Fracture Reduction Procedures
Slipped Capital Femoral Epiphysis
Congenital Dysplasia or Dislocation of the Hip
Spica Cast Placement
Scoliosis
Neuromuscular Scoliosis
Anterior Spinal Fusion

Orthopedic surgery is common in pediatric patients because of the wide variety of bone and muscle injury or disease during childhood. These entities range from simple fractures in healthy children to complex spinal fusions in children with debilitating neuromuscular disorders. Anesthetic considerations for children with these specific disorders are covered in Chapter 5. This chapter focuses on considerations for several types of common orthopedic procedures.

Fracture Reduction Procedures

Pelvic and lower-extremity fractures may be associated with a significant amount of blood loss. The supracondylar fracture at the elbow is one of the most common fractures requiring surgery in children. Accompanying vascular and nerve injury may occur. Nerve injuries (neuropaxia) occur in 15% of cases and resolve spontaneously in most. Primary closed reduction and pinning is the preferred mode of treatment for displaced fractures. The major anesthetic concern is the full stomach. Succinylcholine can be used as a component of a rapid sequence induction, but for most situations a modified rapid sequence induction using rocuronium and propofol will allow for rapid induction of general anesthesia and tracheal intubation.

Slipped Capital Femoral Epiphysis

Slipped capital femoral epiphysis (SCFE), a common hip disorder that occurs during adolescence, is characterized by a displacement of the femoral neck anteriorly, while the femoral head is held within the acetabulum. African-American and Polynesian populations are affected most frequently. SCFE usually affects adolescents aged between 10 and 16 years and has a strong association with obesity. The operative procedure involves percutaneous placement of a femoral head pin within 1–2 days following the diagnosis. The major anesthetic concern is the obesity of these children. Regional anesthesia is possible but is not usually used in children and is not necessary for control of postoperative pain.

Congenital Dysplasia or Dislocation of the Hip

The term CDH (congenital dysplasia or dislocation of the hip) is being replaced by the term DDH...
Scoliosis is defined as a deviation of the spine in the frontal plane. A scoliotic spine also rotates maximally at the apex of the curve. The etiology of scoliosis remains unknown, and the term “idiopathic” remains appropriate when otherwise healthy children develop this condition. For descriptive purposes, the curve locations in children with scoliosis are classified into separate anatomical locations (Table 33-1).

Most cases of idiopathic scoliosis occur in healthy adolescent females. The most important preoperative medical concern in these patients is determination of the severity of restrictive lung disease. In most cases, especially when the scoliosis is idiopathic, there are only mild abnormalities that do not impact on intraoperative ventilation or interfere with successful extubation in the immediate postoperative period. Preoperative pulmonary function testing (PFT) is indicated for curves >80 degrees, or >60 degrees if the child also exhibits reactive airway disease or if an anteroposterior fusion is being performed. A vital capacity less than 30% of predicted may indicate the need for postoperative mechanical ventilation. Severely affected patients may also suffer from cardiovascular dysfunction and will require echocardiography and cardiology consultation.

A thorough discussion should take place with family and patient about the nature and risks of the anesthetic and the surgical procedure. Neurophysiologic monitoring should be explained, especially if it begins in the preoperative period when the patient is conscious. If an intraoperative “wake-up” test is planned, the procedure is discussed in detail with the patient—this will facilitate intraoperative success. The patient and family should also be told that it is common for their face to be extremely swollen postoperatively, and that it will subside over the first two postoperative days. Adolescents may elect to have preoperative intravenous catheter placement, and/or preoperative anxiolysis with oral midazolam.

Preoperative assessment includes hemoglobin and coagulation function testing, and a type-and-crossmatch. Autologous or directed-donor blood donation is performed for most patients. A 1997 study reported that of 168 patients scheduled for idiopathic scoliosis repair, 144 participated in autologous predonation. More than 90% of these patients successfully avoided allogeneic red cell transfusion. Other useful techniques are intraoperative blood salvaging and preoperative erythropoietin administration, especially in cases of Jehovah’s Witness patients. Intraoperatively, normovolemic hemodilution can be useful especially when preoperative autologous blood donation was not performed.

