Patients undergoing orthopedic procedures can be particularly challenging for anesthesiologists. These patients represent a broad scope of problems, ranging from an elderly patient with multiple comorbid conditions to a young, deceptively healthy trauma patient who may have associated injuries that can have a significant impact on the type of anesthetic administered. It is imperative that the anesthesiologist examine the entire patient and not just focus on the area of surgery. In this regard, a complete medical history is important because it may reveal chronic connective tissue diseases that may alter the anesthetic plan.

The field of orthopedics also is changing in many ways that affect the anesthesia care of these patients. Demand for joint replacements in the active aging population is increasing, with the expectation of regional anesthesia, a postoperative pain management plan, and early hospital discharge. More orthopedic procedures are now performed as ambulatory surgery, and the anesthesiologist becomes responsible for which patients can be discharged and how their pain is to be managed. Adult spinal surgery also is dramatically increasing. These procedures can be the most challenging to the anesthesiologist because of difficult airways, hours patients spend in the prone position, large blood loss, and significant postoperative pain.

This chapter discusses the perioperative factors that potentially alter outcome after orthopedic surgery. Complications associated with specific procedures are emphasized with regard to recognition of such complications, avoidance when possible, and management. Choice of the best anesthetic based on current evidence for a given orthopedic procedure also is discussed. In many cases, the pros and cons of regional versus general anesthesia are presented, but this chapter does not concentrate on the technical aspects of regional anesthesia. This chapter provides guidance for anesthesia for patients undergoing common orthopedic procedures.

**PREOPERATIVE EVALUATION**

All patients presenting for orthopedic surgery warrant a thorough preoperative medical evaluation (also see Chapter 38). Any orthopedic patient could represent an anesthetic challenge. Specific types of patients, however, are more likely to have orthopedic surgery and are more likely to have perioperative complications.

**GERIATRIC ORTHOPEDIC PATIENTS**

In 2011, 13% of the U.S. population (41 million) was older than 65 years of age and at least 20 million of these individuals had “advanced” osteoarthritis (see also Chapter 80). In the same year over 600,000 knee replacements were performed. By 2030, the number of U.S. citizens older than 65 years of age is expected to almost double to 72 million. This means that older patients with multiple comorbid conditions will be having increasingly more orthopedic procedures, including total joint replacements.
Postmenopausal and age-associated osteoporosis affects older individuals, increasing their risk for fractures. Age-associated osteoporosis may be the result of increased circulating parathyroid hormone and decreased vitamin D, growth hormone, and insulin-like growth factors. With osteoporosis, a disproportionate loss of trabecular (structural) bone occurs, placing the patient at risk for stress fractures. Although all bones are theoretically at risk, the thoracic and lumbar spine, proximal femur, proximal humerus, and wrist are at the highest risk. Compression fractures of the thoracic and lumbar spine also are common and may require surgical intervention. Osteoporosis compromises the incidence and quality of postoperative fusions. The National Osteoporosis Foundation recommends measuring bone mineral density at the hip or spine in patients at risk and postmenopausal women. Osteoporosis can be partially treated with increased dietary calcium intake and vitamin D and doing weight-bearing and muscle-strengthening exercises, but this population is at risk for fractures with minimal-impact trauma and the pain-relieving joint replacements.

The mortality after hip and knee arthroplasty surgery ranges from 0.4% to 4.6%, depending on primary versus revision replacement surgery. Recent studies suggest that the in-hospital mortality and morbidity after total joint arthroplasty may be decreasing (0.13% to 0.18%), although increased major complications may occur. The in-hospital mortality after repair of hip fractures is 4.8%, and mortality increases to 30% after the first year after hospitalization. The major risk factor for perioperative mortality in all of these studies was advanced age, and the most frequent perioperative complications were cardiopulmonary issues. In their review of 1636 consecutive hip and knee replacements, Parviz and colleagues reported a 6.4% incidence of serious postoperative complications, with the most frequent complication associated with cardiac comorbidities. The reported incidence of a perioperative myocardial infarction at an orthopedic hospital was 0.6% of all nonambulatory procedures (~8000), and 6.5% of those patients were at risk for myocardial ischemia. A nationwide cohort study from the Netherlands reported a significant increase in perioperative myocardial ischemia in the first 2 weeks after total hip replacement (25-fold) and after total knee replacement (31-fold) surgical procedures compared with matched control nonsurgical patients.

**Postoperative Complications**

**Cardiac Complications.** The American College of Cardiology/American Heart Association (ACC/AHA) guidelines recommend preoperative cardiac testing in patients at increased cardiac risk on the basis of clinical risk profile, functional capacity, and type of surgery. The ACC/AHA classify orthopedic surgery as intermediate-risk surgery, which in most cases involves intermediate-risk patients. Older patients have an increased risk for perioperative myocardial morbidity and mortality after orthopedic surgery (see also Chapter 80). The possible reasons for this increased risk are as follows: (1) Many elderly patients have multiple medical comorbid conditions. (2) Elderly patients have limited functional capacity. (3) Some orthopedic procedures initiate a systemic inflammatory response syndrome, (4) some orthopedic procedures are associated with significant blood loss and fluid shifts, and (5) postoperative pain is a major management problem after orthopedic surgery. (see also Chapters 61 and 98). All these factors can trigger a stress response leading to tachycardia, hypertension, increased oxygen demand, and myocardial ischemia.

Because a significant incidence of postoperative cardiac complications occurs after orthopedic surgery, and it is difficult to assess the functional status of these patients owing to the limitations imposed by their orthopedic disease, many of these patients are subjected to preoperative cardiac testing. Data for orthopedic surgery showing that preoperative risk stratification or coronary revascularization, or both, has an effect on outcome are limited, however (see also Chapters 37 and 38). A report by Salerno and associates suggested that preoperative abnormal noninvasive cardiac testing rarely changed medical management before orthopedic surgery. The Decrease-II study questioned the value of preoperative cardiac testing in patients of intermediate risk before noncardiac surgery. In the Coronary Artery Surgery Study (CASS) Registry, Eagle and colleagues reported that coronary artery bypass graft surgery offered no advantage before orthopedic surgery in reducing cardiac mortality. Similar results have been obtained using percutaneous coronary intervention. Postoperative myocardial infarction and death have not been reduced for noncardiac surgery in patients at cardiac risk when preceded by percutaneous coronary intervention. In patients in whom percutaneous coronary intervention involved the placement of stents, restenosis and thrombosis are added risks if antiplatelet therapy has to be discontinued before surgery and increased perioperative bleeding if these medications are not discontinued. If preoperative cardiac testing and revascularization does not decrease postoperative cardiac morbidity, hemodynamic stress reduction might be the answer. Numerous studies have indicated that the use of perioperative adrenergic β-blockers can reduce myocardial ischemia and postoperative myocardial infarctions. Several more recent reports have questioned the efficacy of β-blockers in preventing postoperative cardiac complications, particularly in patients at intermediate risk. In older patients undergoing orthopedic procedures, β-blockers should be continued perioperatively in patients taking long-term β-blockers and initiated in patients at the highest risk, with a target heart rate less than 80 beats/minute.

Patients undergoing orthopedic procedures who are at risk for perioperative cardiac complications should be assessed postoperatively for myocardial ischemia. The diagnosis of a postoperative myocardial infarction is important because these events can be associated with significant cardiac morbidity and mortality if not treated appropriately. In addition, the decision to initiate postoperative physical therapy and rehabilitation, activities that are imperative for optimal mobility in orthopedic patients, depends on whether there has been a diagnosis of a postoperative myocardial infarction. The introduction of plasma cardiac troponin I analysis has markedly increased the ability to detect myocardial damage.
Increases in the plasma concentrations of cardiac troponin I are highly specific for cardiac injury and are a more specific marker for a myocardial infarction after orthopedic surgery than the creatine kinase MB isoenzyme.29,30

Respiratory Complications. The changes in the respiratory system secondary to age may predispose older patients to increased postoperative pulmonary complications. These changes include a progressive decrease in arterial O2 tension, an increase in closing volumes, and a decrease of approximately 10% in the forced expiratory volume in 1 second (FEV1) with each decade of life. Many of these changes are the result of alterations in chest wall mechanics, which are exacerbated in older patients with arthritis. Older patients who have sustained hip fracture have significantly lower PaO2 values than other surgical patients of comparable ages.31 The hypoxia in these patients may reflect the previously noted respiratory changes caused by age, as well as the embolization of bone marrow debris to the lungs after arthroplasty surgery. In addition, with high rates of obesity and obstructive sleep apnea (OSA) prevalent among patients undergoing arthroplasty and spine surgery, respiratory concerns and complications should remain in the forefront of our attention. Patients with OSA are at increased risk for perioperative complications. In a retrospective analysis of patients undergoing hip and knee arthroplasty, OSA was associated with an increased incidence of postoperative transfer to an intensive care unit (ICU).32 Insufficient evidence exists to propose the best perioperative management of patients with OSA; however, preoperative screening using tools such as the STOP-Bang questionnaire and prudent postoperative management would appear to be the best approach.33

Neurologic Complications. After cardiac and pulmonary complications, confusion or delirium is the third most common complication seen in older patients after orthopedic surgery. In 2004, $69 billion from Medicare was spent on the treatment of hospital-acquired delirium. Delirium is associated with an increased length of hospital stay, poor functional recovery, progression to dementia, and increased mortality.34,35 Postoperative delirium manifests as attention and awareness deficits, including acute confusion, reduced ability to focus, change in cognition, irritability, anxiety, paranoia, and hallucinations. Delirium develops acutely, but generally has a fluctuating course over several days (see also Chapter 80).36 Some patients manifest a hypoactive form of delirium, confused but quiet and nondisruptive, which can be difficult to diagnose. The major risk factors for postoperative delirium are advanced age, alcohol use, preoperative dementia or cognitive impairment, psychotropic medications, and multiple medical comorbid conditions. Perioperative events that may trigger delirium include hypoxemia, hypotension, hypervolemia, abnormal electrolytes, infection, sleep deprivation, pain, and administration of benzodiazepines and anticholinergic medications.

