<td>8</td>
<td>10</td>
<td>15</td>
<td>19</td>
<td>23</td>
<td>29</td>
<td>36</td>
<td>44</td>
<td>50</td>
<td>58</td>
<td>65</td>
</tr>
</tbody>
</table>

### Preoxygenation

Adjunctive agents (optional):

<table>
<thead>
<tr>
<th>Drug</th>
<th>2 m</th>
<th>6 m</th>
<th>1 y</th>
<th>3 y</th>
<th>5 y</th>
<th>7 y</th>
<th>9 y</th>
<th>11 y</th>
<th>12 y</th>
<th>14 y</th>
<th>16 y</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atropine (0.01-0.02 mg/kg)</td>
<td>0.1</td>
<td>0.15</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Use in all children or with ketamine.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lidocaine (lignocaine) (1.5 mg/kg)</td>
<td>8</td>
<td>12</td>
<td>15</td>
<td>22</td>
<td>28</td>
<td>35</td>
<td>44</td>
<td>54</td>
<td>66</td>
<td>75</td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>

### Sellick maneuver

Sedative

Hypotension or head trauma

<table>
<thead>
<tr>
<th>Drug</th>
<th>2 m</th>
<th>6 m</th>
<th>1 y</th>
<th>3 y</th>
<th>5 y</th>
<th>7 y</th>
<th>9 y</th>
<th>11 y</th>
<th>12 y</th>
<th>14 y</th>
<th>16 y</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etomidate (0.3 mg/kg)</td>
<td>1.5</td>
<td>2.4</td>
<td>3.0</td>
<td>4.5</td>
<td>6</td>
<td>7</td>
<td>9</td>
<td>11</td>
<td>13</td>
<td>15</td>
<td>17</td>
<td>20</td>
</tr>
</tbody>
</table>

### Status asthmaticus:

<table>
<thead>
<tr>
<th>Drug</th>
<th>2 m</th>
<th>6 m</th>
<th>1 y</th>
<th>3 y</th>
<th>5 y</th>
<th>7 y</th>
<th>9 y</th>
<th>11 y</th>
<th>12 y</th>
<th>14 y</th>
<th>16 y</th>
<th>Adult</th>
</tr>
</thead>
</table>

### Paralyzing agent:

<table>
<thead>
<tr>
<th>Drug</th>
<th>2 m</th>
<th>6 m</th>
<th>1 y</th>
<th>3 y</th>
<th>5 y</th>
<th>7 y</th>
<th>9 y</th>
<th>11 y</th>
<th>12 y</th>
<th>14 y</th>
<th>16 y</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Succinylcholine (suxamethonium) (1.0–1.5 mg/kg)</td>
<td>8</td>
<td>12</td>
<td>15</td>
<td>25</td>
<td>30</td>
<td>40</td>
<td>50</td>
<td>55</td>
<td>60</td>
<td>65</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>Rocuronium (0.6–1.0 mg/kg)</td>
<td>4</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>60</td>
</tr>
</tbody>
</table>

Intubate (tube size) | 3.5 | 3.5 | 4.0 | 4.5 | 5.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.0 female, 8.0 male |
Tube depth at lip, cm | 11 | 12 | 13 | 14 | 15 | 16 | 18 | 19 | 20 | 22 | 22 | 22 |
Laryngoscope blade size | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3–4 |

Abbreviation: ICP, intracranial pressure.
Critical Procedures

26-32

Technique

1. While personnel, equipment, and pharmacologic agents are being assembled and intravenous access is being obtained, the patient should receive high-flow oxygen through a nonrebreather mask. The objective is to completely saturate all available hemoglobin binding sites so that the patient can tolerate a protracted period of apnea if necessary.

2. Briefly assess the patient for a potentially difficult airway (see Chapter 2, The Pediatric Airway in Health and Disease).

3. Prepare all equipment.

4. Secure vascular access and monitor the patient.

5. Administer atropine if indicated.

6. Administer the sedative agent.

7. Administer any adjunctive agents (eg, lidocaine [lignocaine]) if indicated.

8. Administer the neuromuscular blocking agent while an assistant holds optional cricoid pressure (Sellick maneuver).


The first aspect of preparing the patient is usually preoxygenation. When time and circumstances permit, the patient should always be preoxygenated using 100% oxygen, either by having the patient breathe spontaneously through a nonrebreather face mask or, if necessary, by administering assisted or controlled BMV. Effective preoxygenation allows the longest period of “safe” apnea (ie, the patient does not develop hypoxemia), which provides the greatest amount of time for the clinician to perform laryngoscopy and tube insertion. The patient should be confirmed to have a reliable means of intravenous access so that RSI medications can be administered if needed. The patient should be positioned close to the head of the bed and the bed raised or lowered to a comfortable height for performing the procedure.

Next all the necessary equipment should be ensured to be easily accessible and functioning properly. The ETT most likely to be the correct size for the patient should be selected, and because this is only an estimate, two additional tubes (one size smaller and one size larger) should be readily available. To determine the appropriate ETT size, Table 26-6, the formula (age/4) + 4, or a length-based system such as the Broselow tape should be used.\(^20,23,24\)

The laryngoscope blade should be attached to the handle and snapped into position to verify that the light on the blade is working and bright. If a cuffed tube is to be used, the balloon should be checked for easy inflation and lack of air leaks. Any drugs that might be needed to be drawn up in syringes should be asked for and the appropriate dosages confirmed. A stylet (if used) should be inserted into the ETT.

Atropine should be administered if indicated. Atropine is considered optional in adolescents but is recommended in younger children who are more susceptible to bradycardia with laryngoscopy. Atropine is also beneficial if succinylcholine (reduces the risk of bradycardia) or ketamine (reduces the risk of excessive secretions) is to be used.

Next, any other adjunctive agents, then the selected sedative and neuromuscular blocking agent, should be administered. Which of these should go first or second is controversial, but the sedative and neuromuscular blocking agent should be given in rapid sequence regardless of order. It might be preferable to give some sedatives slowly, which argues in favor of giving the neuromuscular blocking agent first so that its time of onset coincides with the completion of sedative administration. However, others recommend that the sedative be given first to ensure unconsciousness before paralyzing the patient.

Once the sedative or neuromuscular blocking agent is administered, continued cricoid pressure sufficient to gently occlude the esophageal lumen (Sellick maneuver) potentially reduces the risk of passive regurgitation (Figure 26.33). Cricoid pressure is currently considered optional.

Although achieving a successful emergent endotracheal intubation involves several coordinated actions, the procedure itself essentially consists of two steps—direct laryngoscopy and tube insertion. Once the patient is fully paralyzed (usually 60-90 seconds after the administration of the neuromuscular blocking agent), the patient’s mouth should be opened and the
Section 10: Emergent Intubation

Figure 26.33 Cricoid pressure occludes the esophagus to prevent gastric reflux.

laryngoscope blade inserted, taking care not to injure the lips, teeth, or tongue (Figure 26.34). Most sources recommend inserting the blade on the right side of the patient’s mouth and “sweeping” the tongue to the left, especially when using a curved blade. However, in most cases it is also acceptable to insert the blade along the midline and slide it over the tongue into the proper position.

If a curved blade is used, it should be inserted into the hypopharynx until the tip of the blade meets resistance at the vallecula and then the handle pulled upward at a 45° angle to retract the epiglottis and reveal the vocal cords (Figure 26.35). If a straight blade is used, it should be advanced under direct visualization (by retracting the tongue) until the epiglottis is seen. If desired, one attempt should be made to retract the epiglottis with the technique used with a curved blade (ie, by inserting the blade tip into the vallecula and lifting upward). If this reveals the cords, then the tube can be inserted. However, if the epiglottis continues to obscure the glottic opening (as will happen in most instances), the blade should be withdrawn slightly and a scooping motion used to directly lift the epiglottis from view with the blade tip. This might take more than one attempt because the epiglottis will sometimes slip off the tip of the blade with even the slightest movement of the laryngoscope handle.

Figure 26.35 Gentle traction should be placed upward along the axis of the laryngoscope handle at 45°.

Next, the ETT should be inserted without losing sight of the glottic opening and vocal cords (Figure 26.36). This is greatly facilitated by having an assistant retract the right cheek slightly by pulling it laterally and holding the tube close by and providing it when needed. Retracting the cheek allows the tube to be inserted from the right side of the hypopharynx so that it does not obscure the cords (Figure 26.37). This also makes it possible to watch the tip of the tube as it enters the glottis, which is the best way to confirm a successful intubation. Remember to always keep both eyes open during this step of the procedure to preserve depth perception. As with threading a needle, maintaining depth perception makes inserting the tube between the vocal cords and into the trachea much easier. Confirm

Figure 26.36 The pediatric straight laryngoscope blade should be inserted into the patient’s mouth.

Figure 26.37
Critical Procedures

intratracheal placement of the tube (and exclude any possibility of an esophageal intubation) by listening for breath sounds in both lungs, by listening over the stomach, and, most importantly, by seeing good color change on a colorimetric carbon dioxide detector and/or good waveforms on a capnograph (ETCO₂ monitor).

Figure 26.36 View of normal anatomical landmarks for advancing the endotracheal tube using a straight blade.

Figure 26.37 The endotracheal tube should be advanced from the right corner of the mouth past the vocal cords and into the trachea.

Once the ETT has been properly inserted, it should be positioned so that the tip lies at an appropriate distance from the carina to achieve midtracheal placement (1-2 cm in younger children and 2-3 cm in older children). The depth of tube placement can be estimated by multiplying three times the ETT size; this value will be the appropriate depth in centimeters. For example, a child who is intubated with a 4-mm ETT should have the depth of placement measuring about 12 cm at the lip. Correct depth can also be found on the length-based resuscitation tape. Table 26-6 provides the expected tube length that should be at the patient's lips for each age group. Although these methods are highly reliable, a chest radiograph should be performed after the tube is secured to verify correct placement.

Finally, secure the tube using adhesive tape and/or cloth tape or, if preferred, a commercially produced device designed for this purpose. There are a variety of methods advocated for taping an ETT, but in general the tube should be anchored well enough that even an inadvertent yank will not dislodge it. Unexpected tube dislodgement often results in a frantic scramble for equipment to provide ventilatory support pending reintubation. Unrecognized tube dislodgement can be fatal; thus, carefully securing the ETT will usually prevent undoing the good work of a successful intubation.

Complications and Pitfalls
Whenever possible, equipment and devices should be tested to ensure that they will function properly during the procedure (eg, the light in the laryngoscope blade, the balloon of a cuffed ETT, wall suction, oxygen source).

Several potentially serious complications can be associated with performing an emergent endotracheal intubation. The most common of these include adverse physiologic effects of the procedure, inadequate oxygenation, barotrauma, mechanical trauma, and aspiration pneumonitis. Adverse physiologic effects are normally only a significant problem with patients who have severe cardiovascular compromise. For example, direct laryngoscopy is a potent inducer of vagal stimulation, especially in infants and younger children. In a healthy child, this is unlikely to produce any deleterious effects; in a child with unstable hemodynamics, however, profound bradycardia (even asystole) can occur, resulting in an abrupt cardiovascular collapse. In addition, direct laryngoscopy is suspected to increase intracranial pressure in children.

The most serious complication of RSI is failure of the intubation attempted in a patient who cannot receive adequate ventilation (the
Section 10: Emergent Intubation

so-called cannot intubate or cannot ventilate situation). In such patients, a rescue airway technique must be used immediately to avoid significant hypoxemic injury. In addition, each of the pharmacologic agents is associated with one or more potential complications. Agents must be chosen with the clinical situation and patient factors (eg, allergies) in mind.

Inadequate oxygenation, typically caused by an esophageal intubation, is generally the most disastrous complication of this procedure. Two ways that esophageal intubation most commonly occurs are by inserting the tube into the esophagus during intubation and by dislodging the tube from the trachea into the esophagus after intubation. Everyone who performs this procedure enough times encounters an esophageal intubation. It is the failure to recognize an esophageal intubation that must be avoided at all costs. Consequently, whenever a child who has recently been intubated has sudden and unexpected hemodynamic decompensation, the prudent clinician will take immediate measures to exclude any possibility of an unrecognized esophageal intubation or dislodgement of the ETT from the trachea.

Barotrauma, as the name implies, occurs as a complication of endotracheal intubation when excessive pressure causes injury to the patient. The most common type of pressure-related complication is a pneumothorax resulting from the administration of excessive tidal volume during positive pressure ventilation. The high level of intrapulmonary pressure induced overcomes the normal elastic properties of the tissues and produces a rupture in the lung. This problem can normally be avoided by carefully observing the patient while performing positive pressure ventilation to ensure that only tidal volumes sufficient to cause chest rise are administered.

Although a significant injury, a simple pneumothorax rarely causes the patient major harm as long as it is recognized and treated appropriately. However, if the problem is not recognized and the patient continues to receive positive pressure ventilation, a much more serious (and potentially fatal) tension pneumothorax can develop. This complication occurs when the “ball valve” effect is created, in which air can enter the thoracic cavity (through the rupture in the lung) but cannot escape. With each positive pressure ventilation, more air is forced into the thoracic cavity, increasing the pressure in the affected hemithorax and eventually causing the mediastinum to shift away from the affected side. As this shift increases, deformation of the vena cava prevents adequate venous return to the heart, producing a rapid decrease in blood pressure. This significant and rapid decompensation takes place within, at most, a few minutes and must be treated immediately with needle decompression of the chest. Because of this potential cascade of events, any pneumothorax identified in a patient who will continue to receive positive pressure ventilation must be treated early with tube thoracostomy.

Mechanical trauma during an emergent intubation occurs when injury to the tissues is caused by improper manipulation of the laryngoscope and/or ETT. Great care must be taken during direct laryngoscopy to avoid using the upper teeth (or in infants, the upper gingival ridges) as a levering fulcrum, which can avulse a tooth or lacerate the gingiva. The lips and tongue can also be contused or lacerated during laryngoscopy. Aside from the obvious detriment of harming the patient, excessive bleeding from such an injury can make intubation much more difficult. Improper insertion of the tube can cause permanent damage to the vocal cords, resulting in lifelong abnormalities of the voice. Therefore, the tube must never be forced.

Aspiration pneumonitis is another serious potential complication of emergent intubation. Any patient with a full stomach and diminished or absent upper airway reflexes (either from a depressed mental status or administration of a paralytic agent) is at risk for aspiration of stomach contents into the lungs. This is precisely the type of situation encountered (or induced) with many patients who require emergent endotracheal intubation. Measures must be taken to prevent aspiration whenever possible. This risk is potentially minimized by having an assistant apply optional cricoid pressure (Sellick maneuver) from the time that a patient first receives assisted or controlled ventilation with a BMV setup until the time that the ETT is inserted into the trachea. When performed properly, cricoid...
pressure potentially minimizes air entry into the stomach during BMV, greatly reducing the likelihood of vomiting, and can limit reflux of stomach contents into the hypopharynx during direct laryngoscopy and tube insertion.