Induction of general anesthesia is performed with standard intravenous or inhalational agents on the patient’s bed or gurney to facilitate turning to the prone position on the OR table. Administration of a moderate dose of a nondepolarizing muscle relaxant to facilitate endotracheal intubation will allow return of neuromuscular function to obtain baseline motor-evoked potentials...
(MEP) before surgery begins. Following induction of general anesthesia and tracheal intubation, and prior to turning the patient prone, all the necessary monitors and lines are inserted. This includes a urinary catheter, nasogastric tube, and two peripheral intravenous lines, one of which should be large enough for rapid fluid and blood administration. The larger-caliber line should be dedicated to the use of warmed fluids. The smaller-caliber line is usually used for infusion of medications.

An arterial line is obtained, usually by cannulating the radial artery. The presence of both an ulnar and radial artery should be checked before cannulating either one. The ulnar artery should not be cannulated if the radial artery on the same side was punctured but not cannulated or if a hematoma of the radial arterial site develops. Early decision to abandon a failed site due to spasm of the artery or hematoma of the site and to move on to the contralateral side will save time and avoid injury.

Maintenance of intraoperative normothermia is essential for avoiding hypothermia-induced coagulation abnormalities and delayed awakening. Hypothermia can be minimized by using a forced warm-air blanket and warming the intravenous fluids and blood products.

Following tracheal intubation and placement of monitors and lines, the patient is placed in the prone position for the procedure. A variety of different types of prone stabilizing devices are utilized, depending on the preference of the surgeon and the institution. All pressure points are well-padded; the anesthesiologist must ensure that the abdomen moves freely with each breath between the pads, and that all skin surfaces are adequately protected, with special attention to the face around the eyes (Fig. 33-3). An increase in intraabdominal pressure may increase bleeding in the epidural venous plexus.

The most important factor that influences the choice of anesthetic agents is the use of evoked potentials to assess spinal cord integrity. Only minimal concentrations of volatile agents are used. Nitrous oxide may or may not be included, depending on the preference of the neurophysiologist. Maintenance of general anesthesia usually consists of a continuous propofol infusion with an opioid (Table 33-2). A remifentanil infusion will allow for easy intraoperative titration tailored to the hemodynamic status. Remifentanil may also preserve integrity of evoked potentials better than intravenous anesthetic agents. If evoked-potential monitoring is not performed, any anesthetic technique can be used.

A variety of neurophysiologic techniques will be used during spinal fusion procedures, depending on the preference of the surgeon and the neurophysiologist. Most commonly, somatosensory evoked potentials (SSEP) and motor evoked potentials (MEP) are used. Their complete description is beyond the scope of this discussion.

A sudden loss of evoked potentials (loss of MEP, or 50% decrease in SSEP) has the same effect as a red traffic light (Fig. 33-4). All surgical momentum stops and, if necessary, the last instrumentation is reversed (e.g., loosening of a pedicle screw or sublaminar wire). The anesthesiologist should increase the mean arterial pressure to at least 90 mmHg. If improvement in the evoked potentials is not observed, the patient is treated with steroids (30 mg/kg bolus of methylprednisolone followed by an infusion at 5.4 mg/kg/h for 23 hours). The instrumentation may be removed and the patient awakened.

Some surgeons still prefer using a Stagnara wake-up test, in which the patient is transiently awakened immediately following spinal cord distraction and asked to wiggle the toes to demonstrate spinal cord integrity. Preparation of the patient is the key to its success. A useful approach is to practice with the child as he or she is being anesthetized by simply asking the child to wiggle the toes several times just before losing consciousness. Even if the wake-up test is not performed, a child who was prepared for it will emerge from anesthesia and wiggle the toes on command rapidly, thus expediting tracheal extubation. It is common practice not to extubate the patient’s trachea until the patient has moved his or her toes, which is the best assurance of spinal cord integrity.