Aging alters the pharmacokinetics and pharmacodynamics of most medications, including anesthetics and analgesics. The “usual” adult doses of these medications may have longer and more profound central nervous system (CNS) effects on older patients. Strategies used to reduce the incidence of postoperative delirium include identifying risk factors and vulnerable and affected patients early, preserving orientation, early mobilization, adequate pain control, maintenance of normal sleep cycles, and avoidance of psychotropic medications. Because in most cases patients present with a change in mental status, delirium represents a diagnosis of exclusion. The diagnosis is obtained by conducting a neurologic examination to rule out focal deficits; blood laboratory analysis to eliminate electrolyte abnormalities, hypercarbia, and hypoxemia; a review of all medications to eliminate unnecessary central-acting medications; and adequate pain management. The treatment options range from simple observation with the assignment of a caregiver to pharmacologic management to provide sedation and anxiolytics to prevent the combative patient from harming self or others. Atypical antipsychotics, which are devoid of extrapyramidal side effects, are effective for the acute treatment of delirium.

Fat embolism is a well-known complication of skeletal trauma and surgery involving instrumentation of the femoral medullary canal.37 Fat embolism syndrome (FES) is a physiologic response to fat within the systemic circulation. Fat embolization and FES are not synonymous. The embolization of fat can be detected in almost all patients who sustain a pelvic or femoral fracture, but the incidence of FES is less than 1%.

The clinical manifestations of FES include respiratory, neurologic, hematologic, and cutaneous signs and symptoms. The manifestation of FES can be gradual, developing over 12 to 72 hours, or fulminant, leading to acute respiratory distress and cardiac arrest. Gurd and Wilson38 in 1974 suggested major and minor criteria to be used for the diagnosis of FES (Box 79-1). The presence of any one major finding plus four minor criteria and evidence of fat microglobulinemia was required for the diagnosis of FES. The requirement for fat droplets in the circulation has been
criticized, however, because fat droplets can be detected in the blood of healthy volunteers, and their presence in trauma patients is not always associated with FES.

In addition, Gurd and Wilson recommended the daily assessment of fat droplets in blood, hypothesizing that a change in the quantity of fat would correlate with symptoms. More recent investigations have indicated that the quantity of fat in the circulation does not correlate with the severity of FES symptoms or the development of acute respiratory distress syndrome (ARDS).  

A petechial rash is pathognomonic of FES, with the rash usually present on the conjunctiva, oral mucosa, and skin folds of the neck and axillae. This is reflected in the Schonfeld FES index, which ranks signs and symptoms of FES in relation to their incidence of presentation (Box 79-2). Respiratory signs also are common in FES; approximately 75% of patients present with mild hypoxemia and radiologic evidence of bilateral alveolar infiltrates, but less than 10% progress to ARDS. Neurologic manifestations of FES range from drowsiness and confusion to obtundation and coma. CNS symptoms have developed in the absence of significant pulmonary complications and may represent the passage of fat droplets across an atrial septal defect or other atrioventricular shunt. Magnetic resonance imaging of the brain of these patients has revealed lesions characteristic of fat embolization (Fig. 79-1).

The pathophysiology of FES is unclear, but it probably involves two processes: the embolization of fat and bone marrow debris, which can mechanically obstruct the capillaries of end organs and the triggering of a systemic inflammatory response. Using transesophageal echocardiography (TEE) during total hip arthroplasty (THA), embolization of bone marrow debris has been detected in the right heart at the time of insertion of the cemented femoral prosthesis (Fig. 79-2). In some patients, this embolization resulted in segmental wall motion abnormalities, elevated pulmonary arterial pressures, decreased right ventricular function, and, in one case, cardiac arrest and death.

In most cases, the embolic events during THA are clinically benign, but some patients still progress to FES. The fat emboli lodged in the microvasculature of the lung and other end organs are metabolized to free fatty acids, which trigger a systemic inflammatory response. This inflammatory response involves the invasion of inflammatory cells, the release of cytokines, and, in the lung, pulmonary endothelial damage and ARDS.

The treatment of FES is supportive with early resuscitation and stabilization to minimize the stress response to hypoxemia, hypotension, and diminished end-organ perfusion. Patients at risk for developing FES should be monitored with pulse oximetry, and tracheal intubation and mechanical ventilation should be instituted before respiratory failure. Although 10% of patients with FES may require mechanical ventilation, in most of these patients the symptoms resolve within 3 to 7 days. Corticosteroids have been studied extensively in the management of FES, with many investigators reporting beneficial effects, but other reports contradict these results. Well-controlled studies with defined outcomes are required before corticosteroids can be recommended in the treatment of FES.

**SPECIAL CONSIDERATIONS IN CONDITIONS LEADING TO ORTHOPEDIC SURGERY**

**Osteoarthritis**

Approximately 22% of the U.S. population (46 million) has been diagnosed as having arthritis, and 8% (17 million) have limitations in physical activity because of arthritis. Osteoarthritis is the most common type of arthritis and involves the loss of articular cartilage and associated inflammation. In most cases, osteoarthritis is a disease of aging, with 90% of women and 85% of men demonstrating the radiologic loss of articular cartilage after age 65 years. Clinical manifestations include pain, crepitance, reduced mobility, and deformity of involved joints. Physical examination of the hands may reveal spurring and swelling of the distal interphalangeal joints (Heberden nodes) and proximal interphalangeal joints (Bouchard nodes).

Although osteoarthritis has no systemic manifestations, the anesthesiologist should be cognizant of previous orthopedic surgeries (including joint replacements) and which joints are painful and have limited mobility.

**BOX 79-2 Schonfeld Fat Embolism Syndrome Index**

<table>
<thead>
<tr>
<th>Sign</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petechial rash</td>
<td>5</td>
</tr>
<tr>
<td>Diffuse alveolar infiltrates</td>
<td>4</td>
</tr>
<tr>
<td>Hypoxemia: PaO2 &lt; 70 mm Hg, FiO2 100%</td>
<td>3</td>
</tr>
<tr>
<td>Confusion</td>
<td>1</td>
</tr>
<tr>
<td>Fever &gt; 38°C (&gt;100.4°F)</td>
<td>1</td>
</tr>
<tr>
<td>Heart rate &gt; 120 beats/minute</td>
<td>1</td>
</tr>
<tr>
<td>Respiratory rate &gt; 30 breaths/minute</td>
<td>1</td>
</tr>
</tbody>
</table>

* Score greater than 5 required for diagnosis of fat embolism syndrome.

This information is important for surgical positioning and the choice of an appropriate anesthetic. An axillary block of the brachial plexus for forearm surgery is inappropriate in a patient with significant ipsilateral shoulder arthritis. Although the operative site would be completely anesthetized, the patient may complain of painful shoulder movement during the procedure. The appropriate regional anesthetic would include the arthritic shoulder; an appropriate anesthetic might be an interscalene block.

**Rheumatoid Arthritis**

Rheumatoid arthritis (RA) is a chronic inflammatory form of arthritis that affects approximately 1% of adults, with a prevalence two to three times higher in women than in men. RA is characterized by persistent joint synovial tissue inflammation leading to bone erosion, destruction of cartilage, and loss of joint integrity. RA is also a systemic disease, affecting multiple organ systems. It often progresses through multiple exacerbations and remissions, but 20% to 30% of affected individuals become permanently disabled within 3 years of diagnosis.

The diagnosis of RA is primarily clinical. Patients commonly present with pain and stiffness in multiple joints. RA is characterized by morning stiffness often lasting more than 1 hour after initiating activity. Usually the wrists and metacarpophalangeal joints are involved; this distinguishes RA from osteoarthritis, which often affects distal interphalangeal joints. The symptoms may emerge over weeks and months, progressing from one joint to multiple joints, and may be accompanied by symptoms of anorexia, fatigue, and weakness. The rheumatoid joints are usually boggy, tender to the touch, and warm. Patients may have prominent epitrochlear, axillary, and cervical lymph node enlargement. Subcutaneous nodules (rheumatoid nodules) may surround joints, extensor surfaces, and bony prominences.

No single diagnostic laboratory test confirms the diagnosis of RA, but rheumatoid factor, an immunoglobulin antibody, is elevated in 90% of patients with RA. In addition, C-reactive protein and erythrocyte sedimentation rate are elevated in patients with RA and are often used to monitor the course of the disease. RA also must be differentiated from other diseases that manifest as polyarthropathies, including seronegative spondyloarthropathies, connective tissue diseases (scleroderma, lupus), fibromyalgia, hemochromatosis, polyarticular gout, polymyalgia rheumatica, and sarcoidosis.

Because joint destruction begins early with RA, disease-modifying antirheumatic drugs should be initiated immediately with the therapeutic goal of preservation of function and quality of life. The most commonly used disease-modifying antirheumatic drugs include methotrexate, hydroxychloroquine, sulfasalazine, leflunomide, infliximab (Remicade), and etanercept (Enbrel). These medications are associated with an increased risk for infection, which is a significant concern in patients with joint replacements. Pharmacotherapy also usually involves a nonsteroidal antiinflammatory drug (NSAID) and oral or intraarticular glucocorticoids. Patients with RA who are taking NSAIDs should be assessed for gastrointestinal side effects and renal complications. Glucocorticoids, although highly effective at relieving symptoms, should be used at low doses and sparingly because of their side effects, which include osteoporosis, cataracts, cushingoid symptoms, and hyperglycemia. Patients taking significant quantities of glucocorticoids need stress-dose steroids for their operations.

Because of the myriad systemic problems associated with RA and the side effects of the medications administered...
to manage RA, the anesthetic considerations can be complex (Table 79-1). The skin is often susceptible to tearing from adhesive tape and bruising from automated blood pressure devices and pressure from positioning. Airway management can be particularly challenging in patients with RA and requires preplanning even in patients receiving regional anesthesia because of the complexity of their airways (see later discussion). Synovitis of the temporomandibular joint may significantly limit mandibular motion and mouth opening in these patients. Arthritic damage to the cricoarytenoid joints may result in diminished movement of the vocal cords, resulting in a narrowed glottic opening; this is manifested preoperatively as hoarseness and stridor. During laryngoscopy, the vocal cords may appear erythematous and edematous, and the reduced glottic opening may interfere with passage of the endotracheal tube. Risk also increases for cricoarytenoid dislocation with traumatic endotracheal intubations.