THE BOTTOM LINE

- Although the task of performing an emergent endotracheal intubation in a pediatric patient is one of the more challenging undertakings a clinician can face, there are few accomplishments in medicine more rewarding than saving the life of a child in severe respiratory distress.
- Because it will be a relatively rare occurrence in the lifetime of most clinicians, the value of preparation (reading, conducting in-service meetings, assembling a pediatric airway tray) and practice (airway workshops, animal labs, mock codes) cannot be overstated.
- In the end, it is our duty as emergency care professionals to do whatever we can to ensure that any young patient who requires an emergent endotracheal intubation will undergo this procedure in the safest and most effective manner possible.20,21,25

11.1 Supraglottic Devices

Indication

These devices can be used to manage the airway in a child who cannot be intubated or effectively ventilated and who does not have upper airway obstruction.

Contraindications

These devices are generally ineffective in patients with upper (extrathoracic) airway obstruction because they do not form a tight seal against the airway. Other contraindications include grossly distorted upper airway anatomy and significant oropharyngeal trauma. Most supraglottic airway devices do not provide adequate protection against aspiration of stomach contents. However, when intubation has failed, the benefit of effective ventilation generally outweighs the risk of aspiration.

11.1A Laryngeal Mask Airway

The laryngeal mask airway (LMA) was originally designed for elective surgery. However, it is an easy-to-use rescue airway device available in a variety of sizes (Figure 26.38).

Section 11: Rescue Airway Techniques

Most children who require urgent or emergent airway management will respond to standard techniques, such as BMV and endotracheal intubation. However, if an experienced intubator has made three unsuccessful attempts despite changing the laryngoscope blade length and type, then the intubation has failed.25

When standard techniques fail and a patient can neither be intubated nor mask ventilated, an alternative approach is indicated. These alternative approaches can be categorized as follows: supraglottic devices, special laryngoscopes, airway guides, and surgical techniques. A complete discussion of these techniques is beyond the scope of this chapter. However, several of the more commonly used approaches are addressed.

11.1 Supraglottic Devices

Indication

These devices can be used to manage the airway in a child who cannot be intubated or effectively ventilated and who does not have upper airway obstruction.

Contraindications

These devices are generally ineffective in patients with upper (extrathoracic) airway obstruction because they do not form a tight seal against the airway. Other contraindications include grossly distorted upper airway anatomy and significant oropharyngeal trauma. Most supraglottic airway devices do not provide adequate protection against aspiration of stomach contents. However, when intubation has failed, the benefit of effective ventilation generally outweighs the risk of aspiration.

11.1A Laryngeal Mask Airway

The laryngeal mask airway (LMA) was originally designed for elective surgery. However, it is an easy-to-use rescue airway device available in a variety of sizes (Figure 26.38).

Technique

1. Choose the correct size LMA based on the child's weight in kilograms. The size for weight and the milliliters needed to inflate the LMA cuff are printed on the side of the device (Figure 26.39).
2. Remove the LMA from its package and inspect the cuff for damage.

3. Completely deflate the cuff. The manufacturer has developed a special deflator for this purpose. Alternatively, the LMA can be placed with the ventilating port against a flat surface (e.g., a countertop). The index and middle fingers of one hand are placed on either side of the device and over the cuff to deflate the cuff. Lubricate the cuff with water-soluble lubricant.

4. Insert the LMA into the mouth with the ventilating port facing down (onto the tongue). Guide the cuff against the palate with one or two fingers.

5. When the device cannot be advanced any further, inflate the cuff. The LMA should seat itself over the glottis.

6. Connect the manual resuscitator and begin ventilation.

Alternative Technique: The Reverse Rotation Technique
Steps 1 and 2 are identical to those described for LMA use.

3. Insert the LMA into the mouth with the ventilating port facing the hard palate instead of the tongue; the black line of the LMA will be facing the patient’s feet.

4. Advance the LMA and rotate the ventilating port 180° into position simultaneously.

5. Inflate the cuff and begin ventilation.

The LMA comes in two styles. The standard LMA is designed to serve as a supraglottic ventilation tool, although some have described ways to use this device as a “bridge” to intubation. An alternative device is the intubating LMA (LMA-Fastrach; Laryngeal Mask Co Ltd, Henley on Thames Oxon, United Kingdom). This device can be used like a standard LMA but is also designed to serve as a conduit for the insertion of a special flexible ETT (Figure 26.40). Although the Fastrach device is somewhat different in appearance, it is inserted in the same manner as the standard LMA and can be used to provide ventilatory support to the patient in the same way. Then, the flexible ETT can be passed into the device.

When the tip of the ETT reaches the laryngeal mask, it lifts a special lever designed to lift the epiglottis and allow the tube unrestricted access to the airway. An indicator mark can be found on the side of the ETT. When this mark reaches the proximal portion of the ventilation port, the tip of the tube will be about to pass into the airway. A rubber stabilizing rod is then attached to the proximal end of the tube and the ETT is advanced into the airway. The LMA is removed over the trachea tube and stabilizing rod, the stabilizing rod is removed, and the adapter is placed on the proximal end of the ETT. An ETCO₂ detector should be used to demonstrate that the ETT is in the airway. Then ventilation can begin in the standard manner (Figure 26.41A-I).
A. The cuff of the mask should be deflated and a water-soluble lubricant applied to the posterior surface. The lubricant should be rubbed over the anterior hard palate.

B. The curved metal tube should be in contact with the chin and the mask tip should be flat against the palate before rotation.

C. A circular motion should be used to swing the mask into place, maintaining pressure against the palate and posterior pharynx.

D. The endotracheal tube (ETT) should be visually inspected and inflated to verify cuff integrity and symmetry. The cuff should be deflated, the ETT lubricated, and the intubating laryngeal mask airway (LMA-Fastrach) tube passed through (rotate with up/down movement) to distribute lubricant. The ETT should be passed to the 15-cm depth marker or the transverse line on the LMA-Fastrach ETT, which corresponds to passage of tube tip through the epiglottic elevating bar.

E. The handle should be used to gently lift the device 2 to 5 cm as the endotracheal tube (ETT) is advanced until intubation is complete. The ETT should not be forced. The ETT cuff should then be inflated and intubation confirmed.

F. The connector should be removed and the intubating laryngeal mask airway (LMA-Fastrach) gently eased out over the endotracheal tube (ETT) into the oral cavity. A stabilizer rod should be used to hold the ETT in position as the LMA-Fastrach is withdrawn over the tube.

G. The stabilizer rod should be removed and the endotracheal tube held onto at the level of the incisors.

H. The intubating laryngeal mask airway (LMA-Fastrach) should be completely removed by gently unthreading the inflation line and pilot balloon of the endotracheal tube.

I. The endotracheal tube connector should be replaced.
11.1B Combitube

The Combitube is a true rescue airway (Figure 26.42) designed specifically as an airway management tool for office-based practitioners. It is available in two sizes and is appropriate for adolescents who are at least 1.2 m (4 ft) tall. It is not available for smaller children. The larger balloon is made of latex so this device should not be used in latex-sensitive individuals.

Figure 26.42 Combitube.

Technique

1. Remove the Combitube from its package and inspect the balloons for damage.
2. Ensure that both balloons are deflated.
3. Insert the Combitube blindly into the oropharynx and advance it until the central incisors lie between the black marks on the proximal portion of the tube.
4. Inflate the smaller balloon (5-15 mL of air) and then inflate the larger balloon (85-100 mL of air).
5. Attempt to ventilate via the esophageal port (blue, labeled number 1). In more than 90% of cases, the Combitube is located in the esophagus. The small balloon occludes the esophagus and the larger balloon occludes the oral cavity. When this is the case, oxygen or air from the esophageal port can only enter the trachea. The chest should rise, and breath sounds should be heard over the lung fields. The arterial oxygen saturation will be maintained in the normal range. Then ETCO$_2$ detection can be used to confirm endotracheal ventilation.

6. If ventilation via the esophageal port is ineffective, the tube might have been inserted into the trachea. Disconnect the bag-mask device from the esophageal port and attempt to ventilate via the tracheal port (clear, shorter tube, labeled number 2). If ventilation through this port is effective, the large balloon can be deflated and the Combitube can function as a standard ETT. Then ETCO$_2$ detection can be used to confirm tracheal ventilation. 26,27

11.2 Specialized Laryngoscopes

Indications

These devices can be used on children who cannot be successfully intubated using a standard laryngoscope.

Contraindications

There are no absolute contraindications. Those devices that rely on fiberoptic technology can be difficult to use in cases of significant oral or oropharyngeal trauma. The presence of secretions and blood can obscure the viewing port. An extremely small mouth opening can also be a contraindication. When a surgical airway is urgently required, these devices cannot serve as a substitute.

11.2A Fiberoptic Scopes

A variety of fiberoptic scopes are available. Clinicians should familiarize themselves with the device to ensure proper use. The key issue is the relationship between the viewing port and the ETT. If the viewing port is at the tip of the stylet onto which the tube is placed, the vocal cords should be seen in the center of the field of vision. If the tube is mounted to the right of
the viewing port, the cords should be placed in the right side of the visual field so that they are aligned with the position of the tube.

**Technique**
1. Prepare the patient for intubation in the standard manner.
2. Assemble the laryngoscope and connect the fiberoptic light source.
3. Place the tube in the proper location on the scope.
4. Clean the distal fiberoptic port with defogging solution.
5. Suction the oropharynx.
6. Insert the laryngoscope and align the vocal cords as described.
7. Pass the tube into the cords under direct vision.
8. Remove the fiberoptic scope from the ETT (similar to removing a stylet).
9. Confirm proper ETT location using ETCO₂ and secure the tube.

### 11.3 Laryngoscopes With Special Blades

A complete discussion of even a few of these devices would be beyond the scope of this chapter. Most commonly, these blades allow extra manipulation (e.g., a flexible tip) for better visualization. In general, they are used exactly like standard laryngoscopes except that, if an adequate laryngoscopic view is not obtained, the tip or blade of the laryngoscope can be moved (by depressing a lever or by some other means) to improve the view.

### 11.3A Video Laryngoscopes

A variety of video laryngoscopes are available. These devices use special laryngoscope blades that house small, high-resolution cameras. Rather than placing the tracheal tube under direct vision, the operator of a video laryngoscope is able to see an enlarged image of the airway on a video screen. In addition, because the image seen is less dependent on the patient’s position, the video laryngoscope can be used in circumstances in which it is difficult to move the patient’s neck.

The use of the videolarygoscope is otherwise similar to the use of the standard laryngoscope. Like fiberoptic scopes, these devices are relatively expensive and subject to fogging of the camera lens unless antifog fluid is applied before insertion of the laryngoscope. In addition, like all alternative airway techniques, practice is required to fully master video laryngoscopy.

### 11.3B Lighted Stylet

The lighted stylet is a device that does not depend on an adequate laryngoscopic view of the airway. The lighted stylet works very well in circumstances in which the laryngoscopic view might be obscured by blood or secretions. It also requires little or no movement of the neck.

**Indications**
The lighted stylet should not be used in circumstances in which the normal airway anatomy is likely to be significantly distorted or in cases of partial or complete tracheal transection.

**Contraindications**
The lighted stylet should not be used in circumstances in which the normal airway anatomy is likely to be significantly distorted or in cases of partial or complete tracheal transection.

**Technique**
1. Choose a properly sized stylet for the patient.
2. Connect the stylet to the light handle and check to make sure that the light is functioning properly.
3. Lubricate the stylet and place the ETT over the stylet so that the light source...
Section 12: Surgical Airway Techniques

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1. Confirm proper ETT location using ETCO₂ and secure the tube.

11.4 Tracheal Guides

Tracheal guides are devices designed to facilitate placement of the ETT in the same way that a guidewire is used in the Seldinger technique. A variety of these devices can be used. Some are semirigid tubes that allow oxygenation, ventilation, and ETCO₂ detection, whereas others are solid flexible guides.

Airway guides can be used in a variety of ways, as follows:

- A guide can be passed through a properly located ETT that is damaged or is too small and then used as a guide for tube replacement.
- A guide can be passed through an LMA and into the trachea. Tracheal position is suggested by the feel as the guide crosses the tracheal rings. If the guide is hollow, tracheal location can be confirmed by ETCO₂ detection. Once the guide is in place, the LMA can be removed and an ETT passed below the cords and into the trachea.
- If laryngoscopy affords only a partial view of the airway, the guide can be passed below the epiglottis and into the trachea and confirmed as described earlier.

Contraindications

Airway guides are contraindicated in cases of tracheal injury.

Section 12: Surgical Airway Techniques

Surgical airway techniques are the final option for management of the difficult airway. These techniques are the most invasive form of airway management and are associated with the most complications.

12.1 Needle Cricothyrotomy

Needle cricothyrotomy is the simplest form of surgical airway management. This technique involves the passage of a needle through the cricothyroid membrane. The needle is then used as a conduit for ventilation.
**Indications**
Needle cricothyrotomy is indicated in the patient who cannot be intubated and who cannot be ventilated by less invasive means. It is often considered in cases of significant facial trauma and life-threatening upper airway obstruction (eg, epiglottitis, foreign body at the level of the vocal cords).

**Contraindications**
Given that this technique is intended for use in children who might otherwise die, there are no true contraindications. Significant injury to the neck might make the procedure difficult or impossible to perform. If the needle is placed for transtracheal jet ventilation (beyond the scope of this chapter), it should be understood that the role of transtracheal ventilation in cases of complete upper airway obstruction remains controversial.31

**Equipment**
- Sterile gloves and mask
- Sterile preparation solution
- 18- to 14-gauge (depending on the size of the child) plastic over-the-needle intravenous catheter
- 10-mL syringe
- Adapter from a 3.0-mm ETT
- Ventilation bag

**Technique**
1. Attach the syringe to the needle.
2. Identify the cricothyroid membrane (Figure 26.44).

   In older children (and adults), the membrane is identified by locating the laryngeal prominence. This is the thyroid cartilage. The inferior border of the thyroid cartilage is the superior border of the cricothyroid membrane. In younger children, identification of the membrane is difficult. It might be possible to follow the trachea superiorly until the cricoid cartilage is palpated. The membrane lies just superior to the cartilage. It is also wise to palpate the area above the thyroid cartilage and attempt to identify the hyoid bone. The thyroid membrane is between these two structures. This membrane lies above the vocal cords and is not an appropriate site for insertion. Knowing the location of the thyroid membrane might prevent this complication. In the dying child, inadvertent puncture of the trachea is preferable to the alternative; the clinician should proceed with the procedure even if he or she is not completely confident that the cricothyroid membrane has been identified.
3. Prepare the neck in standard manner.
4. Insert the catheter with the needle directed inferiorly and aspirate while advancing. Tracheal location is indicated by aspiration of air.
5. Remove the needle, advance the catheter, and attach the adapter from the 3.0-mm ETT into the hub of the catheter.
6. Attach the ventilation bag to the adapter and begin ventilation, taking care not to kink the catheter. Ideally, a designated team member should hold the catheter hub securely to prevent it from kinking. There will be significant resistance to bag ventilation, but adequate ventilation can usually be provided (ie, the bag must be squeezed very hard to deliver a sufficient tidal volume to make the chest rise).

**Complications and Pitfalls**
Tracheal puncture can lead to subcutaneous emphysema. Likewise, vascular structures can be injured, with resultant bleeding. If the puncture site is infected or if sterile technique is not used, the patient can develop an airway infection.