The most common surgical instrumentation used for idiopathic scoliosis is a double-rod technique with hooks or pedicle screws to secure the rods, which are then distracted to straighten the spine (Fig. 33-5). Intraoperatively, at the time when the surgeon is straightening the spine maximally, the spinal cord is vulnerable to ischemia from compression of the arterial supply and from direct damage from insertion of the wires or screws. The anesthesiologist must ensure that the patient is neither anemic nor hypotensive at this point to prevent any decline in oxygen delivery to the spinal cord. Mean arterial pressures are maintained above 70 mmHg and the hemoglobin is raised to over 9 g/dL. During and following the distraction, the neurophysiologist continually monitors the patient’s evoked potential signals to detect any abnormalities that indicate spinal cord compression.

When the surgeon has completed the rod insertion and distraction of the spine and the neurophysiologist is satisfied that the evoked potential signals are intact, the surgeon will begin to close the wound. The anesthesiologist may elect to discontinue all intravenous anesthetic agents and begin administration of N₂O with a small concentration of an inhaled agent, to facilitate rapid awakening at the completion of the procedure. Tracheal extubation is performed after the patient has been turned supine and has demonstrated the ability to move his or her legs and toes to reconfirm spinal cord integrity.

An important aspect of the anesthetic management of these patients is planning for postoperative analgesia. For healthy adolescents, patient-controlled analgesia (PCA) with opioids is the preferred technique. Additional pain control can be gained from administration of
intrathecal opioids. Preservative-free morphine (2.5 µg/kg) is injected into the cerebrospinal fluid (CSF) by the surgeon under direct vision when exposure is obtained. Intrathecal morphine provides prolonged postoperative analgesia and decreased parenteral opioid requirements for the first 24 hours, and may decrease intraoperative blood loss. Placement of an intrathecal opioid requires the child to be admitted to the intensive care unit or another appropriately monitored floor.

**NEUROMUSCULAR SCOLIOSIS**

Commonly encountered neuromuscular diseases include cerebral palsy and various types of myopathies. The primary reason for repairing the spines of these debilitated children is to allow them to sit upright without assistance, thus decreasing the incidence of chronic pulmonary aspiration and extending life-expectancy. The surgical instrumentation used for correction of neuromuscular scoliosis differs from that used for idiopathic repair, and can vary between institutions. The most involved surgical procedure performed in these children is when the spine is instrumented from C7 to the sacrum using a unit rod (Fig. 33-6). These procedures typically involve much greater blood loss than for idiopathic repair, up to 1-3 times the patient’s blood volume. The reason for this increased blood loss in these patients is unclear and is often attributed to their poor nutritional status or lifelong inability to ambulate.

In a study at the author’s institution, when we measured clotting indices in these children, we found abnormally decreased factor levels before and during surgery. Of five patients with severe, spastic cerebral palsy, two had abnormally low factor levels before surgery. All five had at least one factor below normal by the time they lost 25% of their estimated blood volume. Therefore, early use of blood and fresh frozen plasma is recommended. Platelet quantity and quality are often impaired in these children from prolonged use of anticonvulsants. Therefore, if intraoperative bleeding does not abate, or when there is an absence of a clot in the wound despite administration of fresh frozen plasma, administration of platelets is indicated. Procoagulants such as desmopressin (DDAVP), tranexamic acid, and aprotinin have been studied in an attempt to reduce operative blood loss in these patients, but definitive results are lacking.

**ANTERIOR SPINAL FUSION**

Both idiopathic and neuromuscular scoliosis patients may require a combined anterior and posterior spinal fusion. The indications for combined fusion include: (1) a curve >75 degrees, (2) a rigid curve, and (3) patients at risk for crankshaft deformity. A crankshaft deformity is a condition where anterior spinal growth continues despite successful posterior spinal fusion, causing a rotational deformity. This occurs in skeletally immature patients who have potential for further spinal bone growth.