Arthritis of the cervical spine is common in patients with RA. Anterior subluxation of C1 on C2 (atlantoaxial subluxation) may occur in 40% of patients with RA, with symptoms of progressive neck pain, headaches, and myelopathy (Fig. 79-3). Posterior and vertical migration of the odontoid process is less common. Flexion of the head in the presence of atlantoaxial instability could result in the displacement of the odontoid process into the cervical spine and medulla and compression of the vertebral arteries (Fig. 79-4). This may precipitate quadriparesis, spinal shock, and death. Preoperative cervical flexion-extension radiographs should be evaluated in patients with RA who have limited neck movement and neurologic symptoms. If the distance from the anterior arch of the atlas to the odontoid process exceeds 3 mm, the patient should undergo an awake fiberoptic tracheal intubation and the cervical spine should be protected with a cervical collar during the procedure. These patients require postoperative monitoring with pulse oximetry and judicious administration of opioid analgesics because emergent airway management, including tracheotomy, is extremely difficult.

The anesthesiologist also should be aware of several extraarticular manifestations of RA, which could potentially result in significant perioperative morbidity. Patients with RA frequently are affected with acute pericarditis. Restrictive pericarditis is characterized by dyspnea, right heart failure, fever, chest pain, pericardial friction rub, and pulsus paradoxus. Patients with RA who have these symptoms should be evaluated by echocardiography. Pleural disease and intrapulmonary nodules can occur in RA, but are usually asymptomatic. Some patients with RA also may have diffuse interstitial fibrosis.

### Table 79-1: Anesthetic Considerations for Patients with Rheumatoid Arthritis

<table>
<thead>
<tr>
<th>Category</th>
<th>Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airway</td>
<td>Limited TMJ movement</td>
</tr>
<tr>
<td></td>
<td>Narrow glottic opening</td>
</tr>
<tr>
<td>Cervical spine</td>
<td>Atlantoaxial instability</td>
</tr>
<tr>
<td>Cardiac</td>
<td>Pericarditis</td>
</tr>
<tr>
<td></td>
<td>Cardiac tamponade</td>
</tr>
<tr>
<td>Eyes</td>
<td>Sjögren’s syndrome</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>Gastric ulcers secondary to ASA, steroids</td>
</tr>
<tr>
<td>Pulmonary</td>
<td>Diffuse interstitial fibrosis</td>
</tr>
<tr>
<td>Renal</td>
<td>Renal insufficiency secondary to NSAIDs</td>
</tr>
</tbody>
</table>

ASA, Acetylsalicylic acid; NSAIDs, nonsteroidal antiinflammatory drugs; TMJ, temporomandibular joint.

**Figure 79-3.** Magnetic resonance image of a patient with advanced rheumatoid arthritis shows invagination of the odontoid process of C2 (arrow) through the foramen magnum, compressing the brainstem. Notice the degeneration of C4 and C5, a common problem in rheumatoid arthritis.

**Figure 79-4.** Computed tomography scan of the neck shows moderate subluxation of C1 and C2. The odontoid (single arrow) tends to compress the spinal cord (double arrow) against the posterior arch of C1, especially during neck flexion.
with pneumonitis, producing symptoms of progressive dyspnea and a chronic cough. Pulmonary function tests show a restrictive ventilatory pattern. This pattern can progress to respiratory insufficiency, pulmonary hypertension, and right heart failure. These patients would be at higher risk with any orthopedic procedure.

Overlapping connective tissue syndromes also occur. Patients with RA can develop Sjögren’s syndrome, which is associated with drying of the eyes and conjunctival lesions. It is usually treated with artificial tears and ophthalmic ointments, which should be continued perioperatively. Patients with RA and chronic constitutional systems may develop Felty syndrome, which includes splenomegaly, lymphadenopathy, anemia, thrombocytopenia, and leukopenia involving the neutrophils.

**Ankylosing Spondylitis**

Ankylosing spondylitis is a chronic inflammatory arthritic disease that results in fusion of the axial skeleton. Ankylosing spondylitis involves ossification of the axial ligaments progressing from the sacral lumbar region cranially, resulting in a significant loss of spinal mobility (Fig. 79-5). These patients are a significant challenge to the anesthesiologist with regard to airway management because of the reduced movement of their cervical spines and their temporomandibular joints. In most cases, awake fiberoptic endotracheal intubation is required for general anesthesia. The increased rigidity of the thoracic spine in most cases also necessitates intraoperative controlled mechanical ventilation. Although sometimes neuraxial anesthesia can be an attractive alternative to general anesthesia, in these patients the ossification of the spinal ligaments closes the intervertebral spaces, which may block access to the epidural space and prevent successful spinal anesthesia. In some cases, caudal epidural anesthesia may be a feasible alternative approach.

Extraskelatal manifestations of ankylosing spondylitis include aortic insufficiency, cardiac conduction abnormalities, iritis, upper lobe fibrobulous disease, and pleural effusions. Strict attention to intraoperative positioning is needed to avoid fracture of the fused spine with concomitant spinal cord trauma.

**Achondroplasia**

Achondroplasia is the most common cause of dwarfism, with short stature, short trunk, and disproportionate development. The estimated incidence is 1 in 26,000. Achondroplasia is transmitted by an autosomal dominant gene. Affected individuals are of normal intelligence and can lead a full and productive life. Their associated medical problems often require orthopedic surgical intervention, however, with the risk for perioperative complications. The most serious complication of achondroplasia is premature fusion of the base of the skull resulting in a narrowed cervical canal, foramen magnum stenosis, or both. Kyphoscoliosis with kyphoscoliosis, and laminectomies for spinal nerve root compressions.

Conventional laryngoscopy and tracheal intubation can be difficult and dangerous in achondroplastic dwarfs. Laryngeal exposure via direct visualization may be difficult in dwarfs with cervical kyphosis, and neck flexion should be avoided in dwarfs with atlantoaxial instability or foramen magnum stenosis. Awake fiberoptic tracheal intubation is the safest approach to securing the airway in these patients. Intravenous sedation should be administered judiciously during the preparation of the airway because many of these patients experience central sleep apnea owing to brainstem compression. Severe episodes of sleep apnea also can occur in these patients without any other clinical evidence of cord compression.

When the airway is secured, dwarfs can still represent an anesthetic challenge because of restrictive lung disease and pulmonary hypertension. Pulmonary hypertension develops in chronic hypoxemia and hypercarbia secondary to airway obstruction, sleep apnea, and thoracic kyphoscoliosis. Preoperative spirometry can be difficult to interpret in a dwarf, with successive changes in measurements more useful than absolute values. An echocardiogram should be obtained before major surgery to assess the degree of pulmonary hypertension and intracardiac shunts. Pulmonary hypertension leading to cor pulmonale is the most common and devastating cardiovascular complication that develops in dwarfs. In these patients, the anesthetic must avoid aggravating pulmonary hypertension (hypoxemia and acidosis) and ensure adequate cardiac output and end-organ perfusion. In many cases, it is safer to allow the patient to remain intubated and monitored in the ICU until fully awake and spontaneously ventilating.

**ORTHOPEDIC PROCEDURES IN CHILDREN WITH SPECIAL CONDITIONS**

The anesthetic management of pediatric patients undergoing orthopedic surgery is beyond the scope of this chapter (see also Chapters 92 and 93). In most cases, care of pediatric patients would be similar to that for other surgical procedures, except that in many cases regional
Anesthesia might be a preferred alternative to general anesthesia. However, a few pediatric diseases predispose children to multiple orthopedic procedures.

Juvenile Idiopathic Arthritis

Juvenile idiopathic arthritis (JIA) is inflammation of the synovium of the joints that occurs before 16 years of age. JIA is classified into five types, as follows:

1. Oligoarthritis accounts for 50% of JIA and involves fewer than five joints; often these patients also have uveitis.
2. Polyarthritis involves arthritis in five or more joints.
3. Systemic arthritis accounts for 10% to 20% of JIA and is characterized by associated high fever, rash, and nonarticular organ involvement.
4. Enthesitis-related arthritis affects the spine, hips, and attachment points of tendons to bones.
5. Psoriatic arthritis includes psoriasis and arthritis.

As in adult RA, the disease is chronic with quiescent periods interspersed with acute exacerbations. Also as in adult RA, airway issues can make tracheal intubation difficult and potentially dangerous. In most cases, fiberoptic intubation should be performed, and this can be done after the child has been anesthetized and is breathing spontaneously. Muscle relaxants should be reserved until the airway is secured. In contrast to adult RA, pulmonary disease is uncommon, but patients with JIA can have associated pleuritis, pleural effusions, and pneumonitis. Pericarditis is common in patients with JIA, and it responds to steroid therapy. Some patients with JIA also have myocarditis and conducting system abnormalities. In addition, vascular access in patients with JIA can be extremely difficult because of fragile veins and a tendency to bruise and bleed easily. As with adult RA, patients with JIA are managed with similar groups of medications with similar potential complications.

Osteogenesis Imperfecta

Osteogenesis imperfecta is a rare autosomal dominant inherited disease that results in extremely brittle bones because of a defect or deficiency in type I collagen production. Repeated and multiple bone fractures are the most significant clinical manifestation of this disease (Table 79-2). In the most extreme form, multiple fractures occur during delivery and are often fatal. In the milder variations, the individual is affected by multiple fractures produced with seemingly inconsequential force or trauma. Fractures are more common in the lower extremity, with the femur being the most commonly broken bone. Fracture deformities of the pelvis can lead to acetabular protrusions into the abdomen. Kyphoscoliosis is common secondary to decreased ligamentous stability. Affected children usually have a blue sclera because of defective collagen production. Impaired platelet function with increased perioperative bleeding also occurs.

Although osteogenesis imperfecta has been associated with malignant hyperthermia, this has not been verified by muscle biopsy (see also Chapter 43). Hyperthermia and metabolic acidosis can, however, be common intraoperative clinical manifestations of osteogenesis imperfecta. Associated cardiac abnormalities include patent ductus arteriosus, septal defects, and acquired aortic regurgitation and cystic degeneration of the proximal aorta (see also Chapters 93 and 94).

The fragility of connective tissue and bones in osteogenesis imperfecta demands extreme care in positioning and padding during anesthesia. The area under the blood pressure cuff must be padded, and for longer procedures insertion of an arterial catheter avoids the repeated inflation of the cuff and the risk for a humeral fracture. Because patients with osteogenesis imperfecta often have reduced mobility of the cervical spine, tracheal intubation must be achieved with minimal neck manipulation. Fiberoptic intubation techniques in many cases would be the prudent approach. The administration of succinylcholine should be avoided for the induction of anesthesia not only because of the theoretic risk for hyperkalemia and hyperthermia but also because muscle fasciculations may produce bony fractures. Patients with osteogenesis imperfecta should have a preoperative echocardiogram, and any abnormal findings should be managed accordingly.