**12.2 Retrograde Intubation**
Retrograde intubation involves the passage of a guidewire into the airway through the cricothyroid membrane and then using this guide to direct an ETT into the trachea.20,32,33

**Indications**
Retrograde intubation is most useful in an awake, sedated patient with a predicted difficult airway. It can be used to secure the airway in the “cannot intubate and can ventilate” situation; however, it is fairly time-consuming, so it would be difficult to use this procedure in such a situation.

**Contraindications**
This technique should not be used when the anatomy of the neck is severely distorted, when there is a known obstruction that will prevent passage of the ETT, or when the skin overlying the cricothyroid membrane is infected.
Equipment
All or most of the necessary equipment can be found in a commercial retrograde intubation kit. If such a kit is unavailable, the following equipment is required:

- Sterile gloves and drapes
- Sterile preparation solution
- 18- to 14-gauge over-the-needle catheter
- Syringe
- Guidewire—must have a flexible tip and be of sufficient length
- Kelly clamp or needle drivers (at least two)
- Magill forceps
- ETT
- Introducer (optional)

Technique
1. Prepare for and perform the procedure as described for needle cricothyrotomy.
2. Once the catheter is located within the trachea, it should be directed superiorly (Figure 26.45A).
3. Insert the flexible tip of the guidewire into the hub of the catheter and advance it superiorly until the wire can be visualized in the hypopharynx or mouth.
4. Grasp the wire with clamps or Magill forceps and bring it out of the oral cavity, then continue to advance the guidewire until sufficient wire extends from the oral cavity to allow for ETT placement (Figure 26.45B).

Figure 26.44 Cricothyroid membrane.

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5. Pass the ETT over the wire or introducer and down the airway. Some experts recommend passing the wire through the Murphy eye of the ETT (in an outside-to-inside manner) rather than through the lumen of the tube.

6. The tube might encounter resistance at the level of the arytenoids or epiglottis. In this circumstance, it can be manipulated into position by repositioning or with Magill forceps.

7. Once the ETT has reached the level of the cricothyroid membrane, the wire can be removed. Some authorities recommend cutting the wire and then removing it from the oral cavity. Others recommend simply pulling the wire out from either end. There are arguments in favor of either of these approaches. However, all agree that gentle downward pressure should be maintained on the ETT to avoid inadvertent dislodgement of the ETT during wire removal.

8. Advance the ETT into the airway and secure it in the usual manner.

Complications and Pitfalls
Injury to the trachea or vocal cords, airway infection, and injury to nearby structures are possible.
12.3 Wire-Guided Cricothyrotomy
This technique is identical to retrograde intubation except that the (much shorter) wire is passed distally into the airway. An incision is then made into the membrane immediately adjacent to the guidewire (to enlarge the cricothyroid membrane opening around the guidewire), and a small tracheostomy tube resting over a special introducer is passed distally into the airway over the guidewire. Once the tube is in position, the introducer and guidewire are removed and the patient receives ventilation through the ventilating port of the tracheostomy tube.32,33

12.4 Surgical Cricothyrotomy
In the older child or adolescent who can be neither intubated nor ventilated, the procedure of choice is cricothyrotomy.32-34

Indications
Surgical cricothyrotomy is indicated under two circumstances. Most commonly it will be used in patients who can be neither intubated nor ventilated and in whom less invasive alternative techniques cannot be used. It might also be chosen as the primary means of airway management when the anatomy of the face and oral cavity have been very distorted such that other airway management techniques are likely to fail.

Contraindications
There is some debate regarding the age at which surgical cricothyrotomy replaces needle cricothyrotomy as the management technique of choice. Given the small size of the cricothyroid membrane in young children, most authorities agree that this technique should not be performed in patients younger than 5 or 6 years. Some recommend that this technique be used only in those older than 8 years and those younger children with the body habitus of an older child. This technique can be very difficult to perform when the anatomy of the neck is distorted. In a life-or-death situation, however, this should not be considered a contraindication.

Equipment
- Sterile gloves and drapes
- Local anesthetic and syringe (for awake patients)
- Sterile preparation solution
- Scalpel (No. 11 blade recommended, No. 15 blade optional)
- Trousseau dilator (not for use in the smaller child)
- Tracheal hook
- Curved hemostats (two sets)
- Small Mayo scissors
- Appropriately sized tracheostomy tube (Shiley 0 to 4)
- Appropriately sized ETT (4-6 mm, cuffed if available)
- Tape or sutures to secure the tracheostomy tube or ETT

Technique
Note that several variations on this technique are described. A complete description of each of these is beyond the scope of this chapter. The method presented below is a standard approach to the procedure.

1. Prepare the skin in the usual manner.
2. Apply sterile drapes.
3. Identify the cricothyroid membrane as described above.
4. In the awake patient, if time permits, lidocaine (lignocaine) should be infiltrated into the incision site.
5. Using the thumb and middle finger of the nondominant hand, stabilize the larynx.
6. Taking care to incise only the skin and subcutaneous tissue, make a vertical incision approximately 2 cm in length in the midline over the cricothyroid membrane (Figure 26.46A).
7. An assistant should be assigned to provide retraction of the skin and subcutaneous tissue using standard retractors (eg, Army or Navy retractor or Weitlaner).
8. Palpate the cricothyroid membrane with the index finger of the nondominant hand to confirm that the incision has been made in the appropriate location (Figure 26.46B).
9. Bluntly dissect through the sternohyoid muscle to visualize the cricothyroid membrane (Figure 26.46C).
10. Using the scalpel, make a 1-cm horizontal incision into the membrane. Incision in the lower half of the membrane helps to
avoid inadvertent ligation of the superior cricothyroid artery (Figure 26.46D).

11. Insert the tracheal hook into the superior portion of the incision and gently lift the thyroid cartilage. Once placed, the hook should be passed to an assistant.

12. Place the Trousseau dilator a short distance into the anterior portion of the wound with the blades oriented so that the incision is dilated in a cephalad to caudad manner. Alternatively, curved hemostats can be used for this purpose. These should be inserted “upside down” in a caudal direction with the tip of the jaws directed anteriorly (Figure 26.46E). The jaws should be placed to dilate the lateral wound margins.

13. Insert the tracheostomy tube or tracheal tube into the incision, confirm proper position, and secure the tube in place (Figure 26.46F).

Complications and Pitfalls
There are many potential complications of this procedure. The reported incidence of these complications is approximately 20%, with most being minor. However, major hemorrhage and serious injury to the airway or esophagus can occur. Nonetheless, this technique is intended to be used in situations in which the alternative is death or severe hypoxic injury. In such cases, the benefits of the procedure far outweigh its potential complications. Electrocautery should be avoided because high-flow oxygen is generally in use during such an emergency procedure, which might result in explosive combustion.

12.5 Tracheostomy Management
Tracheostomy care is described in more detail in Chapter 13, Children With Special Health Care Needs. The most common complication of tracheostomy placement in a child is obstruction of the tube by hardened secretions. The following technique describes steps to assess and manage the tracheostomy for obstruction.

Technique
1. Ensure that the ventilation bag device is connected to an oxygen source.
2. Ensure that the suction device is functioning.
3. Draw 2 mL of normal saline into a 3-mL syringe. Remove the needle (if present) from the syringe and discard the needle.
4. Open glove and catheter package(s). Apply a glove to the hand that will hold the suction catheter. With the gloved hand holding the suction catheter, connect the catheter to the suction device (connecting tubing). Maintain aseptic technique throughout the procedure.
5. Place a ventilation bag on the end of the tracheostomy tube and attempt to ventilate. If a mechanical ventilator is used, disconnect the ventilator and assist ventilation with a ventilation bag device.
6. If there is no chest rise, remove the ventilation bag device from the tracheostomy tube. Instill 2 mL of normal saline into the tracheostomy tube. Insert a sterile suction catheter through the tracheostomy tube until resistance is met. Suction up to a maximum of 10 seconds while withdrawing the catheter proximally.
7. Attempt to ventilate.
8. Repeat the procedure.
9. If assisted ventilation with a ventilation bag does not result in chest rise after suctioning, remove the entire tracheostomy device.
10. Begin BMV over the mouth with an assistant holding a gauze sponge over the tracheostomy stoma to prevent air leakage.
11. If no chest rise is achieved with BMV, insert the appropriately sized replacement tracheostomy tube or ETT (if available) into the tracheostomy stoma.
   a. ETT size is determined by using a length-based resuscitation tape, width of child’s little fingernail, or the formula (age/4) + 4.
   b. If using an ETT, advance it approximately half the distance of that used for orotracheal insertion.
12. Attach the BMV device and begin to ventilate.
13. Assess for chest rise and fall. Repeat assessment and management as needed.
Cricothyroid membrane identification by palpation

A. A vertical incision should be made approximately 2 cm in length in the midline over the cricothyroid membrane.
B. The cricothyroid membrane should be palpated with the index finger of the nondominant hand to confirm the appropriate location.
C. Dissection should be performed through the sternohyoid muscle to visualize the cricothyroid membrane.
D. A 1 cm horizontal incision should be made into the membrane.
E. A Trousseau dilator or curved hemostats should be placed into the wound to dilate the opening to receive a tracheostomy or endotracheal tube.
F. The tracheostomy or endotracheal tube should be inserted into the incision and secured in place.

THE BOTTOM LINE

• Preparation (equipment availability and practice) is crucial.
• Determine a set of rescue methods before they are actually needed.
• The skills to perform a rescue airway cannot be learned in an emergency.

Section 13: Cardioversion and Defibrillation

Indications
The indications for defibrillation are the presence of ventricular fibrillation or pulseless ventricular tachycardia. The indications for cardioversion include the presence of a dysrhythmia that might respond to cardioversion (e.g., supraventricular tachycardia, perfusing ventricular tachycardia) accompanied by circulatory compromise or when chemical cardioversion has failed. Overall, life-threatening dysrhythmias are unusual in children, and ventricular tachycardia and ventricular fibrillation are especially rare. These facts, although reassuring, are a mixed blessing. On one hand, healthy children are unlikely to require cardioversion or defibrillation. On the other hand, physicians, nurses, and other health care professionals who primarily treat children are less familiar with these procedures than are their counterparts who care for adults. Furthermore, health care professionals should become familiar with the operation of the automated external defibrillator (AED), although it is less likely to be of benefit. The staff must also learn to recognize and treat the most common pediatric rhythm disturbances, especially supraventricular tachycardia. A growing population of children have had cardiac surgery. These children are at greater risk for significant dysrhythmias than their normal peers.

Equipment
• Standard defibrillator or monitor or AED.

• Appropriately sized paddles or appropriately sized contact pads—for children weighing less than 10 kg, the American Heart Association recommends paddles 4.5 cm in diameter; for those weighing more than 10 kg, the American Heart Association recommends paddles 8 cm in diameter.
• Conductive gel for use with the paddles.

Technique
Synchronized Cardioversion:
1. If the patient is conscious, administer sedation.
2. Attach monitor leads to the patient.
3. Turn on the defibrillator and select the lead displaying the tallest R waves.
4. Set the defibrillator to synchronized mode. The R waves shown on the monitor should appear to be tagged with an extra thick stripe in the center of the wave.
5. If paddles are being used, apply conductive gel to them. If contact pads are used, there is no need to apply gel because the pads have a conductive material within them.
6. Place the paddles or pads into contact with the patient’s chest. Two positions are acceptable.
   a. One paddle or pad can be placed on the sternum and the other at the cardiac apex (located in the anterior axillary line just below the nipple) (Figure 26.47).
   b. One paddle is placed on the anterior aspect of the chest over the heart and the other on the posterior aspect of the chest and aligned with the first (Figure 26.48).
7. Ensure that the pads are not touching each other and are not connected by conductive material.
8. Charge the unit. For cardioversion, the initial charge selected is 0.5-1.0 J/kg. If unsuccessful, increase to 2 J/kg, then thereafter the dose remains constant at this level for each subsequent attempt.
9. Ensure that the patient is not touching any metal parts of the bed.
Performing Defibrillation or Cardioversion

- Defibrillation is indicated for ventricular fibrillation and pulseless ventricular tachycardia.
- The most common indication for cardioversion in children is for unstable paroxysmal supraventricular tachycardia or paroxysmal supraventricular tachycardia refractory to drug conversion.
- AEDs are more likely to be available in a nonhospital setting.
- Practice the “clearing chant.”

KEY POINTS

10. Initiate a “clearing chant.” Say, “I am going to shock on three.”
   a. “One. I am clear.” The operator should make certain that he or she is not touching the patient or the bed.
   b. “Two. You are clear.” The operator should ensure that all other personnel are not in contact with the bed or patient.

11. If paddles are used, press them firmly against the chest.

12. Press the discharge buttons and hold them until the shock is delivered. In synchronized cardioversion, there can be a delay of a few seconds before the dose of electricity is delivered.

13. After the cardioversion attempt, check the patient’s rhythm to determine the need, if any, for further treatment.

14. If necessary, double the energy level, recharge the unit, and make another attempt.

13.2 Automated External Defibrillator

The AED represents a significant advance in the care of patients with ventricular fibrillation and pulseless ventricular tachycardia. The 2010 resuscitation guidelines published in Pediatrics (2010;126;e1361-e1399) recommend that AEDs can be used in children of all ages who have no signs of circulation. Ideally, the device should deliver a pediatric attenuator to
reduce the energy dose in children up to 25 kg (approximately 8 years of age), but if a pediatric attenuator is not available, the adult system can be used. In addition, the arrhythmia detection algorithm used in the device should demonstrate high specificity for pediatric shockable rhythms (ie, it will not recommend delivery of a shock for nonshockable rhythms).

**Technique**

1. Remove the AED from its storage container.
2. If not already done by the manufacturer, attach the pads to the cables and the cables to the unit.
3. Attach the pads to the patient as described for cardioversion.
4. Power on the AED.
5. Many newer units will “talk” the operator through the rest of the process.
6. If the unit is fully automated, it should begin analyzing the rhythm right away. If the unit is not fully automated, press the “analyze” button. The AED will analyze the rhythm. This can take up to 15 seconds. During the time the unit is analyzing the rhythm, there is a small theoretical possibility that other devices producing an electromagnetic field might interfere with the unit. Therefore, cellular telephones and radios should not be used while the unit is analyzing. If such devices must be used, they should be kept well away from the patient.
7. If ventricular fibrillation or pulseless ventricular tachycardia is present, the unit will recommend a shock. Fully automated units can perform the clearing chant and deliver the shock without human assistance, but most AEDs will instruct the user to press the shock button.
8. The machine will reanalyze the rhythm and give further instructions. For children weighing less than 25 kg (approximately 8 years of age), a pediatric dose attenuator should be used. But if it is not available, the adult system can be used.