Anterior spinal fusion consists of anterior disk excision, release of the anterior longitudinal ligament, removal of the anulus fibrosis and nucleus pulposus, and excision of the vertebral endplate cartilage through a thoracic approach with the patient positioned laterally. A thoracoscopic approach is preferred by some surgeons, particularly when the number of disks to be released is minimal. This approach will require initial placement of an endotracheal tube that allows single lung ventilation. Most surgeons, however, will employ an open approach which may not intrude within the thoracic cavity. The procedure is often done in combination with a posterior fusion on the same day. Some surgeons may schedule them as separate procedures with several days in between.

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**Case**

A 13-year-old, 55-kg adolescent with idiopathic scoliosis is scheduled for posterior spinal fusion. The preoperative history is positive for reactive airway disease for which she takes albuterol inhaler when needed. Two autologous units of predonated blood are available for intraoperative use.

**Is there anything else you would like to know?**

I would like more details of her reactive airway disease to get a better idea of its severity and frequency. I’ll estimate this by finding out if she’s ever been admitted to the hospital for asthma, and if so, if she required mechanical ventilation. I’ll also find out how often she requires steroid treatment as an indication of the overall severity.

**Should this patient receive premedication?**

An anxiolytic is desirable in this patient. This can consist of oral midazolam 15 mg or oral diazepam 15 mg.
Case Cont’d

How will you maintain general anesthesia for this case?

The neurophysiologist will be monitoring both somatosensory evoked potentials as well as motor evoked potentials, and, therefore, requests TIVA (total intravenous anesthesia). A continuous propofol infusion can be combined with any opioid. Remifentanil is the easiest to use and titrate to hemodynamic status intraoperatively.

After spine exposure and during hook placement, the patient begins to have difficulty maintaining an adequate mean arterial pressure, which is drifting down into the 50’s. What would you do?

An occasional bolus of ephedrine 5–10 mg will allow time to adjust the infusion rates and bring up the mean arterial pressure (MAP), but I need to make sure I don’t lower the propofol too much and risk intraoperative awareness. A bispectral index (BIS) monitor may be helpful here. This situation is almost always amenable to infusion of crystalloid and blood products when appropriate. I will try to keep the urine output steady at 1–2 mL/kg/h, and obtain a blood gas and hemoglobin level to determine the extent of tissue hypoperfusion that is reflected in the severity of metabolic acidosis. The results of these tests will guide further management.

During placement of the second rod, the neurophysiologist states that the motor evoked potential (MEP) on the right side has disappeared. What will you do?

Several things should happen simultaneously. The surgeon should stop whatever he or she is doing and, if possible, loosen the hook. The anesthesiologist should increase the blood pressure by decreasing anesthetic infusions, giving fluids and administering ephedrine or epinephrine. If there is no improvement in the MEP signal by 15–20 minutes, there should be a consideration of administration of steroids. A wake-up test may be indicated at this point, and if still negative, the surgeon should consider reversing all previous spinal instrumentation.

How would you perform a “wake-up” test?

A wake-up test requires a minimum of 20–30 minutes of lead time to prepare the patient for awakening. The anesthetic infusions are discontinued, a 20-mL syringe of propofol is on standby and ready to be injected, an endotracheal (m1) tube with a stylet is immediately available, and the patient’s bed should be in the OR or just outside, in the event that patient needs to be urgently placed in the supine position to secure the airway. As the heart rate and blood pressure begin to rise and the patient starts to breathe spontaneously, a nurse or surgical resident should look under the drapes at the end of the bed to visualize toe movements. When the anesthesiologist believes the patient may be able to follow commands, he or she speaks directly and close to the patient’s ear and asks them to wiggle or move their toes. When the patient has been prepared preoperatively, they will often wiggle their toes when they are seemingly under a fair amount of anesthetic agents. When the surgical team is satisfied, propofol and opioid are rein infused rapidly, and the infusions are continued. Very few, if any, children will remember this sequence of intraoperative events.