The bleeding status of patients with osteogenesis imperfecta should be evaluated preoperatively to prepare for the perioperative transfusion of platelets. In some cases, desmopressin (DDAVP) may reverse the platelet abnormality. Because of the risk for intraoperative hyperthermia and metabolic acidosis, patients with osteogenesis imperfecta should be aggressively hydrated, and, if necessary, active cooling should be instituted. Regional anesthesia is an attractive alternative to general anesthesia, but must be approached with caution to avoid bone punctures and intraosseous injections (see also Chapters 57 and 58).

Cerebral Palsy

Cerebral palsy is a nonprogressive motor impairment arising from lesions in the brain that occurred during the early stages of development—in utero (75%), at birth (10%), and soon after birth (15%) (see also Chapter 93). The cause of cerebral palsy remains unclear; however, intrapartum asphyxia, which was originally thought to be the major cause of the disease, may be responsible for only 10% of the cases. Perioperative infections and low birth weight may play a much more important role. Cerebral palsy is divided into four major classifications to describe the different movement impairments: spastic, athetoid/dyskinetic, ataxic, and mixed. Spastic cerebral palsy, which is the most common type, results from

<table>
<thead>
<tr>
<th>TABLE 79-2</th>
<th>ANESTHETIC CONSIDERATIONS FOR PATIENTS WITH OSTEOSGENESIS IMPERFECTA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Airway</strong></td>
<td>Risk for fractures of the mandible, maxillary surface, and cervical spine</td>
</tr>
<tr>
<td><strong>Bleeding</strong></td>
<td>Platelet abnormalities</td>
</tr>
<tr>
<td><strong>Cardiac</strong></td>
<td>Congenital and valvular heart disease, cystic degeneration of proximal aorta</td>
</tr>
<tr>
<td><strong>Eyes</strong></td>
<td>Exophthalmos—prone positioning</td>
</tr>
<tr>
<td><strong>Hyperthermia</strong></td>
<td>Malignant hyperthermia, hydration, possible cooling</td>
</tr>
<tr>
<td><strong>Positioning</strong></td>
<td>Risk for repeated fractures</td>
</tr>
<tr>
<td><strong>Pulmonary</strong></td>
<td>Kyphoscoliosis—restrictive lung disease</td>
</tr>
<tr>
<td><strong>Regional anesthesia</strong></td>
<td>Fractures, intraosseous injections</td>
</tr>
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</table>
damage to the corticospinal tract, motor cortex, or pyramidal tract. Many of these affected children also have epilepsy and cognitive disorders.  

Although the neurologic deficit in cerebral palsy is nonprogressive, the secondary orthopedic consequences of the disease lead these patients to multiple surgical procedures. Normal skeletal development requires stress from the musculature to attain proper shape and size. Without these stresses or with abnormal stresses, as in cerebral palsy, various angular joint deformities and gracile (thin) shafts and abnormal articular joints develop. Orthopedic surgeries often involve loosening of tight muscles (hip adductor and iliopsoas release), releasing fixed joints, straightening abnormal twists (derotational osteotomy of the femur), rhizotomies to reduce spasm, and spinal surgery to correct kyphoscoliosis.

Patients with cerebral palsy have significant gastroesophageal reflux and poor laryngeal reflexes, placing them at risk for pulmonary aspiration. In most cases, surgical procedures in patients with cerebral palsy require general anesthesia with tracheal intubation, even if also accompanied by regional anesthesia to reduce the need for systemic anesthetics and to provide postoperative analgesia. Postoperative epidural analgesia with local anesthetic alone eliminates the potential complications of opioids and permits continued dosing with diazepam to relieve spasms. Regional anesthesia also may shorten emergence from general anesthesia, which can be prolonged because of inherent cerebral damage and the effects of antiseizure medications. Postoperative pulmonary complications are common owing to multiple causes, including aspiration, poor respiratory effort, and reduced thoracic compliance. After major surgical procedures, cerebral palsy patients should be observed in a monitored setting for several hours.

### PERIOPERATIVE MANAGEMENT OF ORTHOPEDIC PATIENTS

#### THROMBOPROPHYLAXIS IN ORTHOPEDIC SURGERY

Thromboembolic complications remain one of the leading causes of morbidity and mortality after orthopedic surgery. THA, total knee arthroplasty (TKA), and hip and pelvic fracture surgery have the highest incidence of venous thromboembolism, including DVT and PE. Patients with DVT and PE are at risk for short-term and long-term morbidity and mortality. Patients with a symptomatic PE have an 18-fold higher risk for death than patients with a DVT alone. The short-term complications of survivors of acute DVT and PE include prolonged hospitalization, bleeding complications related to DVT and PE treatments, local extension of the DVT, and further embolization. Long-term complications include postthrombotic syndrome (hypoxemia and pulmonary hypertension) and recurrent DVTs.

Because venous thrombi consist of fibrin polymers, anticoagulants should be administered for the prevention and treatment of DVT. Thrombolytics should be administered only in the event of a severe, possibly fatal PE. Perioperative treatment should follow the guidelines of the Ninth American College of Chest Physicians Conference on postoperative DVT and PE. Low-molecular-weight heparin (LMWH) is recommended over unfractionated heparin (intravenous or subcutaneous) for initial therapy of DVT and PE. LMWHs do not require monitoring for the degree of anticoagulation. Although DVT prophylaxis may be more efficient when started preoperatively, the risk for surgical bleeding also increases. LMWH for thromboprophylaxis should be started either 12 hours or more preoperatively, or 12 hours or more postoperatively,

### REGIONAL VERSUS GENERAL ANESTHESIA

Many orthopedic procedures are well suited for regional anesthetic techniques (see also Chapters 57 and 92). The controversy as to whether regional anesthesia has an advantage over general anesthesia has been debated for decades without clear evidence documenting the superiority of one method. Regional anesthesia may reduce the incidence of major perioperative complications with certain surgical procedures, however, including deep vein thrombosis (DVT), pulmonary embolism (PE), blood loss, respiratory complications, and death. In addition, regional anesthetic techniques provide superior pain relief after orthopedic surgery. Peripheral nerve blocks employing long-acting anesthetics or catheters provide both excellent intraoperative anesthesia and superior postoperative analgesia. Regional anesthesia may provide preemptive analgesia, and some evidence exists that regional analgesia may block the progression of severe acute postoperative pain into a chronic pain syndrome. In addition to improved pain control, functional outcome in the form of physical therapy milestones may benefit from both regional anesthesia and analgesia.
rather than within 4 hours or less preoperatively or 4 hours or less postoperatively (grade 1B).74,75 Extended prophylaxis to 35 days after surgery in the outpatient period would be supported in most patients undergoing major orthopedic surgery (grade 2B).74 Risk factors for the development of PE after surgery are advanced age, obesity, previous PE and DVT, cancer, prolonged bed rest, and thrombophilia. Thrombophilia is a prothrombotic condition that increases the risk for perioperative DVT. Many are hereditary conditions that increase the activity of coagulation factors. Factor V Leiden is the most common hereditary thrombophilia associated with DVT. Warfarin (Coumadin) is often employed in the long-term treatment of DVT, with a target international normalized ratio (INR) of 2.5 maintained for the duration of therapy. Warfarin exerts its anticoagulant effect by blocking vitamin K–dependent coagulation factors (predominantly factor VII); thus a lag occurs in biologic effectiveness while endogenous factor activity decays and new inactive factors are synthesized. Therefore, because the anticoagulation effects of warfarin may take days and its biologic activity can be unpredictable, many have advocated the use of LMWH. In the United States, LMWH (enoxaparin) is administered at 30 mg every 12 hours, and considerably higher doses of LMWH are administered for DVT treatment. In all cases, spinal hematoma is a risk after neuraxial anesthesia.

Recently alternatives to warfarin and LMWH have been developed. Fondaparinux, a synthetic pentasaccharide, is a selective inhibitor of factor Xa and has a plasma half-life of approximately 18 hours. When administered once daily, fondaparinux produces a predictable anticoagulant response.76 Dabigatran is a thrombin inhibitor with a plasma half-life of approximately 8 hours, which is prolonged in individuals with renal insufficiency. Dabigatran will prolong the activated partial thromboplastin time, but this effect is not linear and should not be used as an indication of the degree of anticoagulation. At present, the only reversal agent available for dabigatran is recombinant factor VIIa.

The American College of Chest Physicians guidelines do not recommend the sole use of aspirin or DVT prophylaxis after THA, TKA, and hip fracture surgery. Some recent reports, however, have supported the use of aspirin, pneumatic compression, and early mobilization as the sole effective prophylaxis for DVT after THA and TKA.77

The use of perioperative anticoagulants has a significant impact on the use of regional anesthesia, in particular neuraxial anesthesia, with the potential risk for an epidural hematoma. The American Society of Regional Anesthesia (ASRA) published and updated consensus conference recommendations with regard to the use of anticoagulants and regional anesthesia.78 Full anticoagulation is a contraindication to regional techniques. The risk for an epidural hematoma is significantly increased with the use of LMWH, so the ASRA issued the recommendations listed in Box 79-3.

Aspirin and NSAIDs do not appear to increase the risk for an epidural hematoma after neuraxial anesthesia.79 The latest ASRA recommendations for patients receiving warfarin and other anticoagulants are listed in Box 79-4.
PART V: Adult Subspecialty Management

BOX 79-4 Regional Anesthetic Management of the Patient on Oral Anticoagulants

1. Caution should be used when performing neuraxial techniques in patients recently discontinued from long-term warfarin therapy. In the first 1 to 3 days after discontinuation of warfarin therapy, the coagulation status (reflected primarily by factor II and X levels) may not be adequate for hemostasis despite a decrease in the INR (indicating a return of factor VII activity). Adequate levels of II, VII, IX, and X may not be present until the INR is within reference limits. We recommend that the anticoagulant therapy must be stopped (ideally 4 to 5 days before the planned procedure) and the INR must be normalized before initiation of neuraxial block (grade 1B).

2. We recommend against the concurrent use of medications that affect other components of the clotting mechanisms and may increase the risk for bleeding complications for patients receiving oral anticoagulants and do so without influencing the INR. These medications include aspirin and other NSAIDs, ticlopidine and clopidogrel, UFH, and LMWH (grade 1A).