**Standard Defibrillator**

1. Turn on the defibrillator.

2. Select appropriately sized paddles or pads as described for cardioversion.
3. If the patient is not on a monitor, the paddles or pads can be used for a “quick look” rhythm interpretation by placing them as described for synchronized cardioversion and turning the selector switch to the setting that allows the paddles to be used as sensing leads. As described in cardioversion, if paddles are used, they should be prepared with conductive gel before use.
4. If the rhythm is either ventricular fibrillation or pulseless ventricular tachycardia, then charge the machine. For defibrillation, the correct energy dose is 2 J/kg for the first attempt, 4 J/kg for defibrillation, the correct energy dose is 2 J/kg for the first attempt, 4 J/kg for the next attempt, and higher energy levels may be considered (up to 10 J/kg or the adult maximum dose) for subsequent attempts.
5. As with cardioversion, ensure that the patient is not touching metal parts of the bed and perform the clearing chant as described previously.
6. If paddles are used, press them firmly against the chest and discharge the device to deliver the shock.
7. After the shock is delivered, immediately resume cardiopulmonary resuscitation for two minutes, then check the rhythm. If the patient remains in ventricular fibrillation or pulseless ventricular tachycardia, follow the current algorithm.

**THE BOTTOM LINE**

Children are not likely to need defibrillation or cardioversion, but when it is necessary, practice and familiarization with defibrillation and cardioversion equipment are essential.
Section 14: Vascular Access

Intravenous fluids and medications are often required in the treatment of ill and injured children. In most cases, catheters placed into peripheral veins are sufficient. However, sometimes central venous access is required. Central venous catheters can be used to monitor central venous pressure, pulmonary artery wedge pressure, and central venous oxygen saturation. On occasion, a central venous catheter will be placed after several attempts to place a peripheral venous catheter have failed.

14.1 Peripheral Venous Catheter Placement

Equipment

- Catheters—the catheter size chosen should be appropriate for the vein selected. If a standard over-the-needle intravenous catheter is unavailable, a butterfly or similar needle can be used as a temporary alternative.
- Rubber or elastic tourniquet
- Antiseptic soap or wipes
- Syringes
- Flush solution
- Tape
- Dressing material
- Clear dressing material (optional)
- Local anesthetic cream (optional)
- Local anesthetic injection (optional)
- 18- to 20-gauge needle (optional)

Technique

Easily accessible peripheral veins are located in several anatomical areas. The most commonly cannulated veins are located on the dorsum of the hand (branches of the cephalic and basilic veins) (Figure 26.49), the antecubital fossa (cephalic vein, basilic vein, medial cubital vein) (Figure 26.50), the forearm (cephalic vein), the dorsum of the foot (dorsal arch veins), the medial side of the foot (saphenous vein, medial marginal vein), and the lateral side of the foot (small saphenous vein, lateral marginal vein) (Figure 26.51a, b). Less commonly, the external jugular veins (Figure 26.52) or the scalp veins are used.

When peripheral veins are difficult to identify, ultrasound can be used to locate them.

1. Select the vein into which the catheter will be placed. When time permits, local anesthetic cream can be applied to the site. This can reduce the discomfort associated with intravenous catheter placement but takes approximately 30 minutes to 1 hour for the medication to have a significant anesthetic effect. Alternatively, a small amount of local anesthetic can be injected at the insertion site immediately before the needlestick. This method of anesthesia is, unfortunately, associated with a second needlestick.

2. Apply a tourniquet (exception: external jugular vein—see below) proximal to the site. A rubber band around the head makes a good tourniquet for scalp vein access.

3. Clean the site with alcohol or sterile preparation liquid.

4. Visualize and/or palpate the vein to be cannulated, if possible. Some veins (eg,
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Figure 26.51A, B Intravenous sites on the foot.

Figure 26.52 The external jugular veins can also be used.

the saphenous vein) are reliably located near anatomical landmarks, and these veins can be accessed blindly, if need be.

5. Some physicians choose to make a hole in the dermis with a larger gauge needle before catheter insertion. They argue that this technique avoids damage to the plastic catheter as it passes through the skin. This step is optional.

6. Insert the catheter through the skin at a shallow angle parallel to the vein. Some authorities recommend inserting the catheter with the bevel facing down in very small or collapsed veins. This technique is intended to prevent unintentional penetration of the posterior wall of the vein.

7. Advance the catheter until blood return is seen in the hub and then advance 1 to 3 mm further to ensure that both the needle and the catheter are located within the vein.

8. Using the index finger of the dominant hand or the thumb and index finger of the nondominant hand, gently advance the catheter into the vein. Blood should flow freely from the catheter, but lack of blood flow does not necessarily mean that the catheter has not been properly placed. This is especially true in the case of external jugular veins.

9. If blood is needed for laboratory studies, it might be possible to obtain it from
the catheter before infusion of flush or intravenous fluid.

10. The catheter should be flushed with normal saline. During this process, it is important to observe the surrounding tissues for evidence of infiltration of fluid into the surrounding tissues. This is particularly critical for intravenous lines that will be used to administer certain medications that might cause significant tissue injury if they are extravasated.

11. Secure the line with tape or a clear plastic dressing. In younger children, it might be necessary to wrap the site in gauze or to restrain the child’s upper extremities so that he or she cannot remove the intravenous catheter.  

14.2 External Jugular Vein Cannulation

The technique for placing a catheter in the external jugular vein varies slightly from that used in cannulating other veins. The external jugular veins are located in the lateral aspect of the neck (Figure 26.53). They are most prominent when the patient is supine (in the Trendelenburg position) or when intrathoracic pressure is high (eg, vigorous crying). It might be necessary to place a small towel roll under the child’s neck and turn his or her head away from the insertion site to access the vein. In addition, the position of the mandible can interfere with placement, and the insertion needle might need to be bent slightly for the catheter to pass below it. To stabilize the vein, the skin should be taut at the insertion site. Furthermore, it might be useful to make a small hole in the skin before insertion of the catheter.

It is not unusual to have little or no spontaneous blood return from the catheter even when it is in the correct location. However, on aspiration with a syringe, blood should return relatively easily.  

Complications and Pitfalls

Peripheral intravenous cannulation is safely accomplished hundreds of times each day by medical professionals of all types. It is relatively free of serious complications. The most common and important complications are as follows:

- Injury to a contiguous structure (eg, an artery or a nerve)
- Extravasation of fluid into the tissues leading to compartment syndrome or, in the case of certain toxic medications, leading to damage to the tissues
- Infection
- Phlebitis or thrombophlebitis

Almost all of these complications can be avoided with attention to proper technique. However, the most serious problem with peripheral intravenous catheterization is failure to recognize when the technique has failed. Repeated attempts to obtain peripheral access in a critically ill child are not warranted. Once three or four skilled nurses and/or physicians have failed to place a peripheral catheter, an alternative method of vascular access should be chosen. When a child is in shock, it is not appropriate to delay vascular access via intraosseous access or central venous catheter placement.

14.3 Central Venous Catheter Placement

Indications

Central venous access is required for central venous and pulmonary artery wedge pressure monitoring and for the placement of a transvenous cardiac pacing device. It might also be necessary for fluid infusion or blood transfusion if peripheral access cannot be established.
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Equipment
- Sterile gloves
- Sterile gown and mask (optional)
- Sterile preparation solution
- Local anesthetic
- Central venous catheter kit—a number of different types of kits are available. All have the use of the Seldinger over the wire technique for placement. Likewise, the type of catheter inserted varies with its intended purpose. A multiple lumen catheter might be needed to infuse several different types of vasoactive medications, whereas a large-bore catheter is better for infusing a large volume of fluid or as a port for inserting a Swan-Ganz catheter.
- Syringes
- Sterile flush solution
- Suture material (might be included in the kit)
- Dressing material

Technique
The three central veins most commonly used for catheter insertion are the femoral vein, the internal jugular vein, and the subclavian vein. The insertion technique is as follows:

1. Determine the vein into which the catheter will be inserted and identify the external landmarks.

a. Femoral vein: the femoral vein lies in the medial portion of the anterior aspect of the thigh (groin). The portion of the vein distal to the inguinal ligament is most commonly used as a site for catheter insertion (Figure 26.54). This section of the vein is medial to and slightly posterior to the femoral artery, and both the vein and the artery are somewhat superficial. To identify the correct site for insertion, identify the arterial pulse 1 to 2 cm distal to the inguinal ligament. A towel roll placed beneath the ipsilateral buttock can improve exposure. The correct site for insertion is variable (depending on the size of the patient), but in the range of 0.5 to 2 cm medial to the femoral arterial pulse. The needle is directed along the course of the vein and at a 45° angle to the skin.39

b. Internal jugular vein: the internal jugular vein is located in the anterior aspect of the neck. The more cephalad portions of the vein are located somewhat deep within the neck, but the caudal portions are more superficial. The location of the vein is best understood in relation to the sternocleidomastoid muscle. For much of its course, the vein runs directly beneath the muscle. However, its more cephalad section lies just medial to the sternal head of the muscle. Its medial portion courses through a triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle. As the vein progresses caudally, it is found medial to the clavicular head of the muscle. The internal jugular veins ultimately join the subclavian veins to become the innominate veins, which in turn empty into the superior vena cava (SVC). On the right side, the internal jugular forms a nearly straight pathway into the SVC; therefore, the right internal jugular is preferred when possible. The carotid artery lies medial to and slightly posterior to the vein. Several approaches to cannulation of the internal jugular have been described. Of these, the most popular is the “median” approach. The key landmark is the apex of the triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle. When the patient’s head is turned away from the insertion site, this triangle becomes relatively easily identified. The needle is inserted at the apex at an approximately 30° angle with the skin and is directed toward the ipsilateral nipple (Figure 26.55).39

c. Subclavian vein: the subclavian veins lie just beneath the clavicles. They are less often chosen as an insertion site because attempted cannulation of the subclavian veins is associated with many potentially serious com-
5. The easy aspiration of dark-colored venous blood indicates that the needle is in the correct location. If the blood is bright red, the syringe should be removed from the needle. Pulsatile blood return suggests that the needle has entered the arterial lumen. If this occurs, the needle should be removed and pressure held on the site.

6. Once the clinician is reasonably certain that the needle is within the lumen of the vein, the syringe is removed and the guidewire inserted into the needle. The flexible, or “soft,” end of the guidewire should be inserted into the vein first. The guidewire should then be advanced well into the vein. If the needle and wire are in the proper location, there should be almost no resistance to wire advancement. Significant resistance indicates that the needle and wire are improperly located. In such cases, the wire should be removed and the needle repositioned or removed and reinserted.

7. When the wire is positioned, withdraw the needle. Keep one hand firmly holding the wire at all times.

8. Using a No. 11 scalpel blade (often supplied in the kit), make a small nick in the skin over the guidewire. Take care not to injure the underlying vessel.

9. Pass the dilating device down the wire and insert it fully into the vessel lumen. A slight twisting motion can facilitate placement.

10. Remove the dilating device and insert the central venous catheter by passing it down the guidewire and into the vessel. A slight twisting motion can facilitate placement.

11. Remove the guidewire and confirm proper location by aspirating blood from the catheter.

12. Infuse fluids into the catheter to keep the lumen patent and secure the catheter in place with sutures. Apply a sterile dressing to the site.

Note that ultrasonography using a high-frequency vascular probe is a valuable adjunct in the identification of central veins, especially the femoral vein and the internal jugular vein. The clavicle makes identification of the subclavian vein more difficult.

The technique for ultrasound identification is as follows:

- Under sterile conditions, place an ample volume of ultrasound gel into a sterile glove or sterile probe cover.
- Prepare the site as described in number 2 below.
- Place sterile ultrasound gel over the site to be visualized (the anatomical landmarks described above can be used to determine the most appropriate site).
- Using a sterile glove to hold the probe or with the assistance of an operator, move the probe until the vein in question can be identified. In addition to being found in their known anatomical locations, veins are readily compressible, whereas arteries are not.
- The target site on the skin can be marked and the probe removed or the probe can be used to visualize cannulation of the vessel.

2. Prepare the area with sterile preparation solution and apply sterile drapes.

3. Recheck landmarks and administer a small amount of local anesthetic medication into the skin and subcutaneous tissue without puncturing the vein.

4. Attach a 5- to 10-mL syringe to the needle. Insert the needle using the landmarks above and advance the needle while aspirating continuously.

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Figure 26.54  Femoral vein.

Figure 26.55  Internal jugular vein.

Figure 26.56  Subclavian vein.

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14.4 Umbilical Vein Catheterization

Umbilical vein catheterization should be considered as a potential intravenous access site in infants up to 2 weeks old. The procedure is indicated for neonates with shock or cardiopulmonary failure.

**Equipment**
- 5F or 8F catheter or a 5F feeding tube
- 10-mL syringe
- Umbilical cord tape or suture to tie the base of the cord
- Flush solution

**Technique**
1. Place the infant beneath a radiant warmer and restrain the extremities.
2. Prepare the abdomen and umbilicus with antiseptic solution (surgical preparation).
3. Drape the umbilical area in a sterile manner. The infant’s head is exposed for observation.
4. To anchor the catheter after placement, place a constricting loop of umbilical tape at the base of the cord. Using a scalpel blade, trim the umbilical cord to 1 to 2 cm above skin surface.
5. Identify the umbilical vessels. The umbilical vein is a single, thin-walled, large-diameter lumen, usually located at 12 o’clock. The arteries are paired and have thicker walls with a small-diameter lumen (Figure 26.57).
6. Obtain an umbilical vascular catheter (5F). Flush the catheter with heparinized saline (1 U/mL) and attach it to a three-way stopcock.
7. Measure and mark 5 cm from the tip of the catheter.
8. Close the ends of a pair of smooth forceps, then insert the end into the lumen of the umbilical vein. Dilate the opening by allowing the ends of the forceps to separate, then insert the catheter into the lumen of the umbilical vein and advance it gently toward the liver for 4 to 5 cm or until blood return is noted.
9. If resistance to advancement of the catheter is encountered, the tip might be...

in the portal vein or the ductus venosus. The catheter should be pulled back until blood can be withdrawn smoothly.

10. Remove the catheter when resuscitation is complete and peripheral vascular access has been obtained.

**Complications and Pitfalls**
Central venous catheterization is an invasive form of vascular access, and many potential complications are associated with this technique. Some of these potential complications are common to all sites of insertion, whereas others are site specific. The complications common to all insertion sites are as follows:
- Arterial injury: the most common complication of this technique is...

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unintentional puncture and/or cannulation of the adjacent artery. In most cases, this results in a minor injury to the artery that can be easily managed with direct pressure at the insertion site or by application of a pressure dressing. Obviously, it is much harder to control significant bleeding of one of the carotid arteries, but fingertip pressure applied directly to the site might be sufficient. Use of the vein dilator or a mishap with the scalpel can result in more serious injury to the artery, necessitating the involvement of a vascular surgeon. If possible, it is best to avoid injuring the artery.

- Infection: central venous catheters are foreign bodies and can, like any such object, become colonized by bacteria. Central venous catheter infections can have devastating consequences, particularly in critically ill children. Furthermore, the emergence of multiple-resistant bacteria in many hospitals increases the risks substantially. Attention to sterile technique is critical. When time permits, those involved in the placement should don sterile gowns and wear masks and hats. Large sterile drapes can prevent inadvertent contamination of the guidewire and catheter before insertion.