Article To Know


This study demonstrates how one should use caution and exercise common sense and good judgment when reading the experimental literature. Eight adolescents undergoing idiopathic scoliosis correction were enrolled in a study in which they predonated blood immediately prior to their surgery to achieve a hemoglobin level of 7 g/dL. This predonation was in addition to the more conventional autologous predonation of 2–4 units of packed red cells 3–30 days prior to surgery. Normovolemia was maintained by infusing 5% albumin. The goal of the study was to determine the safety of hemodilution based on acid-base status and hemodynamic parameters. Further fluid administration during surgery lowered the patients’ hemoglobin to an average of 3.0 ± 1.6 g/dL. One of eight patients had transient ST segment depression that resolved upon reinfusion of autologous blood. In another patient, the mixed venous saturation decreased below 60%, which also triggered retransfusion of autologous blood. Thus, two of eight patients demonstrated limits of cellular oxygen delivery. In spite of these adverse effects, the study concluded that profound hemodilution to a mean hemoglobin level of 3.0 g/dL is safe.

This article is noteworthy because the authors radically lowered these patients’ hemoglobin levels far below what most physicians would consider unsafe, yet few patients demonstrated physiologic derangements and no patient was harmed in any obvious way. The authors attribute their success to the maintenance of normovolemia with colloid administration, and the healthy baseline status of the patients. Despite publication of this report, the practice of allowing hemoglobin levels to decrease below 7 g/dL has not been adopted in most centers.
Acknowledgments
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ADDITIONAL ARTICLES TO KNOW


Table 33-1 Classification of Scoliosis by Anatomic Location

<table>
<thead>
<tr>
<th>Description</th>
<th>Spinal Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical</td>
<td>C2–C6</td>
</tr>
<tr>
<td>Cervicothoracic</td>
<td>C7–T1</td>
</tr>
<tr>
<td>Thoracic</td>
<td>T2–T11</td>
</tr>
<tr>
<td>Thoracolumbar</td>
<td>T12–L1</td>
</tr>
<tr>
<td>Lumbar</td>
<td>L2–L4</td>
</tr>
<tr>
<td>Lumbosacral</td>
<td>L5 or below</td>
</tr>
</tbody>
</table>

Table 33-2 Intravenous Anesthetic Agents during Scoliosis Repair

<table>
<thead>
<tr>
<th>Agent</th>
<th>Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propofol</td>
<td>150–250 µg/kg/min</td>
</tr>
<tr>
<td>Sufentanil</td>
<td>0.2–0.3 µg/kg/h</td>
</tr>
<tr>
<td>Remifentanil</td>
<td>0.1–1.0 µg/kg/min (usually varies greatly during case)</td>
</tr>
<tr>
<td>Fentanyl</td>
<td>2–4 µg/kg/h</td>
</tr>
<tr>
<td>Ketamine*</td>
<td>2–4 µg/kg/h</td>
</tr>
</tbody>
</table>

*The ketamine dose will vary, especially when it is used as the main anesthetic in a neuromuscular scoliosis patient.
Figure 33-1  Schematic drawing of a spica cast that immobilizes both lower extremities and lower torso.

Figure 33-2  A child is placed on a elevated platform while a spica cast is being applied. A folded towel placed beneath the upper part of the case to create room for respiratory movements.

Figure 33-4  The top 'trace' shows a representation of a normal evoked-potential waveform. The second curve depicts loss of the evoked-potential wave following insertion of a hook. The bottom shows eventual recovery of the evoked-potential wave.
Figure 33-3  Prone position with all pressure points padded. Electrodes for evoked potential monitoring are in place.

Figure 33-5  Radiographic views before and after correction of idiopathic scoliosis with a double rod technique. Also shown is a lateral view after correction is included, showing the pedicle screws.
Figure 33-6  Radiographic views before and after correction with a unit rod technique in a child with neuromuscular scoliosis. The spine is fused from T1 to the sacrum.