3. In patients who are likely to have an enhanced response to the drug, we recommend that a reduced dose be administered. Algorithms have been developed to guide physicians in the appropriate dosing of warfarin based on desired indication, patient factors, and surgical factors. These algorithms may be extremely useful in patients at risk for an enhanced response to warfarin (grade 1B).

4. In patients receiving an initial dose of warfarin before surgery, we suggest that the INR be checked before neuraxial block if the first dose was given more than 24 hours earlier or if a second dose of oral anticoagulant has been administered (grade 2C).

5. In patients receiving low-dose warfarin therapy during epidural analgesia, we suggest that their INR be monitored on a daily basis (grade 2C).

6. Neurologic testing of sensory and motor function should be performed routinely during epidural analgesia for patients on warfarin therapy. To facilitate neurologic evaluation, we recommend that the type of analgesic solution be tailored to minimize the degree of sensory and motor blockade (grade 1C).

7. As thromboprophylaxis with warfarin is initiated, we suggest that neuraxial catheters should be removed when the INR is less than 1.5. This value was derived from studies correlating hemostasis with clotting factor activity levels greater than 40%. We suggest that neurologic assessment be continued for at least 24 hours after catheter removal for these patients (grade 2C).

8. In patients with INR greater than 1.5 but less than 3, we recommend that removal of indwelling catheters should be done with caution and the medication record reviewed for other medications that may influence hemostasis that may not affect the INR (e.g., NSAIDs, ASA, clopidogrel, ticlopidine, UFH, LMWH) (grade 2C). We also recommend that neurologic status be assessed before catheter removal and continued until the INR has stabilized at the desired prophylaxis level (grade 1C).

9. In patients with an INR greater than 3, we recommend that the warfarin dose be held or reduced in patients with indwelling neuraxial catheters (grade 1A). We can make no definitive recommendation regarding the management to facilitate removal of neuraxial catheters in patients with therapeutic levels of anticoagulation during neuraxial catheter infusion (grade 2C).


ASA, Acetylsalicylic acid; INR, international normalized ratio; LMWH, low-molecular-weight heparin; UFH, unfractionated heparin.

LOWER EXTREMITY SURGERY

Arthroscopy

Arthroscopic procedures for the knee, hip, and ankle are increasingly performed as ambulatory procedures (see also Chapter 89). These cases can be particularly challenging for the anesthesiologist who must decide on the appropriateness of the patient and procedure for outpatient surgery and an anesthetic that is adequate for the procedure, but also provides the patient’s expectation of an uncomplicated postoperative recovery with minimal pain.

Limited data are available to determine which patients are inappropriate adult ambulatory patients. In most centers, morbidly obese patients and patients with sleep apnea require monitored observation overnight after procedures in which systemic anesthetics and analgesics have been administered. The presence of stable preexisting disease does not increase the incidence of postoperative complications in ambulatory patients, but the American Society of Anesthesiologists (ASA) grade 3 and 4 patients should have a medical clearance that documents the stability of their medical conditions. It follows then that medically unstable patients are not outpatient surgical candidates.

In a prospective study of 1088 patients for ambulatory surgery, Pavlin and co-workers reported that the most important factors in determining discharge time were pain, nausea and vomiting, unresolved neuraxial blocks, and urinary retention. This study emphasizes the role of anesthesia in prolonging ambulatory surgical stay. General anesthesia is a safe and effective anesthetic for arthroscopic surgery, but it has been associated with increased postoperative nausea and vomiting and pain. A properly designed regional anesthetic may reduce the importance of some of these factors.

Arthroscopic knee surgery can be performed with a combination of extraarticular and intraarticular injections of local anesthetics. Short-duration local anesthetics are often combined with longer acting local anesthetics (bupivacaine) and morphine to provide postoperative analgesia. Intraarticular morphine does not provide significant additional analgesia after arthroscopic knee surgery. For more involved arthroscopic procedures, such as an anterior cruciate ligament repair, surgical relaxation is also required. Spinal anesthesia with pencil-point atraumatic needles to prevent postdural puncture headaches provides excellent operating conditions for these procedures.

Problems related to neuraxial anesthesia for ambulatory surgery include unpredictable onset and regression of the spinal blockade, urinary retention, and transient neurologic symptoms (TNS). A dose of 45 mg of isobaric spinal mepivacaine results in a mean motor block of 142 ± 37 minutes. Using 30 to 40 mg of spinal chloroprocaine, Yoos and Kopacz reported 155 ± 34 minutes to ambulation in outpatient surgical patients. TNS are
symptoms of pain in the gluteal region that can radiate down both legs and appear within a few hours to 24 hours after an uneventful spinal anesthetic. The incidence of TNS is more frequent after outpatient surgery performed in the lithotomy position and in patients undergoing knee arthroscopy. The pain can vary from mild to severe, last 2 to 5 days, and is best treated with NSAIDs. TNS is more common after a spinal anesthetic with lidocaine (−14%) than with mepivacaine (6.5%) and bupivacaine (<1%). For ambulatory patients, the benefit of short-acting spinal anesthetic must be weighed against the risk for developing TNS. For postoperative analgesia after anterior cruciate ligament repairs, a femoral nerve block with a long-acting local anesthetic is superior to intraarticular injections. Because the quadriceps muscle is blocked, it is important for the patient to be fitted with a knee brace before ambulation. Blocking the saphenous nerve in the adductor canal may provide postoperative analgesia without also interfering with early ambulation.

Hip arthroscopy has become a common outpatient procedure for the diagnosis and treatment of pathologic processes in the hip. The patient can be placed in either the supine or the lateral position (operative side up) with 50 to 75 lb of traction applied to the operative limb to gain access to the joint with the arthroscope. In positioning the patient, the anesthesiologist must ensure that the perineal post is padded and not compressing the pudendal nerve and that excessive traction for prolonged periods is not applied (see also Chapter 41). Because complete muscle relaxation is required for the procedure, the patient must have either a general anesthetic or a neuraxial block. A lumbar plexus block can be performed for postoperative analgesia.

**Hip Fractures**

Hip fractures in older individuals are common (1 in 50 individuals older than 60 years of age), and as previously stated are associated with significant morbidity and mortality (1-year mortality of 30%). The high perioperative complication rate is related to many factors, including cardiac conditions, pulmonary conditions, DVT, and delirium. Postoperative confusion and delirium are common, reported in 50% of older patients after the repair of hip fractures and associated with increased mortality. In many cases, dehydration and electrolyte abnormalities contributed to this delirium. In one study, the incidence of hyponatremia was 4% and was associated with a sevenfold increase in hospital mortality.

These patients often arrive in the hospital in pain and under considerable stress, which may elicit signs and symptoms of myocardial ischemia. Although preoperative preparation is essential, delaying surgery may exacerbate these problems and increase the incidence of complications. Early surgery (<12 hours) has resulted in lower pain scores, decreased length of hospital stay, and reduced perioperative complications. However, early surgery has not been associated with increased overall survival in contrast to delaying surgery. Using geriatric services has been shown to improve outcomes, especially better lower limb function.

Patients with hip fracture are often dehydrated and anemic because the fracture site can accommodate considerable extravasated blood. Blood hematocrit values are often normal because of the contracted blood volume in a dehydrated patient. A normal intravascular blood volume should be restored before anesthesia and surgery; this is best achieved with central venous catheter monitoring. Central venous catheter monitoring also may prevent overhydration, which can precipitate congestive heart failure. Placement of an arterial catheter permits accurate blood pressure monitoring during surgery and the ability to follow serial arterial blood gases. Hypoxemia, possibly owing to fat embolization, has been a major determinant of mortality in these patients.

Several studies have reported improved outcome with regional anesthesia compared with general anesthesia in these patients. Patients undergoing hip fracture surgery have the greatest risk for death from a PE. In a meta-analysis of patients undergoing the repair of femoral neck fractures, the incidence of DVT was almost four times greater in the patients who received general versus regional anesthesia. A spinal anesthetic with isobaric 0.5% bupivacaine provides a stable regional anesthetic of sufficient duration to complete the surgical repair. Epidural anesthesia with postoperative analgesia is usually not indicated, because in most cases aggressive postoperative anticoagulation is instituted. Intravenous sedation during the procedure must be coupled with the ability of the patient to remain adequately oxygenated. Long-acting benzodiazepines should be avoided because of their association with postoperative confusion. In many cases, these patients require postoperative monitoring in an ICU-like setting.

**PELVIC FRACTURES**

Pelvic fractures are often the result of significant trauma to the lower trunk and hence are accompanied by additional injuries, including chest (21%), head (16%), and liver and spleen (8%). The 3-month mortality for pelvic fractures approaches 14%. Acute mortality directly related to the pelvic fracture may result from retroperitoneal bleeding. An indication for emergency exploratory surgery after a pelvic fracture would include persistent hypotension and increasing abdominal girth. Injuries to the bladder and urethra are also often associated with pelvic fractures; thus urology clearance is usually indicated before inserting a Foley catheter. Because there is a significant risk of DVT and PE, many of these patients require a temporary inferior vena cava filter before surgery.

Recent reports suggest that the optimal time for stabilization of a pelvic fracture is within the first week of trauma; however, associated injuries often delay the operation. An optimal anesthetic may be the combination of a general anesthetic with the placement of an epidural catheter for postoperative analgesia. Because iatrogenic sciatic nerve injury is the most frequent surgical complication (~18%), the use of intraoperative neuromuscular monitoring precludes dosing of the epidural catheter during the procedure and dictates waiting to dose the catheter until after the preservation of lower extremity movement and sensation has been confirmed. In most cases, these patients require monitoring with arterial and central venous catheters, as well as the placement of large-gauge venous catheters in the event of sudden surgical hemorrhage.
HIP AND KNEE ARTHROPLASTIES

As the population ages and remains physically active through their sixth decade, major orthopedic joint replacement procedures are increasingly more common. Between 1991 and 2010, the number of annual TKA procedures in Medicare patients increased 162% from 93,230 to 243,802.90 The rate of major adverse events after hip and knee arthroplasties is 6.4%, and as stated earlier the most important risk factor is advanced age (see also Chapter 80).4-10 The most common complications after THA and TKA are cardiac events, PE, pneumonia and respiratory failure, and infection.5,10,91,92 Older patients with major comorbidities, including cardiac disease, pulmonary disease, and diabetes, should have a complete preoperative medical evaluation. In addition, obesity, particularly in a patient who has undergone TKA, can be a problem anesthetically, as well as postoperatively, with regard to OSA and infections.33,92 Many of these patients require prolonged postoperative monitoring in the postanesthesia care unit or ICU (see also Chapter 96).