- Thrombosis: just as any foreign object can become infected, almost any foreign object can become a nidus for thrombus formation. The risk is highest with polyvinylchloride catheters and when the rate of infusion through the catheter is less than 3 mL per hour. Flushing the catheter with heparin when it is not in use and using heparinized fluid when the rate of infusion is less than 3 mL per hour might prevent thrombus formation. Catheters made of Teflon have surface characteristics that are not conducive to the thrombus formation. Unfortunately, these catheters are also stiff and can injure vascular structures. Likewise, catheters that are impregnated with heparin are less often associated with thrombus formation.

- Guidewire misplacement: in rare instances, the guidewire enters the central venous circulation and must be retrieved by an angiographer or a surgeon. This complication can be avoided by ensuring that one hand remains in firm contact with the wire at all times.

- Air embolus: allowing a bolus of air to enter the catheter can result in an air embolus when the end of the needle or catheter is open to the air and the venous pressure is low. This complication is most likely to occur when the catheter is placed into the internal jugular vein or the subclavian vein. An air embolus can be avoided by covering the open end of the catheter with the thumb after the guidewire has been removed, before connecting the intravenous fluids, and by positioning the patient with the insertion site slightly dependent. Such positioning has the added benefit of aiding catheter placement because it dilates the veins. Aspirating the catheter before flushing will remove air within the catheter. Older patients can be asked to perform a Valsalva maneuver during internal jugular and subclavian cannulation to avoid negative pressure within the vein.

**Site-Specific Complications**

- Femoral vein: few significant complications are associated with femoral vein cannulation. The most potentially serious complication is inadvertent penetration of the peritoneal cavity or rectum. This complication can be avoided by ensuring the site of insertion is below the inguinal ligament and the needle is not directed too posteriorly or inserted too deeply.

- Internal jugular vein: cannulation of the internal jugular vein is also relatively safe but less so than femoral vein cannulation. As previously described, inadvertent puncture of the carotid artery can be problematic. Unintentional injury to the brachial plexus has also been described. The most important potential complication is unintentional pneumothorax.
Section 14: Vascular Access

14.5 Intraosseous Needle Placement

Indications
Intraosseous access is indicated under two circumstances. In the moribund child, it might be wise to first insert an intraosseous needle for the immediate infusion of fluids and medications and then attempt to insert an intravenous or central venous catheter. Alternatively, intraosseous access might be required in the treatment of a child who requires urgent vascular access and when attempts to place standard intravenous catheters have failed.

Equipment
- Antiseptic preparation solution
- Local anesthetic (optional in the moribund patient)
- Intraosseous needles (Figure 26.58)—intraosseous needles and bone marrow aspiration needles are made by several different manufacturers; an 18- to 20-gauge spinal needle can be used as an alternative.
- Syringe
- Flush solution (saline or sterile water)
- Gauze pads and tape (optional)

Technique—Manual
Several bones contain active marrow. In theory, any of these can be used as a site for IO infusion. In practice, three locations are most commonly used. The three sites are the distal femur, proximal tibia, and distal tibia (medial malleolus). Of the three sites, the proximal tibia is most commonly used. The technique is as follows:

1. Select the location for insertion and identify the landmarks:
   a. Proximal tibia (Figure 26.59)—the landmark is on the medial side of the tibia, 1 to 2 cm below and avoiding the tibial tuberosity, approximately half the distance between the prominent anterior ridge of the tibia and its medial edge.
   b. Distal femur—the femur is a triangular bone with the point of the triangle on its anterior aspect. Its shape makes needle insertion somewhat challenging. The site of needle insertion should be 1 to 2 cm proximal to the superior border of the patella and slightly medial or lateral to the anterior ridge. The bone is flatter in these locations, and access is easier.
   c. Distal tibia—the insertion site is located approximately 1 to 2 cm proximal to the medial malleolus in the center of the bone.

2. Prepare the area. In the alert child, 1 to 3 mL of lidocaine (lignocaine) can be infiltrated into the skin and down to the periosteum before proceeding. When time is of the essence, however, this step can be omitted.

3. Grasp the needle in the dominant hand and place it on the insertion site with the point angled slightly away from the joint space. When possible, pinch the needle itself with the thumb and forefinger of the dominant hand and allow the hub of the needle to rest against the palm or the hy-
pothenar area. Do not allow the patient's limb to rest in your nondominant hand, because an unintentional slip or penetration of both cortices of the bone can result in a needlestick injury with its attendant risk of acquiring a blood-borne disease.

4. Use firm downward pressure and rotate the needle back and forth. It will gradually penetrate the cortex of the bone. A sudden decrease in resistance can often be felt as the needle penetrates the cortex. This decrease in resistance might be immediately preceded by or accompanied by a popping sound. At this point, the needle can be advanced a few millimeters more to ensure placement into the marrow cavity.

5. Remove the trochar (or stylet) and, if possible, attempt to confirm that the needle is in the marrow space. This can be done by aspirating marrow or by infusing a sufficient volume of fluid to determine that fluid flows easily into the space and there is no extravasation of fluid into the soft tissues around the insertion site.

When the device is determined to be in the correct position, it can be used to infuse medications or fluids.

6. There is some debate about the best way to secure an intraosseous catheter. The needle is in a bone, and when placed in a child who is not moving, it is unlikely to become dislodged. One option for securing the intraosseous needle that allows visualization of the site is taping the needle in a “goal-post” manner (similar to an umbilical vessel catheter).41,42

Technique—Drill

1. Select a needle appropriate to the size of the patient:
   a. 3–39 kg: 15 mm
   b. 40 kg or greater: 25 mm
   c. Obese: 45 mm

2. After sterile preparation as described above, insert the needle into the skin over the proposed insertion site such that at least 5 mm of the needle is visible above the skin surface.

3. Attach the electric driver to the needle hub as per the manufacturer’s directions.
4. Depress the trigger of the driver and advance the needle with gentle downward pressure until either a sudden decrease in resistance is noted or the needle is inserted to the correct depth.

5. Attempt to confirm the needle's position and secure it as described in steps 5 and 6 above.

Complications and Pitfalls
Intraosseous catheter placement is often successful and is relatively free of complications. The most significant potential problems associated with this procedure are as follows:

- Failure to place the needle into the marrow space. This technique occasionally fails. When this occurs, it is generally best to move to another bone rather than attempt to place the needle into the same bone.
- Fracture—there is some risk of fracture. This is especially true in infants and young children. In theory, the most significant potential complication of fracture is damage to the growth plate. In practice, this has not been reported.
- Infection—improper attention to sterile technique can result in a variety of infectious complications, ranging from cellulitis to osteomyelitis. In addition, the risk of osteomyelitis increases when the needle is left in place for more than 24 hours. This complication can be minimized by establishing intravenous access once the child is adequately resuscitated and then removing the intraosseous needle.
- Compartment syndrome—compartment syndrome can result from extravasation of fluid into the soft tissues or possibly from a fracture at the insertion site. The area of greatest potential risk is the proximal tibia. Insertion sites, even sites of failed insertions, should be examined periodically in the hours after the procedure for significant edema or tension.14,41,43,44

14.6 Venous Cutdown
When it is impossible to secure venous access by standard methods, a venous cutdown can be considered. The most common sites are the greater saphenous vein (at the ankle or groin), cephalic vein, or basilic vein. Of these, the two saphenous vein techniques are the most commonly used and are described here.43-46 This procedure has largely been replaced by intraosseous vascular access.

Indications
Venous cutdown is indicated when the patient requires resuscitative fluids or drugs and other methods of venous access are impossible or contraindicated. Situations in which venous cutdown might be considered include hypovolemic shock, trauma, thermal burns, and cardiac arrest.

Contraindications
Potential contraindications to venous cutdown include the following:

- Known vascular or orthopedic injury proximal to cutdown site
- Major blunt or penetrating trauma to groin or abdomen
- Infection at the proposed site of cutdown
- Availability of standard venous access

Equipment
- Sterile preparation solution, local anesthetic, syringes, needles
- Scalpels (No. 10 and 11 blades)
- Curved Kelly hemostats, straight mosquito hemostats, Iris scissors, needle holder, fine tooth forceps
- Suture material: 3-0 and 4-0 silk, 4-0 nylon; for infants, 5-0 silk and 6-0 nylon
- Intravenous needle and catheters (22 to 14 gauge), intravenous extension tubing, saline flush
- Resuscitative fluids or medications
- Sterile 4×4 gauze, antibiotic ointment

Technique: Distal Saphenous Vein Cutdown
1. Stabilize the extremity with an armboard if the patient is awake.
2. Prepare the medial ankle with sterile preparation solution.
3. Identify landmarks: the saphenous vein lies 1 to 2 cm superior and anterior to the medial malleolus (Figure 26.60).
4. Anesthetize the skin in an awake patient. (Omit in cardiac or traumatic arrest.)
5. With a No. 10 blade, make a 2-cm (infant) to 4-cm (adolescent) transverse
superficial incision superior and anterior to the medial malleolus.

6. With the curved hemostat (tip pointing downward), bluntly dissect subcutaneous tissue down to the tibia.

7. Locate the saphenous vein against the periosteum and bluntly dissect surrounding adventitious tissue to isolate it.

8. Elevate the vein with the hemostat, grasp the silk suture in the middle with the hemostat, and pull it under the vein. Cut the suture material in half, leaving two strands perpendicularly under the vein. Bluntly dissect a space under the vein so that the two sutures are separated by at least 1 cm.

9. Tie off the distal suture (ligating the vein), leaving long ends to use as a handle to elevate the vein.

10. Leave the proximal suture untied, and use it as a handle to elevate and isolate the vein.

11. Using a No. 11 blade, perform a venotomy (small nick) on the superficial surface of the vein. Hold both ends of the vein by the suture material and nick the vein transversely with an upward motion of the scalpel. Do not transect the vein. The venotomy must include the lumen of the vein for successful venous access. Once the lumen is entered, bleeding can be controlled by upward tension on the proximal suture, which will pinch the vein and prevent further bleeding.

12. Insert a catheter (angiocatheter or intravenous tubing) into the venotomy site. Advance the catheter by reducing tension on the proximal suture. Aspirate the catheter to confirm blood return, and then flush the catheter with intravenous fluid.

13. Tie the proximal suture around the vein with the catheter in place to secure it.

14. Attach intravenous tubing and fluids. Medications can also be administered via this route.

15. Close the incision with fine sutures.

16. Apply antibiotic ointment and a dressing.

17. Perform routine wound care and remove sutures in 7 to 10 days. Bleeding from catheter removal can be controlled with sustained direct pressure.

Figure 26.60 Distal saphenous vein cutdown site.


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Section 15: Thoracic Procedures

15.1 Needle Thoracostomy (Thoracentesis)

When intrapleural pressure exceeds atmospheric pressure, an existing pneumothorax can progress to a tension pneumothorax. The patient is unable to receive ventilation because of the increased intrathoracic pressure. Cardiac function can be compromised. Absence of breath sounds, tracheal deviation, and jugular venous distention are often noted. After the insertion of a needle to relieve pressure, a chest tube is usually inserted to maintain stability.

Indications

There are several indications for the performance of a needle thoracostomy. In some circumstances, this technique can be used to

The Bottom Line

Vascular Access in Infants and Children

- Immediate vascular access is best obtained via peripheral intravenous or intraosseous catheters.
- Central venous and peripheral vein cutdowns require more time but have other advantages and disadvantages.
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definitively or temporarily treat a pneumothorax. However, the emergency practitioner is most likely to use this technique when he or she suspects a tension pneumothorax based on the patient’s clinical findings.47–49

Equipment

• Sterile preparation solution
• 14-gauge angiocatheter (a smaller catheter or a butterfly needle can be used in infants)
• Syringe (use a large syringe for a tension pneumothorax)
• Optional stopcock

Technique

1. Elevate the head of the bed to 30° if possible.
2. Identify the second intercostal space in the midclavicular line (alternative location—fourth intercostal space in the anterior axillary line) (Figure 26.62).
3. Cleanse the site with sterile preparation solution in the usual manner.
4. Attach the syringe to the angiocatheter or needle and insert it perpendicular to the chest wall. To avoid injury to vascular structures (which lie under the rib), insert the needle at the superior margin of the third rib (Figure 26.63).
5. Apply negative pressure (aspirate) to the syringe as the needle is advanced. A rush of air denotes entrance into the pleural space and partial or nearly total relief of the pneumothorax. However, for a tension pneumothorax, continued repeated aspiration might be required to improve heart rate, blood pressure, and oxygenation. Stopcock closure between syringe aspiration cycles is generally not necessary when evacuating a tension pneumothorax.
6. Listen for the return of breath sounds.
7. Perform the tube thoracostomy procedure once the patient has stabilized.

Complications and Pitfalls

The major complication associated with this procedure is the failure to recognize the presence of a tension pneumothorax. This diagnosis should be made clinically and not with radiographs. If the needle is inserted near the lower margin of the second rib, vascular structures can be damaged. It can be difficult or impossible to perform this procedure in large, muscular adolescents.47

15.2 Tube Thoracostomy

The purpose of a chest tube is to drain an abnormal collection of air, blood, or other fluid from the pleural space and permit full reexpansion of the affected lung tissue.47,48

Indications

The following are indications for placement of a chest tube:

1. The presence of a pneumothorax (air collection in the pleural space) resulting from chest trauma or occurring spontaneously (If a tension pneumothorax is suspected clinically and if the patient is symptomatic, a needle thoracostomy should be performed first, followed by the insertion of the chest tube.)
2. The presence of a hemothorax (blood collection in the pleural space), usually resulting from trauma
3. Tube thoracostomy, which is sometimes used in the treatment of pleural effusion, empyema, or chylothorax
Contraindications
The following are potential contraindications to this procedure:
1. The presence of a coagulopathy
2. The presence of massive hemothorax before fluid resuscitation
3. The patient with a recognized need for open thoracotomy
4. The presence of pulmonary adhesions or blebs

Equipment
Many centers have a prepared tray for chest tube placement.
- Sterile preparation solution, sterile gloves, drapes, face shields
- Local anesthetic, syringes, needles
- Scalpel, curved Kelly hemostats (two or more), suture scissors
- Chest tube of appropriate size
- Water-sealed drainage apparatus
- Needle holder, forceps
- Suture material, 3-0 and 4-0 silk, 4-0 nylon
- Sterile petroleum jelly gauze, sterile 4 × 4 gauze, antibiotic ointment, adhesive tape

Technique
1. Place the patient in the supine position. Elevate the head of bed 30°, if possible.
2. Have the patient place his or her ipsilateral arm behind his or her head.
3. Provide adequate analgesia and/or sedation.
4. Prepare the area in the usual manner.
5. Anesthetize the skin at the site of the planned incision (usually the fourth intercostal space) (Figure 26.64).
6. Anesthetize the subcutaneous tissues (ie, muscle, periosteum of rib, pleura) with a longer needle. Direct the needle along the top surface of the rib to prevent injury to the neurovascular bundle. Aspirate while advancing the needle.
7. Make an incision 1 cm (infant) to 4 cm (adolescent) over the fifth rib at the anterior axillary line through the skin to the muscle layer.
8. Using firm pressure, advance and dissect over the fifth rib with a curved hemostat. The tips should be pointed toward the

Figure 26.63 The needle should be inserted over the top of the rib margin in the fourth intercostal space (pictured) at the anterior axillary line or in the second intercostal space at the midclavicular line.
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thoracic cavity, using small opening and closing motions.