THA may be performed via an anterior or lateral approach. The anterior approach offers the advantage of exposure without violation of the muscles, but restricts full access to the femur, with the risk for lateral femoral cutaneous nerve injury. The lateral posterior approach provides excellent exposure to the femur and the acetabulum with minimal muscle damage, but increases the risk for posterior dislocation. Most surgeons prefer the lateral posterior approach, which places the patient in the lateral decubitus position, surgical side up, for the operation. The anesthesiologist must be aware that this position may compromise oxygenation, particularly in obese and severely arthritic patients, as a result of ventilation-perfusion mismatch. In addition, to prevent excessive pressure on the axillary artery and brachial plexus by the dependent shoulder, an anterior roll or pad must be placed beneath the upper thorax.

The nerve supply to the hip joint includes the obturator, inferior gluteal, and superior gluteal nerves. Regional anesthesia for THA is best achieved with a spinal or epidural anesthetic. Although most studies suggest decreased postoperative respiratory complications, including a reduction in the incidence of DVT and PE with regional anesthesia compared with rates in general anesthesia, some controversy still remains.61 A lumbar paravertebral block may be used for postoperative analgesia when postoperative antiocoagulation requires removal of the epidural catheter.93

Blood loss during THA can be significant, and with revision procedures the patient can lose 1 to 2 L of blood. Several studies have shown that controlled hypotensive epidural anesthesia with mean arterial blood pressures of 50 to 60 mm Hg can reduce intraoperative blood loss to as low as 200 mL for primary THAs.94 Older patients (mean age 72 years) were able to tolerate this degree of blood pressure reduction without cognitive, cardiac, or renal complications.95 In addition to reduced overall blood loss during THA, hypotensive anesthesia may improve the prosthesis-to-bone fixation by limiting bleeding in the femoral canal.96 An intravenous bolus injection of tranexamic acid or intraoperative fibrin spray also have been shown to reduce blood loss after joint arthroplasty.97

The femoral prosthesis can be fixed to the femoral canal through methyl methacrylate cement or bony ingrowth. Cemented fixation of the femoral prosthesis has been complicated by the bone-cement implantation syndrome, which may result in intraoperative hypotension, hypoxia, and cardiac arrest and FES postoperatively (Fig. 79-6; see Fig. 79-2).42-44 Several mechanisms have been suggested for these events, including embolization to the circulation of bone marrow debris during pressurization of the femoral canal, toxic effects of circulating methyl methacrylate monomer, and release of cytokines during reaming of the femoral canal that promote the formation of microthrombi with subsequent pulmonary vasoconstriction. The intravenous
injection of the cement monomer in dogs induces systemic hypotension, but not most of the other systemic events, including myocardial depression, which are manifested during the FES. The embolization of intra-medullary debris is the most likely explanation for the FES, because this debris can be visualized in the right heart using TEE (see Fig. 79-2).

The hypotensive events that follow bone marrow embolization should be treated with epinephrine. In addition, the hemodynamic consequences of bone marrow embolization can be ameliorated through high-pressure pulsatile lavage of the femoral canal and drilling a vent hole in the femur before prosthesis insertion. Risk factors for this complication include revision surgery, a long-stem femoral prosthesis, THA for a pathologic fracture, preexisting pulmonary hypertension, and the quantity of cement used. These patients should be monitored with arterial and central venous catheters.

During THA, embolization of a blood thrombus is possible. The hip is dislocated and the femoral vein is probably obstructed during reaming and insertion of the femoral prosthesis, resulting in blood stasis and blood clot formation. With relocation of the hip and unkinking of the femoral vein, the embolic material generated is released into the circulation. At some institutions an intravenous bolus of heparin is administered before dislocation of the hip. TKA also is becoming a major orthopedic procedure in the aging population, and these patients require the same preoperative medical evaluation as outlined for patients undergoing THA. The innervation of the knee includes the tibial nerve, the common peroneal nerve, the posterior branch of the obturator nerve, and the femoral nerve. Although general anesthesia can be safely provided for TKA, a prospective case-controlled study found general anesthesia with endotracheal intubation to be a major risk for nonsurgical complications after TKA. Regional anesthesia in the form of a neuraxial block (spinal or epidural) or a combination of a femoral and sciatic block can be provided for the surgery. However, in TKAs for valgus deformities, sciatic nerve blocks may prevent the early detection of sciatic and peroneal nerve palsies.

Patients who have undergone TKA have severe postoperative pain, and several studies have reported a reduction in postoperative complications and improved outcomes when this pain is managed with regional anesthesia. Single-injection femoral nerve blocks in combination with intravenous and epidural patient-controlled analgesia have been employed to manage postoperative pain and improve functional recovery. When LMWH is used for DVT prophylaxis, the infusion of local anesthetics through continuous femoral nerve catheters may be used in place of patient-controlled epidural anesthesia.

A pneumatic tourniquet is routinely inflated over the thigh during TKA to reduce intraoperative blood loss and provide a bloodless field for cement fixation of the femoral and tibial components. When the tourniquet is deflated, however, blood loss begins and usually continues for the next 24 hours. Tourniquets are usually inflated to a pressure 100 mm Hg above the patient’s systolic blood pressure for 1 to 3 hours. Nerve injury after extended tourniquet inflation (>120 minutes) has been attributed to the combined effects of ischemia and mechanical trauma. A peroneal nerve palsy, which is a recognized complication of TKA (incidence of 0.3% to 10%), may be caused by the combination of tourniquet ischemia and surgical traction. Horlocker and colleagues reported an incidence of combined tibial and peroneal nerve dysfunction in 7% of patients who had undergone TKA that was associated with younger age, the presence of preoperative flexion deformities, and longer total tourniquet times. When prolonged tourniquet inflations are required, deflating the tourniquet for 30 minutes of reperfusion may reduce neural ischemia.

Pain related only to tourniquet inflation also may occur after 60 minutes, despite the presence of a regional anesthetic that is adequate for the surgery. It has been postulated that tourniquet pain is caused by the unblocking of unmyelinated C fibers during recession of a neuraxial block. The addition of opioids to spinal or epidural anesthesia may ameliorate tourniquet pain. After tourniquet release, mean arterial blood pressure decreases significantly, partly owing to the release of metabolites from the ischemic limb into the circulation and the decrease in peripheral vascular resistance. In patients with known preexisting sciatic neurapraxias, neuropathic pain, and vascular disease in the operative leg, the operation can be performed without a tourniquet.

Many patients have symptomatic arthritis of both knees and require bilateral TKA to achieve functional improvement in pain and lifestyle. However, controversy still exists as to whether both knees should be replaced sequentially in a single operation (simultaneous bilateral total knee arthroplasty [SBTKA]) or as a two-staged procedure, usually separated by several months. The advantages of SBTKA include exposure to the risks of one anesthetic, one postoperative course of pain, reduced rehabilitation and hospitalization, and an earlier return to baseline function. However, SBTKA has been associated with a higher incidence of serious perioperative complications, including myocardial infarction, fat embolization, and thromboembolic events. Serious postoperative complications are more prevalent in older patients with cardiovascular disease. Patients undergoing SBTKA also require increased numbers of blood transfusions, are more likely to be transferred to a rehabilitation center, and have a higher incidence of postoperative ICU admissions.

Two more recent reports suggest that SBTKA can be performed without major complications. Urban and associates reported that with regional anesthesia and aggressive clinical management, which included 24-hour postoperative monitoring in an ICU, patients undergoing SBTKA had a major complication rate similar to that in matched control patients undergoing unilateral TKA, with a significantly higher incidence of FES and cardiac arrhythmias than patients undergoing unilateral TKA, possibly because of an enhanced inflammatory response. Using published reports of patients who underwent SBTKA and who were at risk for postoperative complications, Urban and associates published guidelines for the exclusion of patients from SBTKA (Box 79-5).
BOX 79-5 Patients Excluded for Single Operation for Bilateral Total Knee Arthroplasty

Age ≥75 years
ASA class III
Active ischemic heart disease (positive stress test)
Poor ventricular function (LVEF <40%)
Oxygen-dependent pulmonary disease
Patients considered at increased risk for morbidity and mortality
IDDM
Renal insufficiency
Pulmonary hypertension
Steroid-dependent asthma
Morbid obesity (BMI >40)
Chronic liver disease
Cerebrovascular disease

ASA, American Society of Anesthesiologists; BMI, body mass index; IDDM, insulin-dependent diabetes mellitus; LVEF, left ventricular ejection fraction.

FOOT AND ANKLE SURGERY

Regional anesthesia that combines sciatic and femoral nerve blocks is sufficient for all surgical procedures below the knee that do not require a thigh tourniquet. The femoral nerve innervates the medial leg to the medial malleolus, and the remainder of the leg below the knee, including the foot, is innervated by the common peroneal nerve and tibial nerve, both branches of the sciatic nerve. The sciatic nerve is usually blocked high in the popliteal fossa to ensure anesthesia to the tibial and peroneal nerves. The nerves are identified through the use of a nerve-stimulating needle with foot inversion as the motor response or with ultrasound guidance. For procedures that also involve the medial aspect of the leg, the femoral nerve (saphenous nerve) can be blocked on the medial aspect of the leg, just below the knee. The popliteal sciatic nerve block has been shown to reduce postoperative pain and opioid requirements after foot and ankle surgery, when performed as a single preoperative injection or as a continuous catheter infusion.109,112

Acute compartment syndrome exists when edema and blood accumulate within a confined osseofascial space, compromising the circulation and tissues within that space.113,114 If not treated promptly, the pressure in the compartment leads to muscle and nerve ischemia and necrosis, with potential loss of limb. Compartment syndrome can occur after fractures of the tibia, followed less commonly by fractures of the femur and ankle. Delay in diagnosis and treatment (surgical decompression) is the most common cause of serious complications. Pain out of proportion to the clinical situation is the usual early symptom. Thus, after the surgical repair of tibial and ankle fractures, a discussion with the surgeon with regard to the risk for compartment syndrome should occur before administering long-acting sciatic nerve blocks.

The ankle block is used for surgical procedures on the foot that do not require the use of a thigh tourniquet, although an ankle-level Esmarch tourniquet may be used. Because the block is primarily an infiltrative block, it usually is not performed by eliciting a paresthesia.

Figure 79-7. Cutaneous distribution of anesthesia produced by an ankle block. (From Carron H, Korborn GA, Rowlingson JC: Regional anesthesia: techniques and clinical applications, New York, 1984, Grune & Stratton.)

Five terminal nerves are usually blocked to provide complete anesthesia to the foot: (1) posterior tibial nerve, which provides sensation to the plantar surface; (2) saphenous nerve, which innervates the medial malleolus; (3) deep peroneal nerve, which supplies the interspace between the great and second toes; (4) superficial saphenous nerve, which supplies the dorsum of the foot and the second through the fifth toes; and (5) sural nerve, which supplies the lateral foot and lateral fifth toe (Fig. 79-7). Mineo and Sharrock115 reported that the ankle block performed at the midtarsal level with 30 mL of 0.75% bupivacaine provided a mean duration of 17 hours of analgesia with safe blood levels of local anesthetic.

UPPER EXTREMITY SURGERIES

Surgery for the upper extremity, from the shoulder to the hand, can be performed successfully by blocking the brachial plexus at several points until it branches into peripheral nerves (Table 79-3). Several methods are used to document the optimal location for neural blockade of the brachial plexus, including eliciting a paresthesia, motor nerve stimulation, ultrasound guidance, and perivascular infiltration. Regional anesthesia for the upper extremity also can provide postoperative analgesia using long-acting local anesthetics or continuous catheter techniques.

Regional anesthesia for shoulder surgery (see also Chapters 57 and 58) has not gained wide acceptance because of the thought by anesthesiologists and surgeons that it is often inadequate for surgical anesthesia and the concern for postoperative neurologic symptoms (PONS). Several studies have reported 97% or greater successful surgical anesthesia using the interscalene block (ISB) approach to the brachial plexus with documentation of a paresthesia or the use of a nerve stimulator or ultrasound guidance to locate the optimal site of injection.116-119

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The brachial plexus is formed from the ventral rami of C5-T1 nerve roots. After these roots pass between the anterior and middle scalene muscles, they fuse into three trunks (superior C5-6, middle C7, inferior C8-T1). During performance of the ISB, local anesthetic is injected between the scalene muscles at the level of the cricothyroid notch (C6) (Fig. 79-8).

The major acute complications and side effects associated with ISB are respiratory depression, intravascular injection with seizures and cardiac arrest, pneumothorax, epidural and spinal anesthesia, Horner syndrome, hoarseness, and dysphagia. The ipsilateral phrenic nerve is blocked in all patients undergoing ISB, resulting in hemidiaphragmatic paresis. Because hemidiaphragmatic paresis may result in a 25% reduction in pulmonary function, patients with severe respiratory disease may not tolerate an ISB without the addition of mechanical ventilation. An ISB would be contraindicated in patients after pneumonectomy on the contralateral side and for bilateral operative procedures. The supraclavicular approach to the brachial plexus with ultrasound guidance may provide effective shoulder anesthesia without complete ipsilateral paresis of the phrenic nerve.

Because of the proximity to major vascular structures (vertebral artery, carotid artery, jugular vein), CNS toxicity is usually cited as a major risk of ISB. The reported incidence of CNS effects has been very low, however. Conn and associates reported that ISB resulted in 3 of 100 patients experiencing CNS symptoms and only one seizure. Urban and Urquhart reported that 2 of 266 patients had CNS symptoms and none had seizures.

PONS related directly to brachial plexus anesthesia is often cited as the reason to avoid regional anesthesia for shoulder and hand surgery. The few large studies that have attempted to ascertain the extent of nerve injury associated with ISB have concluded that although some patients may have neurologic issues after surgery, many of the problems cannot be attributed to the anesthetic and most of them resolve (Table 79-4). In the retrospective study by Conn and associates, 2 of 100 patients had PONS that persisted for 7 months and 18 months, respectively. In the prospective analysis of 266 patients by Urban and Urquhart, 9% reported paresthesias on the day after surgery, two thirds of which resolved after 2 weeks and one that persisted beyond 6 weeks. Liguori and colleagues reported the incidence of PONS after ISB performed with either the documentation of a paresthesia (10 of 108) or the use of a nerve stimulator (11 of 118). There is some evidence that these events are the result of a cardiac inhibitory reflex, the Bezold-Jarisch reflex, which occurs in response to diminished ventricular volume (venous pooling in the sitting position) and a hypercontractile ventricle. Prophylactic administration of β-blockers, anxiolytics, and intravenous fluids reduces the incidence of these events.

For surgery from the elbow to the hand, the brachial plexus can be blocked via either the infraclavicular block approach or the axillary approach. Blockade of the nerves to the arm at the axilla can be achieved by a transarterial technique or the stimulation of a single nerve or multiple nerves. Advocates of the multiple paresthesia technique cite the report by Thompson and Rorie, which states that within the axillary sheath the nerves are separated by discrete septa. Using a transarterial approach, Urban and Urquhart reported a success rate of 93%. Advocates of the paresthesia or nerve stimulator technique for
the axillary block argue that the transarterial approach may produce a hematoma with the potential for ischemic damage to the brachial plexus. When the transarterial axillary block was used in 242 patients for forearm and hand surgery, 23% of the patients complained of tenderness and bruising at the axilla, and 19% had acute PONS.116

The infraclavicular block to the brachial plexus may be the best approach for elbow surgery, and it may result in less patient discomfort and PONS when used for forearm and hand surgery compared with the axillary approach, although objective evidence is still lacking.127,128 Using the nerve stimulator technique, two large series of infraclavicular blocks reported 90% to 94% success with only posterior cord stimulation, whereas other reports still recommend a double stimulation technique. Performing the infraclavicular block with ultrasound guidance may avoid the need for multiple needle passes and the complications of vascular puncture and pneumothorax.129

Forearm and hand surgery also can be performed under intravenous regional anesthesia. Intravenous regional anesthesia is a simple technique that involves exsanguinating the arm by wrapping it with a tight band, inflating an upper arm tourniquet to approximately 250 mm Hg, and injecting in a hand vein approximately 50 mL of a short-acting local anesthetic (0.5% lidocaine). A second tourniquet, proximal to the first, is often inflated 15 minutes later with subsequent deflation of the first, to minimize tourniquet pain. This technique is limited to short surgical procedures (~1 hour). Complications occur when the tourniquet fails during initial anesthetic injection or the tourniquet is deflated early (<30 minutes), risking systemic local anesthetic toxicity.

**SPINAL SURGERY**

In the United States with an active, aging population, 4.6 million individuals will require spinal surgery at some time during their life. Spinal surgery includes a wide variety of procedures ranging from a microdiskectomy for a herniated disk to complex reconstructive surgery for spinal deformities. These procedures can be simple or involve fusions at multiple levels, anterior or posterior approaches, and considerable blood loss. A few procedures, such as a discectomy, can be performed under regional anesthesia.130

Most spinal surgeries require general anesthesia. In this patient population with preexisting arthritic conditions, tracheal intubation often poses a challenge (Box 79-6). Awake, sedated fiberoptic intubation of many of these patients is the safest approach to general anesthesia. This is the standard of care in a patient with cervical spinal instability who requires posterior stabilization. These patients should be intubated first with a flexible fiberoptic bronchoscope, then positioned prone for surgery sedated but awake (if possible) and assessed for movements of upper and lower extremities before the induction of general anesthesia. Some patients with reduced but stable cervical mobility, may be intubated using glide scope technology after the induction of general anesthesia.

The careful positioning of patients for spinal surgery is an important shared responsibility of the anesthesiologist and surgeon (see also Chapter 41). As stated previously, patients at risk for spinal cord compression should be positioned under light sedation, then observed for upper and lower extremity movement before inducing general anesthesia. Because some posterior cervical spine decompressions are done in the sitting position, preparations must be made for the possibility of a venous air embolism. Complex spinal deformity procedures often require anterior and posterior approaches to the spine. For a low lumbosacral anterior approach, the patient is supine with the legs spread wide. Pelvic retraction during this procedure may compromise blood flow to the legs, and a pulse oximeter placed on a toe may be used as a monitor for compromised lower extremity blood flow. Patients undergoing anterior thoracolumbar procedures are usually positioned in the lateral decubitus position, in which attention must be focused on the dependent arm and leg and the position of the neck. Table 79-5 outlines possible complications from prone positioning for these spinal procedures.

Postoperative airway management in patients after single-stage multilevel anterior, posterior, or both cervical spinal decompressions and fusions should be a major concern of the anesthesiologist. Postoperative complications include dysphagia (12%), dysphonia (4%), and

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### BOX 79-6 Predictors of a Difficult Endotracheal Intubation

<table>
<thead>
<tr>
<th>Airway</th>
<th>Tracheal deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ETT kinking, dislodgment</td>
<td>Upper airway edema</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Neck</th>
<th>Cervical rotation—compromised blood flow to brain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperextension or hyperflexion</td>
<td>Corneal abrasion</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Eyes</th>
<th>Orbital pressure—central retinal artery occlusion, supraorbital nerve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulnar nerve compression—arms at the side</td>
<td>Small mouth opening (interincisor gap)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abdomen</th>
<th>Pressure transmitted to epidural veins, increased bleeding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachial plexus stretch—arms out</td>
<td>Pressure lateral to fibula—peroneal nerve palsy</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower extremity</th>
<th>Flexion of hips—occlusion of femoral vein, DVT, kinking of vascular grafts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure on iliac crest—lateral femoral cutaneous nerve</td>
<td>Damage to adjacent structures</td>
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</tbody>
</table>

*See Chapter 41.

**TABLE 79-5 COMPLICATIONS OF THE PRONE POSITION**

<table>
<thead>
<tr>
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<th>ETT kinking, dislodgment</th>
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<td>Upper airway edema</td>
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*See Chapter 41.

**DVT, Deep vein thrombosis; ETT, endotracheal tube.**
airway compromise (up to 14%). Tissue trauma from the procedure often causes airway edema, which can progress to complete airway obstruction. Reported risk factors for postoperative respiratory complications are length of surgery, volume of infused crystalloid, obesity, revision surgery, four or more levels fused, and fusion of C2. A protocol for the management of these patients should be established such that patients at risk for postoperative airway complications are monitored with emergency airway equipment and specialists available and/or the patients kept intubated overnight and extubated when upper airway edema has subsided.