9. When the Kelly hemostat reaches the pleura, guide it over the rib until it passes through the pleura. This is heralded by loss of resistance and a rush of air or fluid.

10. Enlarge the opening by spreading the tips of the hemostat.

11. In a large child, place a gloved finger into the hole that was just created and attempt to palpate lung tissue and/or the inner chest wall. Assure yourself that this is the proper location. (Avoid placement into solid organ.)

12. Discard the trochar from the chest tube and place a closed curved hemostat into a distal side hole of the chest tube.

13. With the tip pointing toward the thoracic cavity, advance the chest tube through the incision, over the rib, and into the thoracic cavity.

14. Guide the chest tube posteriorly and superiorly until all drainage holes are within the pleural space. Posterior placement can be facilitated by rotating the hemostat, holding the chest tube 90° so that the points are directed posteriorly, and then opening the clamp and advancing the tube. Posterior placement is not always required. For example, if the lung is severely collapsed, the lung will reexpand when negative pressure is applied to the chest tube. Only then can it be determined whether the chest tube is posterior or anterior to the lung.

15. Connect the proximal end of the tube to the water seal.

16. Confirm proper placement by observing bubbles in the pleural drainage system when the patient coughs (if possible).

17. Consider using an autotransfusion device for patients with brisk bleeding.

18. Secure the chest tube to the skin using a purse string suture.

19. Wrap the tube with petroleum jelly gauze to prevent leakage of air.

20. Cover with a dressing.

Complications and Pitfalls

The following are potential complications of tube thoracostomy:

1. Damage to the thoracic neurovascular bundle that lies beneath the superior rib
2. Tamponade by the hemothorax of a bleeding vessel, with removal resulting in severe hemorrhage (Clamp the chest tube to reinstate the tamponade, pending definitive surgical care.)
3. Infection at the site or resultant empyema
4. Penetration of solid organs, stomach, diaphragm, or mediastinal structures
5. Subcutaneous emphysema resulting from incorrect placement of the tube dissecting subcutaneously instead of in the pleural space

15.3 Emergency Thoracotomy

This lifesaving procedure requires technical expertise and proper judgment as to when it should be performed. Although survival rates for patients undergoing emergency thoracotomy are low, those whose underlying conditions are
detected and repaired early have a chance of survival to hospital discharge. Patients with penetrating trauma who arrest in transit or in the ED have the greatest likelihood of survival and are the best candidates for this procedure. Patients who incur blunt trauma have little, if any, chance of benefiting from this procedure. The physician should have a clear understanding of the sequence of events that will be performed after the chest is opened. Necessary equipment should be readily available, and a surgeon should be available to provide definitive care if the patient is resuscitated. Opening the chest of a pediatric patient is an extreme procedure that is rarely successful. In the patient with penetrating chest trauma who sustains circulatory arrest in the ED, thoracotomy can provide one last opportunity to save his or her life. Preparation and teamwork are the keys to successful performance of this procedure.

**Indications**

An ED thoracotomy should be considered in the following types of patients:

1. The child or adolescent who incurs penetrating chest trauma and who sustains a circulatory arrest a few minutes before arrival or while present in the ED
2. The patient with penetrating chest trauma who is in shock and who fails to respond to aggressive fluid resuscitation
3. The patient who incurs blunt trauma and sustains a circulatory arrest in the ED during the resuscitation

**Contraindications**

This procedure is contraindicated in those with blunt trauma who sustain a circulatory arrest in the field, in patients who have clearly lethal injuries (eg, decapitation), and in those who have less severe injuries and can be treated by more conservative means or can be safely transferred to the operating room. Lack of a surgeon who can provide definitive management after the emergency thoracotomy should be considered a relative contraindication. Likewise, this procedure should not be performed in mass casualty situations because the physicians should devote their efforts to the care of patients who are likely to survive.

**Equipment**

A prepared tray with all necessary equipment should be available.

- Sterile preparation solution, sterile gloves, drapes, face shields and masks
- Scalpel (No. 10 blade)
- Chest wall retractor (child and adult sizes available)
- Mayo and Metzenbaum scissors, forceps, curved hemostats, right-angle clamps, Lebsche knife or sternal saw
- Foley catheters (various sizes), sutures, pledgets, needle holder
- Chest tubes
- Vascular clamps, aortic cross-clamp instrument

**Technique**

1. With the patient supine, rapidly sterilize the entire thorax with a sterile preparation solution.
2. Locate the left fifth intercostal space (under nipple).
3. Make an incision extending from the sternum to the posterior axillary line, following the natural curve of the rib. Incise through the skin and chest wall muscles.
4. Using Mayo scissors, cut the intercostal tissues and pleura.
5. Insert rib spreaders with the ratchet side down and the handle pointing toward the head.
6. Spread the chest open.
7. Use suction to remove any blood that might obstruct the view of the heart (consider autotransfusion).
8. Identify and repair sources of bleeding, if possible, then proceed.
9. Identify and carefully open the pericardium widely with Metzenbaum scissors to relieve tamponade, and remove clots and/or identify cardiac injury. Remember to keep the heart warm by bathing it in warm saline.
10. Repair ventricular injury by inserting a Foley catheter into the opening and inflating the balloon. The lumen can be used to infuse fluids, if necessary.
11. Other methods for cardiac repair include horizontal mattress sutures or application of sutures with Teflon pledgets.
12. Injuries to coronary arteries should be managed by applying direct pressure until definitive repair can be performed.
13. Open cardiac massage and/or internal defibrillation can be performed.
14. If abdominal injury is suspected, cross-clamp the aorta with a vascular clamp by rotating the left lung anteriorly and dissecting the aorta from the fascia of the spine posteriorly and esophagus anteriorly. Cross-clamping the aorta is performed to preferentially perfuse the heart and brain with available blood. The aorta can also be occluded using direct pressure or an aortic occlusion device.
15. If no obvious injury exists, prepare to extend the incision to the right hemithorax, using a sternal saw or Lebsche knife (to transect the sternum), scalpel, and Mayo scissors. Follow the curve of the fifth rib, opening the chest in a “clam shell” manner.
16. Identify and ligate the internal mammary artery.
17. Identify and repair the source of bleeding.
18. If resuscitation is successful, consult with a surgeon regarding definitive care.

Complications and Pitfalls
Many serious complications are associated with this procedure. However, if the procedure succeeds, a child who would otherwise have died might survive. Therefore, in properly selected patients, the potential benefits outweigh the risks. The most significant complications of thoracotomy are as follows:
1. Inadvertent cutting of breast tissue or breast bud on initial incision
2. Injury to vascular tissues: intercostal, coronary, or intrathoracic vessels
3. Infection, postoperative pericarditis, dysrhythmias
4. Injuries to the heart, lungs, and/or aorta

15.4 Pericardiocentesis
The normal pericardial sac contains 20 to 30 mL of fluid. Larger volumes of fluid are often well tolerated, especially when the fluid accumulates slowly. In some cases, however, the volume of fluid is great enough to significantly affect cardiac function. In such cases, the patient experiences cardiac tamponade. Many patients with cardiac tamponade will eventually require surgery, but, as a temporizing measure, some of the fluid can be drained percutaneously, thus restoring normal or near-normal cardiac function.53

Indications
Pericardiocentesis is indicated for the emergent correction of immediately life-threatening cardiac tamponade. The mere presence of excessive pericardial fluid is generally not an indication for this procedure. Pericardiocentesis is not without risks and should only be performed when there is evidence of circulatory compromise.53

Equipment
- Sedative agents (optional)
- Local anesthetic
- Sterile preparation solution
- Sterile drapes
- Sterile gloves
- Mask
- 3-mL syringe and needle (for local anesthetic)
- 20- to 60-mL syringes
- Needle for procedure:
  - Infant: 2.5 cm (1 inch), 20-gauge needle
  - Older child: 3 to 5 cm (1.5 to 2 inch), 20-gauge needle
Adolescent: 7.5 cm (3 inch), 18- to 20-gauge needle

- ECG monitor
- Alligator clip attached to one precordial lead

**Technique**

1. If time and the patient's clinical condition permit, administer sedation and monitor the patient. The patient should be in the supine position.
2. Apply sterile preparation solution to the precordial area.
3. Apply sterile drapes.
4. Administer local anesthetic (as appropriate) at a point approximately 1 cm to the left of and immediately inferior to the xiphoid process.
5. Place the patient slightly into the reverse Trendelenburg position, if possible.
6. Attach the needle to the syringe and attach the alligator clip to the proximal portion of the needle. If the alligator clip is not available or if time is short, the procedure can be performed using anatomical landmarks alone.
7. Insert the needle into the skin (on the left side and just below the xyphoid) at a 45° angle to the skin surface and direct it toward the tip of the left scapula. In older children and adolescents, some authorities prefer to insert the needle in the left fifth intercostal space, immediately adjacent to the sternum. The needle is inserted perpendicular to the skin and advanced as described below.
8. Advance the needle slowly, aspirating continuously.
9. If fluid is obtained, the pericardial space should be drained as completely as possible.
10. If an ECG lead has been attached to the needle, contact with the ventricular wall is indicated by ECG changes. The most common manifestations are ST segment changes, QRS complex widening, or premature ventricular contractions. If any of these are seen, the needle should be withdrawn slightly until the ECG change disappears. If the ECG tracing does not normalize, remove the needle. If no ECG lead is used, then assign an assistant to watch the cardiac monitor for changes.
11. Accurate needle placement can be aided by ultrasonography or echocardiography, if available.

**Complications and Pitfalls**

Pericardiocentesis is associated with several potentially severe complications. However, in the setting of cardiac tamponade, the risks of the procedure are outweighed by its potential benefits. The most significant complications associated with the procedure are as follows:

- **Pneumothorax**
- **Injury to coronary arteries with subsequent ischemic injury to the heart**
- **Infection**
- **Injury to the heart**
- **Creation of a pericardial effusion or tamponade when none was initially present**

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Section 16: Miscellaneous Procedures

### 16.1 Nasogastric or Orogastric Intubation

**Indications**

A nasogastric or orogastric tube can be used to decompress the stomach in cases of bowel obstruction or to improve the effectiveness of mechanical ventilation by reducing intra-abdominal pressure. Likewise, nasogastric and orogastric tubes can be used in gastric decontamination for unintentional poisoning and for administration of activated charcoal. Finally, many children will not voluntarily drink oral contrast material for computed tomography and will require a nasogastric or orogastric tube for administration of this material. Sometimes enteral rehydration and enteral nutrition using a nasogastric tube can be more efficient than administering fluids and nutrition parenterally.
The choice between orogastric and nasogastric intubation will be dictated by the clinical situation. For simple gastric decompression or enteral rehydration, a small nasogastric tube is often well tolerated. Nasogastric tubes also offer the advantage of being easy to secure, and they cannot be bitten. On the other hand, gastric lavage after ingestion of particulate matter might require a large-bore tube, and such tubes often cannot be passed via the nasogastric route. Likewise, in the patient with facial trauma, nasogastric intubation is contraindicated. Trauma to the face can disrupt the cribriform plate, and attempted passage of a nasogastric tube under such circumstances can result in passage of the tube into the cranium. Other relative contraindications to nasogastric intubation include bleeding disorders, severe epistaxis, and nasal obstruction.

Neither nasogastric nor orogastric intubation should be attempted blindly in the patient with a depressed gag reflex before the airway is secure. The absence of an intact gag reflex places the patient at risk for inadvertent endotracheal intubation.

**KEY POINTS**

**Use of Orogastric and Nasogastric Tubes in Children**

- **Advantages:**
  - Nasogastric—smaller, easier to tolerate
  - Orogastric—larger lumen for lavage and/or charcoal
- **Disadvantages:**
  - Nasogastric—epistaxis, can enter the cranium if the cribriform is fractured
  - Orogastric—more noxious, patient might bite it

**Equipment**

- Phenylephrine (optional—nasogastric)
- Viscous lidocaine (lignocaine) or lidocaine (lignocaine) jelly (optional—nasogastric)
- Nebulized lidocaine (lignocaine) (optional—nasogastric or orogastric)
- 20% Benzocaine spray (optional—nasogastric or orogastric)
- Water-soluble lubricant
- An appropriately sized nasogastric or orogastric tube
- Tape

**Technique**

1. Determine the correct length of tube to be inserted. The time-honored way to accomplish this is to measure along the external surface of the body from the tip of the nose along the side of the face and down to the left side of the epigastric area. For orogastric insertion, the measurement is made from the corner of the mouth to the left epigastric area. An alternative method to determine depth of insertion has recently been described. This method involves the use of a height-based graph (**Figure 26.65**).4

2. When time permits, insertion can be made more comfortable and less traumatic by the following:
   a. If not contraindicated, a small amount of phenylephrine or similar substance sprayed into the nostril will minimize the risk of bleeding.
   b. Swabs coated with viscous lidocaine (lignocaine) or lidocaine (lignocaine) jelly can be inserted into the nostril. This process, although effective, takes several minutes.
   c. For orogastric administration, local anesthetic spray can be used to anesthetize the mouth and throat.
   d. Alternatively, a cooperative patient can inhale nebulized lidocaine (lignocaine) in a standard nebulizer for 5 to 10 minutes.

3. Lubricate the tube well with water-soluble lubricant.

4. Using the dominant hand, insert the tube into the nose. The tube should be parallel to the floor of the nostril (ie, directed posteriorly and not superiorly) and not directed up toward the cribriform plate. For orogastric insertion, the tube is placed into the mouth and directed posteriorly.
In older children, a bite block might be required to prevent biting of the tube.

5. Having the patient flex his or her neck will facilitate gastric intubation.

6. Older children can be directed to swallow, and in the case of nasogastric insertion, infants can be allowed to suck a pacifier.

7. Once the tube has been inserted to the desired length, its position should be confirmed. Traditionally, this determination is made by having one member of the team inject 60 mL of air into the tube while another auscultates the epigastric area. Aspiration of the tube with the return of gastric contents also indicates that the end of the tube is in the stomach. Cooperative patients should be asked to speak. The ability to speak in a normal voice confirms that the tube is not between the vocal cords. Similarly, infants who are crying loudly are not likely to have the tube between the vocal cords, but a muffled or hoarse cry suggests endotracheal placement.

8. Nasogastric tubes can be easily secured to the nose with standard tape. Orogastric tubes are more difficult to secure but can often be taped to the side of the face with standard tape.

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Complications and Pitfalls

Most complications associated with nasogastric and orogastric intubation are minor. The most common of these is epistaxis, although there are several more significant complications. The tube can injure the tonsil or adenoid and cause bleeding. As previously described, injury to the cribriform plate can permit the very unusual but devastating complication of intracranial tube placement. Finally, the tube can be improperly placed, either coiled in the esophagus or, worse, placed in the trachea. This latter complication can be devastating if unrecognized, especially if substances, such as activated charcoal, are administered through the tube.35

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16.2 Catheterization of the Bladder

Indications

Bladder catheterization is a common procedure in most EDs. It is the most reliable method for obtaining a sterile urine specimen in infants and children too young for a “clean catch” specimen. Bladder catheters are also used to monitor urine output in children with dehydration, hemorrhage, and other critical illnesses. In some cases, contrast material must be infused into the lower genitourinary tract for imaging studies. In fact, a urethrogram demonstrating an intact urethra is mandatory before proceeding with bladder catheterization in children with lower abdominal and pelvic trauma. Urinary bladder catheters are used for this purpose. Lastly, urinary catheters are occasionally required to drain the bladder in cases of urethral obstruction (eg, posterior urethral valves) or neurogenic bladder or when medications have caused urinary retention.