Posterior lumbar fusions for degenerative disk disease are often accompanied by anterior fusions to stabilize the surgical area and increase the success of the fusions. The anterior open procedures have recently been replaced in many cases by minimally invasive techniques, including transperitoneal anterior lumbar interbody fusion and extreme lateral interbody fusion. To reduce the risk for nerve root injury during disk excision, intraoperative electromyographic monitoring is used, which precludes the use of neuromuscular blocking drugs. Large-bore venous access out of proportion to the usual blood loss should be secured in these patients, because the techniques are performed in close proximity to major vascular structures that are at risk for iatrogenic injury.

Complex corrective surgery of the spine includes patients with scoliosis, kyphosis, kyphoscoliosis, and revision surgery on patients with previous thoracolumbar fusions. Kyphosis is an exaggerated anterior flexion of the spine, as seen in ankylosing spondylitis. Scoliosis is defined as a lateral rotation of the spine greater than 10 degrees accompanied by vertebral rotation. Scoliosis is classified as idiopathic, congenital, or neuromuscular. Congenital scoliosis is the result of early embryonic errors in vertebral column formation, and half of the cases are associated with other organ system anomalies. Adolescent idiopathic scoliosis is common, present in 2% to 4% of children 10 to 16 years of age. Only 10% of these adolescents have curves that require some type of medical intervention. Surgical intervention occurs when the curve magnitude estimated by the Cobb method is more than 40 degrees (Fig. 79-9) and the likelihood of curve progression is strong. Most idiopathic scoliosis curves are right-sided; a left thoracic curve is more likely to be associated with other thoracic anomalies.

Thoracic scoliosis results in a narrowed chest cavity producing a decrease in chest wall compliance and restrictive lung disease. Cobb angles of greater than 65 degrees usually cause significant decreases in lung volumes. Although exercise tolerance is an important determinant of the effects of the severity of the curve on respiratory function, formal pulmonary function studies should be obtained before surgery. This information guides decisions regarding the extent of surgery permitted at one time and the requirement for postoperative ventilatory support. A vital capacity of less than 40% of the normal range is predictive of the requirement for postoperative ventilation. The major abnormality in arterial blood gases is hypoxemia, secondary to ventilation-perfusion inequalities caused by alveolar hypoventilation.

Figure 79-9. Radiograph of a patient with scoliosis. The Cobb angle is an angle formed by a line drawn perpendicular to the top of the superior vertebra of the scoliotic curve and a similar perpendicular line drawn along the bottom of the inferior vertebra. The Cobb angle in this patient is 62 degrees. (From Reamy BV, Slakey JB: Adolescent idiopathic scoliosis: review and current concepts, Am Fam Med 64:1-10, 2001.)

Chronic hypoxemia produces elevated pulmonary vascular resistance, which ultimately leads to cor pulmonale. An echocardiogram should be assessed for pulmonary hypertension and right ventricular hypertrophy. In patients with pulmonary hypertension, the electrocardiogram may reveal evidence of right ventricular hypertrophy and right atrial enlargement.

Surgical spinal corrections involving high anterior thoracic levels or video-assisted thoracoscopic surgery require the isolation of one lung. One-lung ventilation traditionally has been achieved with a double-lumen endotracheal tube. In single-staged anterior then posterior spinal fusions and for postoperative ventilation, the double-lumen endotracheal tube must be replaced with a single-lumen endotracheal tube. A single-lumen endotracheal tube with an enclosed bronchial blocker also can provide one-lung ventilation, but has the advantage of being left in place as a single-lumen endotracheal tube with the blocker deflated at the end of the anterior procedure. In patients with restrictive lung disease, adequate oxygenation may be difficult during one-lung ventilation and may require continuous positive airway pressure to the nonventilated lung and positive end-expiratory pressure to the ventilated lung.

Surgery for the correction of spinal deformities is usually associated with large blood losses. Multiple factors have been suggested to influence the magnitude of this blood loss, including surgical technique, operative time, number of vertebral levels fused, anesthetics, mean arterial blood pressure, platelet abnormalities, dilutional coagulopathy, and primary fibrinolysis. Several techniques have been employed to reduce this blood loss and limit the need for homologous blood transfusions, including proper positioning of the patient to reduce intraabdominal pressure, surgical hemostasis, deliberate
controlled hypotensive anesthesia, reinfusion of salvaged blood, intraoperative normovolemic hemodilution, use of pharmacologic agents that promote clot formation, and preoperative donation of autologous blood.

Controlled hypotensive anesthesia has been used commonly in limiting blood loss during idiopathic scoliosis corrections in adolescents, but must be used with caution in older patients. In a young healthy patient, a mean arterial pressure of 50 to 60 mm Hg is well tolerated, but higher pressures may be required in adult patients with cardiovascular disease. In addition, perfusion of the spinal cord during deformity-correcting surgery may be exquisitely sensitive to low perfusion pressures. The adequacy of end-organ perfusion can be estimated with invasive monitoring, a urine output of 0.5 to 1 mL/kg/hr, and periodic blood gas analysis looking for evidence of metabolic acidosis. In addition, central venous oxygen saturation with an arterial blood gas provides an indication of end-organ oxygen supply and demand. Although an increase in heart rate during hypotensive anesthesia may indicate anemia, hypovolemia or “light” anesthesia, the use of a β-blocker to reduce the risk for myocardial ischemia and ameliorate renin release with concomitant pressure rebound when the surgery has ended eliminates this physiologic marker. Synthetic lysine analogues, such as aminocaproic acid and aprotinin, a polypeptide with serine protease inhibitor activity, also have been used to limit blood loss during these procedures by reducing fibrinolysis, but there may be concern because of more recent findings in postoperative cardiac cases.

A postoperative neurologic deficit is one of the most feared complications of complex spinal reconstructive surgery. In a large survey of 97,586 spinal surgeries, neurologic deficits occurred in 0.55% of the cases. To reduce this complication, Vauzelle and colleagues introduced the concept of waking the patient up during surgery to determine the functional integrity of the spinal cord. This test is limited to gross motor movements of the lower extremities and can be influenced by anesthetics and the cognitive integrity of the patient. In addition, complications related to the test include inadvertent extubation of the patient during movement in the prone position, air embolism during a deep inspiration, and dislodgment of the instrumentation during violent movements.

Multimodal intraoperative monitoring has become the standard of care for complex reconstructive spinal surgery. This monitoring includes somatosensory evoked potential (SSEP), motor evoked potential (MEP), and electromyogram (EMG) monitoring. EMGs are used to monitor nerve root injury during pedicle screw placement and nerve decompressions (see also Chapter 49). The posterior (sensory) portion of the spinal cord is evaluated using SSEP monitoring. MEPs assess the integrity of the anterior (motor) spinal cord. Potential adverse effects of MEP monitoring include cognitive deficits, seizures, bite injuries, intraoperative awareness, scalp burns, and cardiac arrhythmias. It is advisable to employ a soft bite block during MEP monitoring to prevent tongue biting and dental damage. MEP monitoring should be avoided in patients with active seizures, vascular clips in the brain, and cochlear implants. In SSEPs, an impulse is sent from a peripheral nerve and measured centrally. In MEPs, an impulse is triggered in the brain and monitored as movement of a specific muscle group. SSEPs and MEPs are evaluated with regard to amplitude—strength—of the signal and latency—time it takes the signal to travel through the spinal cord—compared with the patient’s nonsurgical control values.

Numerous physiologic factors attenuate SSEP and MEP monitoring, including hypotension, hypothermia, hypocarbia, hypoxemia, anemia, and anesthetics. The potent inhaled agents reduce the amplitude of the signal and increase latency in a dose-dependent manner. If a volatile anesthetic is used for the anesthesia, the concentration should be kept at approximately half minimum alveolar concentration and not varied throughout the procedure. Nitrous oxide produces a decrease in the amplitude of the signal and may have to be eliminated during MEP monitoring. Total intravenous anesthesia has been used successfully for MEP and SSEP monitoring.

MEPs are the least affected by opioids, midazolam, and ketamine, but are depressed by propofol. The depressant effect of propofol is diminished, however, with ketamine, such that the best total intravenous anesthetic may be an infusion of an opioid, ketamine (at low doses), and propofol. Muscle relaxants cannot be administered during MEP monitoring.

Postoperative visual loss (POVL) is another devastating complication of spinal surgery (see also Chapter 100). POVL is rare after spinal surgery (≤0.1%) and may be caused by ischemic optic neuropathy (ION), retinal artery or vein occlusion, and cortical brain ischemia. In an attempt to delineate the cause of POVL, the ASA Committee on Professional Liability established a POVL registry to collect detailed information on these cases. Most patients with central retinal artery occlusion had evidence of unilateral ocular trauma, suggesting a role for improper head positioning. ION was the most common cause of POVL after spinal surgery. ION can be divided into anterior ION and posterior ION depending on the visual field cut and whether edema to the optic disk is present early (anterior ION) or later (posterior ION). Both types are the result of reduced blood flow or oxygen delivery from end-arteriole branches of the ophthalmic artery.

The ASA registry of 93 POVL cases after spinal surgery reported that most patients were relatively healthy and that blood loss greater than 1000 mL and duration in the prone position for longer than 6 hours were present in 96% of the cases. ION occurs in the absence of direct pressure on the eye. In a multicenter case-control study that compared the 80 adult patients with ION in the ASA registry to 315 adult patients who had undergone central spinal fusion without ION, the risk factors for ION identified were obesity, Wilson frame use, length of surgery, blood loss, and decreased colloid use with fluid replacement. Because ION occurred in the absence of vascular injury to other critical organs and in cases in which neither hypotension nor anemia was reported, optic nerve blood supply may be uniquely vulnerable to hemodynamic perturbations in the prone position.

Patients experience considerable pain after multilevel spinal fusions with instrumentation (see also Chapter 98). Most of these patients are initially treated with intravenous opioids, but because of the multiple side effects of
these drugs, a multimodality approach with other agents has been recommended. For lumbar fusions, an epidural catheter placed at a level above the incision can be used for patient-controlled epidural anesthesia infusions of local anesthetics and opioids. For procedures involving more extensive spinal levels, intrathecal morphine administered during surgery has been shown to provide reliable postoperative pain control. NSAIDs may have a negative influence on the success of spinal fusions, however. For opioid-tolerant patients, subanesthetic doses (0.2 mg bolus, then 2 mcg/kg/hr) of ketamine reduced postoperative pain after posterior spine fusions.

Complete references available online at expertconsult.com

REFERENCES

References


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