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Equipment

- Sterile gloves, preparation solution, and drapes
- Syringes
- Water-soluble lubricant
- An appropriately sized catheter

Technique

1. Determine the size of the catheter to be placed. When a Foley catheter will be used, the size can be determined by using the standard formula of (age/4) + 4 for ETT size selection and then doubling the result. For example, a 4 year old requires a 5.0-mm ETT and a 10F Foley. Alternatively, an 8F catheter can be used for an infant, a 10F catheter for a young child, and a 12F catheter for an older child.

2. Apply sterile preparation solution to the genital area. If necessary, the nondominant hand can be used to manipulate the labia or penis. In uncircumcised boys, the nondominant hand can be used to gently retract the foreskin. The dominant hand should remain sterile, and only this hand should touch the catheter. Apply sterile drapes.

3. Procedure for female patients (Figure 26.66):
   a. Separate the labia. (The presence of labial adhesions can make catheterization impossible. If adhesions are present, the labia should not be forced apart.)
   b. The urethra is located just anterior to the vaginal introitus. It is best visualized by lateral and anterior traction. An assistant can perform this maneuver or the clinician can use his or her nondominant hand.
   c. Insert the lubricated catheter into the urethra until urine is obtained, and then advance the catheter further to ensure that the balloon is within the bladder.
   d. Inflate the balloon and withdraw the catheter until the balloon abuts the internal wall of the bladder.

4. Procedure for male patients (Figure 22.67):
   a. Grasp the penis in the nondominant hand and apply gentle traction such that the shaft is straight and approximately 90° from the body.

Figure 26.66 With girls, the urethra is short and generally easily catheterized with adequate visualization of the urethral meatus.

Figure 26.67  Bladder catheterization for male patients.

b. Insert the lubricated catheter until urine is obtained. Resistance at the external bladder sphincter can be overcome by application of gentle constant pressure and by having the patient relax his abdominal musculature.

c. Advance the catheter until the balloon is well within the bladder, inflate it, and withdraw the catheter until the balloon rests against the internal wall of the bladder.

5. If the catheter is not to remain in place, a simple bladder catheter can be used instead of a Foley, and the catheter can be removed once its purpose has been served.

Complications and Pitfalls
Bladder catheterization is generally quite safe. The most common potential complication is the introduction of bacteria into the bladder and subsequent development of a urinary tract infection. Attention to sterile technique is, therefore, very important. Male patients can sustain damage to the penile urethra if an overly large catheter is inserted or excessive force is applied during insertion. Likewise, it is important to ensure that the balloon is deflated before removing a Foley catheter. Failure to return the foreskin to its normal position in an uncircumcised patient can cause a paraphimosis.\(^5^6\)

THE BOTTOM LINE

Bladder Catheterization
- Female patients: labial or vulvar adhesions are a contraindication.
- Uncircumcised male patients: do not forcibly retract the foreskin.
- All patients: determine correct catheter size and do not use excessive force in catheter placement.

Section 17: Orthopedic Procedures
Bone and soft tissue injuries are among the most common reasons children and adolescents are brought in for emergency treatment. Most of these injuries are minor and can be managed definitively in an ED or a physician’s office. Some, however, will require the involvement of an orthopedic surgeon. If one is immediately available, he or she should be consulted and involved in the patient’s care from the outset. However, some injuries result in restricted blood flow to distal extremities. Because a significant delay in restoration of circulation can leave the patient permanently disabled, the emergency physician might need to take the necessary steps to ensure adequate blood flow before the patient is transferred to the care of an orthopedic surgeon. The procedures described in this section are those required to adequately assess and, if necessary, treat extremity injuries with vascular compromise.

Clinical Features
The presence of ischemia distal to an injury can be subtle. The prudent physician will perform a rapid but complete evaluation of the injured extremity before treatment. The evaluation should be performed as follows:

1. Ensure adequate exposure of the extremity.

2. Pain, fear, and anxiety will make the child less likely to cooperate. These should be addressed as follows:
   a. If possible, apply a splint that encompasses the injury and the points above and below the injury. This step alone can significantly reduce the child’s discomfort.
   b. If necessary, narcotic analgesics can be administered. The goal is to reduce the child’s pain and anxiety without creating sedation. Morphine sulfate (0.1 mg/kg) or fentanyl (1 mcg/kg) can be titrated to achieve the desired effect.

3. Briefly examine the extremity, looking for signs of circulatory compromise. Comparing the injured extremity to the contralateral, uninjured extremity is a good idea. Remember the six Ps that suggest circulatory compromise: (1) pain out of proportion to the injury or distal to the injury; (2) pallor distal to the injury; (3) paresthesias distal to the
injury; (4) paresis; (5) pulselessness (or diminished pulses) distal to the injury; and (6) poikilothermia (coolness) of the extremity distal to the injury. Presence of any one of these suggests circulatory insufficiency. Conversely, the absence of these signs does not rule out a compartment syndrome. For example, strong pulses are frequently present in an acute compartment syndrome.

4. Perform a complete examination of both the injured and uninjured extremities. Pay attention to subtle differences between the extremities and look for less obvious changes, such as diminished capillary refilling time and mild sensory changes.

17.1 Compartment Syndrome

In some cases, injuries to the forearm or lower extremity (below the knee) will result in damage to muscle tissue. Because the muscles are encased within fascial sheaths, there is little room for the tissue to expand to compensate for edema or hematoma formation, and the pressures within the muscle compartment rise. Over time, this elevated pressure can decrease perfusion of the extremity distal to the injury. Most commonly, a compartment syndrome occurs as a result of either blunt or penetrating trauma to the extremity. Rarely, however, recurrent injury to the extremity can result in compartment syndrome as well. When the intracompartmental pressure has become high enough to cause vascular compromise, the patient might be expected to have some of the signs of impaired circulation described above. However, these are late findings (often too late); thus, the diagnosis must be made earlier than this, before irreversible injury occurs. A common misconception is to believe that ischemia occurs when the compartment pressure exceeds arterial pressure, but ischemia and potential infarction occur at intracompartmental pressures well below the arterial pressure.

Clinical Features

Of the six P’s, only pain and paresthesia are usually present during the initial presentation of a compartment syndrome. It is typical yet paradoxical that the patient will often experience pain together with diminished sensation. Muscle tenderness not associated with a fracture or another injury is considered to be a sensitive early sign. Likewise, pain with passive or active stretching of the muscle group also suggests the possibility of a compartment syndrome. Paresis (weakness or paralysis), together with pain and paresthesia, is highly suggestive of acute compartment syndrome. Pulselessness and pallor will occur with an arterial transection or occlusion (e.g., embolization), but a compartment syndrome is actually a venous infarction, so pulselessness and pallor will be absent until infarction has already occurred (i.e., too late). Excessive swelling of the extremity should lead the clinician to consider compartment syndrome,
but this sign is not always present. Splints and casts can also cause a compartment syndrome.

**Diagnostic Studies**

Once a compartment syndrome is suspected, the diagnosis is made by measuring the intracompartmental pressure. Portable, battery-powered devices are made exclusively for this purpose and should be used if available. However, three other methods have been described. 

Intracompartmental pressures between 30 and 45 mm Hg are high risk and can represent a compartment syndrome. The actual numbers are controversial, but intracompartmental pressures in this range or higher require an immediate surgical consultation or surgical intervention. Failure to diagnose a compartment syndrome or intervene in a timely manner will result in irreversible extremity damage (contracture, paralysis, paresis, gangrene, chronic pain). Identification of a compartment syndrome requires immediate orthopedic consultation and surgical intervention to restore perfusion.

**Method 1—The Manometer Method**

This method is the most complex of the three (and it might not work), but it has the advantage of requiring equipment available in most physician’s offices and EDs.

**Equipment**

- A standard mercury manometer
- Two lengths of clear intravenous line tubing at least 10 to 20 cm long
- A three-way stopcock
- Sterile saline or sterile water
- Several sterile 18-gauge needles
- Local anesthetic
- A sterile 20-mL syringe
- 5- to 10-mL syringe
- Sterile preparation material

**Technique**

1. Attach one length of tubing to the manometer and then to the rear port of the three-way stopcock (Figure 26.68).
2. Attach the other length of tubing to the front port of the 3-way stopcock.
3. Draw about 15 mL of air into the 20-mL syringe and attach this to the top port of the stopcock.
4. Attach an 18-gauge needle to the tubing attached to the front port of the stopcock.
5. Open the stopcock to the top and front ports and insert the 18-gauge needle into the bag or bottle of saline or sterile water.
6. Use the syringe to draw saline or sterile water into the system so that liquid fills about half of the length of the front tubing.
7. Close the front port of the stopcock and exchange the needle for a new one.
8. Sterilize the skin over the site of needle insertion.
9. Anesthetize the site, taking care not to inject a significant amount of anesthetic into the muscle compartment, thereby increasing the intracompartmental pressure.
10. Insert the 18-gauge needle into the muscle compartment.
11. Open the stopcock to all three ports.
12. Apply steady pressure to the plunger of the 20-mL syringe. The pressure in the mercury manometer will rise.
13. The manometer reading when the saline in the front tubing just begins to move toward the needle represents the intracompartmental pressure (Figure 26.69).
Method 2—The Intravenous Infusion Pump Method

This method is the easiest, but it requires an intravenous infusion pump that has a manometer feature to measure pressure within the intravenous tubing.

**Equipment**
- An intravenous infusion pump with an internal manometer with a digital readout
- A length of intravenous tubing
- Normal saline or sterile water
- 18-gauge needles
- Sterile preparation material
- Local anesthetic

**Technique**
1. Attach a bag of intravenous fluid to the infusion pump in the standard manner.
2. Attach a sterile 18-gauge needle to the distal end of the intravenous tubing.
3. If the pump can move up and down, it should be moved to the level of the injured extremity. Alternatively, the bed can be raised or lowered.
4. Set the pump to infuse a small amount of fluid (eg, 2 mL per hour).
5. Obtain a baseline reading by pressing and holding the pressure button before the needle is inserted. Ideally, this baseline number will be zero, but it might not be. If the baseline number is negative, it is important to know that some pumps place a limit on the amount of negative pressure that can be accurately reported. Lower pressures are simply reported as the lowest number that the pump can report.
6. Record the baseline pressure.
7. Prepare and drape the area in the standard manner.
8. Anesthetize the skin with local anesthetic as previously described.
9. Insert the needle into the compartment and press the start or pressure button again.
10. Record the pressure obtained and then add or subtract the baseline number as appropriate to obtain the intracompartmental pressure.
Method 3—The Arterial Line Monitor

**Method**

**Equipment**
- A standard multichannel monitor with a module for monitoring the blood pressure using an arterial line manometer
- Sterile saline or sterile water
- 18-gauge needles
- Sterile preparation solution
- Local anesthetic

**Technique**
1. Prepare and drape the area in the standard manner.
2. Anesthetize the skin with local anesthetic as previously described.
3. Set up and zero the monitor or manometer as would be done for an arterial catheter.
4. Attach a needle to the end of the line, prime it with fluid, and insert the needle into the compartment.
5. Infuse a small amount of fluid (<0.5 mL) and read the pressure.

THE BOTTOM LINE

**Compartment Syndrome**
- Compartment syndrome must be recognized early when pain and paresthesia are present.
- Several methods are available to measure compartment pressure.
- Immediate orthopedic consultation and surgical intervention are required to restore perfusion.

17.2 Dislocations

Many dislocations are minor and are easily treated in an office or ED setting. However, some dislocations compromise the distal circulation by compressing, stretching, or tearing major arteries. These dislocations often require urgent reduction to avoid permanent disability.

**Equipment and Personnel**
- Sedative medications and equipment for monitoring and resuscitation
- Splinting materials
- Assistant

17.3 Shoulder Dislocation

The shoulder joint is hypermobile and prone to dislocation with traction when the upper extremity is raised over the head. Common motions associated with a shoulder dislocation include forceful throwing, spiking a volleyball, and serving a tennis ball. Falling onto the shoulder area when the upper extremity is outstretched can also cause a dislocation. Most shoulder dislocations are “anterior” dislocations (the humerus is anterior to the glenoid). A bulge will be visible and/or palpable anterior to the shoulder. This might not be obvious if the patient is obese or very muscular. A fracture can mimic a dislocation or occur in conjunction with a dislocation. Thus, radiographs should be obtained to rule out a fracture before a reduction attempt. Posterior dislocations are uncommon and sometimes associated with severe direct trauma or a seizure. Posterior dislocations usually require reduction by an orthopedic surgeon.

**Technique**

Parenteral analgesia and/or sedation is optional and is based on patient preference. There are many methods to reduce an anterior shoulder dislocation. The external rotation method is described as follows:

1. Have the patient remain supine or sitting up. The affected upper arm should be adducted against the torso. Flex the elbow to 90°.
2. Grasp the patient’s hand and slowly externally rotate the humerus by using the forearm as a lever (Figure 26.70). If the patient experiences pain, administer intravenous analgesia and/or encourage the patient to relax. Once the pain subsides and muscle relaxation is achieved, continue external rotation.
3. As the forearm approaches the coronal plane, reduction occurs spontaneously. This method has the advantage of not requiring strength, traction, or weights.
4. Once reduction has occurred, check for light touch sensation over the lateral portion of the deltoid, then place the patient in a shoulder immobilizer.
Complications and Pitfalls
A branch of the axillary nerve can be injured during a shoulder dislocation. This can be assessed by checking the axillary nerve dermatome over the lateral aspect of the deltoid. Fractures can mimic a dislocation. Even minor trauma can cause a fracture if the bone is weak in this area. The proximal humerus is a common area for bone cysts that can predispose the patient to a pathologic fracture (Figure 26.71). Shoulder dislocations are fairly common in older teens, but they are uncommon in younger children. Young children are more likely to have a fracture. Obtaining radiographs before a reduction attempt is recommended (exception might be those patients who experience recurrent dislocations).

17.4 Elbow Dislocation
Posterior elbow dislocations can occur when a child falls onto the hand of a hyperextended arm. This injury most commonly occurs in adolescent males. In more than half of reported cases, the dislocation is accompanied by a fracture of the distal humerus, the radial head, or the coronoid process.

Technique
1. Administer sedation or analgesia and monitor the patient.
2. Place the patient prone on an examination table. Allow the affected arm to hang over the side of the table.
3. Slightly flex the elbow and apply gentle traction to the proximal forearm. If necessary, an assistant can provide gentle countertraction.
4. Place the thumb of the hand not providing traction onto the patient’s olecranon process and apply gentle forward and downward force while simultaneously gently flexing the elbow.
5. Once the dislocation has been reduced, maintain the elbow in 90° flexion with a posterior splint (Figure 26.72).

Figure 26.70 External rotation technique for reduction of an anterior shoulder dislocation.

Figure 26.71 Bone cyst of the proximal humerus and an associated pathologic fracture sustained during minor trauma.

Figure 26.72 Technique for reduction of elbow joint dislocation.

Complications and Pitfalls
The brachial artery or the median or ulnar nerve can become entrapped during reduction. Entrapment is more likely if the elbow is hyper-extended or pronated during the reduction. Because associated fractures are common, these should be identified.

17.5 Knee Dislocation
Dislocation of the knee is a serious injury. The popliteal artery is relatively fixed within the popliteal fossa, and in approximately 30% to 40% of knee dislocations the artery is torn. Failure to restore adequate circulation to the knee within 6 hours is associated with an 85% incidence of limb loss. The type of dislocation depends on the relative position of the tibia and the femur. When the tibia is positioned forward relative to the femur, the patient has sustained an anterior dislocation. When the tibia is posterior to the femur, the patient has sustained a posterior dislocation.

Technique
1. Administer sedation or analgesia and monitor the patient.
2. Have an assistant apply longitudinal traction to the extremity (Figure 26.73).
3. To reduce an anterior dislocation, lift the femur anteriorly or push the tibia posteriorly.
4. To reduce a posterior dislocation, ensure that the knee is extended but not hyperextended and then lift the tibia anteriorly.
5. After reduction, an evaluation by an orthopedic surgeon and/or a vascular surgeon is mandatory. Most authorities recommend that the patient undergo angiography as soon as possible after the reduction so that injuries to the popliteal artery can be identified and repaired.
6. The knee should be maintained in a knee immobilizer or a posterior splint after reduction.
7. If transfer to another facility is required, it should occur promptly.

Complications and Pitfalls
As previously discussed, the most common complication is injury to the popliteal artery. Injury to the peroneal nerve is also possible. Tibial spine fractures and other fractures of the femur and tibia can occur in association with this injury. In some cases, the dislocation is not reducible. This can occur when soft tissues or bone

Figure 26.73 Technique for reduction of knee joint dislocation.

fragments are interposed between the bones. This is a true medical emergency and warrants an urgent evaluation by an orthopedic surgeon.

17.6 Hip Dislocation
Like a knee dislocation, a hip dislocation represents a true medical emergency. Fortunately, this injury is rare in children. In older children and adolescents, hip dislocation often results from significant trauma, and the patient can have other serious injuries. On the other hand, younger children, presumably because they have more ligamentous laxity, can sustain a hip dislocation with less serious trauma.

Hip dislocations are potentially serious because they place the sciatic nerve and the vascular structures at risk. Posterior dislocations are less often associated with neurovascular injury than are anterior dislocations, although posterior dislocations can injure the sciatic nerve. Anterior dislocations are generally reduced in the operating room with the patient under general anesthesia. This reduction should occur within 6 hours, if possible, to minimize the risk of neurovascular compromise. Posterior dislocations can, however, be reduced in the ED. The technique for reduction of posterior dislocations is discussed below.

Technique
1. Administer sedation or analgesia and monitor the patient.
2. Position the patient on the stretcher in either a prone or a supine position with the knee in 90° of flexion. The hip should be slightly internally rotated and adducted.
3. Apply anterior traction to the leg to fatigue the muscle and overcome muscle spasm. If the patient is in the supine position, the person providing traction can either stand or kneel on the stretcher itself to gain mechanical advantage.
4. Using a gentle external rotary motion of the femur, guide the femoral head laterally and anteriorly over the posterior rim of the acetabulum and into proper position.
5. Once the dislocation is reduced, as evidenced by easy extension of the hip and knee, apply longitudinal traction to maintain the reduction.
6. The patient should be admitted or transferred.

Complications and Pitfalls
Failure of the reduction is the most frequent complication of this procedure. Most failed reductions require reduction in the operating room with the patient under general anesthesia. Avascular necrosis of the femoral head complicates approximately 10% of hip dislocations.

17.7 Splinting
Indications
Splints serve to immobilize and protect injured extremities. They can be used to stabilize fractures pending definitive management, immobilize injured joints, and protect sensitive wounds.61,62

Equipment
- Cotton stocking or sleeve (cotton stocking)—optional
- Soft cotton cast padding roll
- Splint materials—one of the following:
  - Commercial fiberglass or plaster splint material
  - Plaster or fiberglass casting material
  - Preformed metal or plastic splint
- Elastic bandage roll
- Sling (optional)
- Crutches (optional)

Technique
1. Determine the length of splint material required. Measuring of the uninjured extremity is usually more comfortable for the patient. Once the correct length of splint has been determined, the splint material can be prepared as follows:
   a. Commercial splint material can be cut to the desired length.
   b. Plaster or fiberglass casting material often comes in strips or rolls. Several layers (usually 5-15) are usually required to make a strong splint. Roll out the first layer to the desired length, then fold the material and roll out a second layer in the opposite direction. Continue the process until the desired num-
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The number of layers has been added. If one roll is inadequate, additional rolls can be used. If the correct number of layers is reached using a part of a roll, then tear or cut the plaster at that point.

c. Plastic or metal splints for arms and legs are generally preformed and sized; simply select the correct size for the patient. However, some metal finger splints are long strips of padded metal that can be cut to the correct length.

2. If cotton stocking material is to be used, it should be cut to the appropriate length and then applied like a sleeve. If the hand is to be incorporated into the splint, cut a thumb hole in the cotton stocking material. Cotton stocking material has the advantage of protecting the skin but the disadvantage of requiring manipulation of the injured extremity. The cotton stocking material must be loose enough to accommodate swelling of the extremity.

3. Roll one or two layers of cast padding over the cotton stocking material or, if no cotton stocking material has been used, directly onto the skin. As is the case with cotton stocking material, the cast padding should not be so tight as to constrict the extremity.

4. Wet the splint or cast material. In general, fiberglass material requires less water than plaster. Cool or cold water should be used for two reasons. First, the chemical reaction that causes the plaster to harden releases heat, and if the splint is already warm it can seem uncomfortable to the patient as it hardens. Second, hot water can accelerate the process of hardening, which might not allow enough time for the splint to be applied and shaped.

5. Apply the splint material and shape it into the general shape needed.

6. Roll the elastic wrap over the splint material. The elastic wrap should be only tight enough to hold the splint in place.

7. Finish shaping the splint.

8. Keep the extremity and splint in the correct position until the splint has hardened (30-60 seconds, in most cases).62

17.7A Volar Arm Splint

Indications
Indications for a volar arm splint are forearm fractures, Colles fractures, wrist fractures, metacarpal fractures, dislocations, and lacerations.

Technique
To place a splint on the volar surface of the palm and forearm (Figure 26.74), proceed as follows:

1. Measure from the proximal interphalangeal joint (PIP) or metacarpal-phalangeal joint (MCP) joint to:
   a. the midforearm for hand injuries
   b. 6 to 10 cm distal to the elbow for wrist injuries
   c. the midhumerus for forearm injuries
2. Shape the splint with the elbow at 90° flexion, wrist neutral, and the MCP joint at 45° to 90° flexion.

Figure 26.74 Volar arm splint.

17.7B Sugar-Tong Splint (Forearm)

**Indications**

Forearm injuries are the main indication for the sugar-tong splint (forearm). This splint can be combined with an upper arm sugar-tong splint to immobilize the elbow.

**Technique**

To place the splint on the dorsal and volar sides of the forearm, looping around the elbow, proceed as follows:

1. Measure from the palmar PIP joint to the dorsal PIP joint, looping around the elbow.
2. Shape the splint with the elbow in 90° flexion, wrist neutral, and the MCP joint in 45° to 90° flexion.

17.7C Ulnar Gutter Splint

**Indications**

Injuries to the middle, ring, and/or small finger and ulnar styloid fractures are indications for ulnar gutter splints.

**Technique**

To place a splint on the ulnar side of forearm, proceed as follows:

1. Measure from the tip of the longest finger included (often the ring finger) to 7 to 10 cm distal to the antecubital fossa (Figure 26.75).
2. Shape the splint with the wrist neutral and the MCP joint in 50° to 80° flexion.

17.7D Thumb Spica Splint

**Indications**

Injuries to the thumb, scaphoid fracture, and de Quervain tenosynovitis are indications for the thumb spica splint.

**Technique**

To place a splint on the radial side of the forearm and hand, incorporating the thumb but no other digits (Figure 26.76), proceed as follows:

1. Measure from the tip of the thumb to 7 to 10 cm distal to the antecubital fossa.
2. Shape the splint with the wrist neutral, thumb slightly abducted and flexed. The thumb end of the splint should partially encircle the thumb to immobilize it.

Figure 26.75  Ulnar gutter splint.
17.7E Posterior Long-Arm Splint (Upper Extremity)

**Indications**
The posterior long arm splint is most commonly applied for fractures of the elbow (eg, supracondylar fractures of the distal humerus and radial head fractures).

**Technique**
To place a long arm splint from the proximal humerus passing posterior to the elbow, then into the palm, proceed as follows:

1. Measure the distance from the proximal humerus to the palm with the elbow flexed at 90°.
2. It won’t be possible to wrap the humerus portion above the axilla so the proximal end can be moved more distally.
3. Pass the splint material over the elbow, then along the forearm into the palm. The extra length of splint into the palm can be rolled or folded.

17.7F Finger Splints

**Indications**
Finger injuries are the major indication for finger splints.

**Technique**
To place a splint on the palmar and/or dorsal sides of the finger, proceed as follows:

1. Measuring depends on the injury. If the MCP joint is involved, the splint should extend from the finger tip to 2 to 5 cm proximal to the wrist.
2. Shape the splint with the wrist neutral, MCP joint neutral, and PIP and distal interphalangeal joint joints in slight flexion. Small finger fractures can usually be splinted with padded malleable aluminum or metal splints by curving the splint to a position of comfort and applying an elastic bandage starting at the wrist, encompassing the hand, then the injured finger with a neighboring finger, then back to the hand and wrist to finish.

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*Figure 26.76* Thumb spica splint.

17.7G Posterior Splint (Lower Extremity)

**Indications**
Lower limb injuries are the major indication for posterior splints (lower extremity). If the splint is extended above the knee, it can make a “poor man’s” knee immobilizer.

**Technique**
To place a splint on the plantar surface of the foot and posterior leg: (Figure 26.77), proceed as follows:

1. Measuring depends on the injury. For ankle, foot, and distal tibia or fibula, the splint should extend from the great toe to 7 to 10 cm distal to the popliteal fossa. For distal femur, knee, and proximal tibia or fibula, it should extend above the knee to a point approximately half the distance from the popliteal fossa and the lower gluteal fold.

2. Shape the splint with the ankle neutral. If the knee is incorporated into the splint, it should be slightly flexed to allow for crutch walking.

![Image](Figure 26.77) Posterior splint, lower extremity.


17.7H Sugar-Tong Splint (Lower Extremity)

**Indications**
Ankle injuries (including sprains) are the major indication for sugar-tong splints (lower extremity). When combined with a posterior splint, the sugar-tong splint (also called stirrup splint) can be used for more serious injuries (Figure 26.78).

![Image](Figure 26.78) Sugar-tong splint, applied over a posterior splint, lower extremity.


**Technique**
To place a splint on the lateral and medial aspects of the lower leg, looping under the foot, proceed as follows:

1. Measure about 6 to 9 cm distal to the popliteal fossa on either side of the leg.

2. Shape the splint with the ankle neutral.

**Complications and Pitfalls**
The most serious complication associated with splinting is ischemic injury to the extremity secondary to constriction by the splint. This can

**Key Points**
- Perform emergent reduction procedures before splinting.
- Knee dislocation is a true emergency to restore blood flow.
- Obtain orthopedic consultation on dislocations and fractures that might result in neurovascular compromise.
- Review and practice splinting methods.
occur because the cotton stocking material, cast padding, or elastic wrap is put on too tightly or because it is too tight to allow for limb edema. Other complications include mechanical injury to the underlying skin associated with an improperly padded splint and (usually minor) thermal injury when the splint is hardening.

### Fitting
- Determine the height of the patient.
- Choose child, youth, or adult size—each has the range of appropriate patient height written on it.
- Adjust the top of the crutch to a height two fingerbreadths below the axilla.

### Teaching Use to the Patient
- Grasp handles with both hands simultaneously and place crutches a comfortable distance in front (approximately 15-30 cm [6-12 inches]) and to the sides of the planted foot.
- Shift weight to the arms, swinging lower body forward while stepping ahead with uninjured leg. Keep injured leg or foot off the ground by flexing the knee.
- Do not allow the top of the crutch to come in contact with the axilla.

### Points to Emphasize to the Patient
- The purpose of crutches is to protect and rest the injured limb.
- Climb stairs only with assistance.
- Avoid slippery surfaces.
- Wear nonslip footwear. Do not wear flip-flops or sandals.
- Support body weight with the handgrips. Do not press the crutches into the armpits. Hold the elbows straight, with the tops of the crutches pressed against the sides of the upper chest.

### The Bottom Line

**Splinting**
- Splinting an injured extremity reduces pain, swelling, and complications of the injury.
- Splinting is a temporizing measure before definitive orthopedic care.

### 17.8 Crutch Walking

When a fracture of an extremity is suspected, put the extremity to rest and splint it in the anatomical position of function to include the joints above and below the area of injury. Immobilization will reduce pain and reduce the likelihood of further injury to soft tissues as a result of fracture fragment movement. The use of crutches can help rest lower extremity injuries.
**Check Your Knowledge**

1. All of the following statements regarding impedance pneumonography are true EXCEPT:
   - A. display can be affected by patient movement.
   - B. measures chest wall movement.
   - C. measures respiratory effort.
   - D. measures ventilation.
   - E. uses the electrocardiographic (ECG) monitor leads.

2. Which of the following statements regarding basic airway management is correct?
   - A. Chin-lift maneuver is acceptable for most trauma patients.
   - B. Chin-lift maneuver is acceptable for unconscious trauma patients as long as cervical spine films are normal.
   - C. Jaw-thrust maneuver is preferred for trauma patients.
   - D. Nasal airways can only be used in conscious patients.
   - E. Oral airways work best in conscious patients.

3. Which of the following statements regarding pericardiocentesis is correct?
   - A. Any pericardial effusion requires emergency drainage.
   - B. ECG changes, including ST segment changes and premature ventricular contractions, suggest that the needle is in contact with the heart muscle.
   - C. Injury to the coronary arteries during pericardiocentesis has never been described.
   - D. Normal pericardial space contains less than 5 mL of fluid.
   - E. Not possible for a pneumothorax to be created during pericardiocentesis.

4. Which of the following statements regarding compartment syndrome is correct?
   - A. Most patients with compartment syndrome experience pain out of proportion to their clinical findings.
   - B. Muscle tenderness not associated with an underlying fracture or other severe injury is an important sign of compartment syndrome.
   - C. Pulselessness is a late finding (too late).
   - D. Untreated compartment syndrome can result in permanent damage to the extremity.
   - E. All of the above.

**References**


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