Critical care in orthopedic and spine surgery

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Orthopedic and spine operations are being performed at an increased rate and account for a significant part of the health care budget [1]. Familiarity with the perioperative aspects of these procedures will help improve outcomes, reduce the length of stay (LOS) in the intensive care unit (ICU), and limit health care costs. The need for ICU care can often be predicted based on patient's comorbidities and operative considerations. Unplanned admissions can also arise from problems that occur in the operative or recovery period. This article reviews those aspects of critical care related to elective orthopedic and spine surgery.

Hip

An estimated 200,000 total hip replacement (THR) operations are performed each year in the United Sates for management of painful arthritic hips [2]. Newer anesthetic techniques, better perioperative care, and improved prophylaxis for deep vein thrombosis (DVT) have contributed to a threefold decrease in morbidity and mortality.

Preoperative considerations

Data from a National Institutes of Health (NIH) survey estimate the overall risk of death after THR to be less than 1% [3]. The most important determinant of mortality is age. Patients between 66 and 69 years of age have a perioperative mortality of 0.34%, compared with 3.75% in the age group above 85 years. Women usually have a lower mortality rate. Total hip replacement for hip fracture carries a greater mortality risk (6.2%) than THR for arthritis or revision (0.95%) [4].

Baseline pulmonary function correlates with the risk of postoperative pulmonary complications. Patients with chronic obstructive pulmonary disease (COPD) or abnormal pulmonary function tests have a 70% pulmonary complication rate [5]. Age has an independent effect on lung function manifested by a progressive reduction in forced expiratory volume in 1 second (FEV1) and loss of elasticity. Arterial blood gases and spirometry are recommended preoperatively for smokers and patients with known lung disease.

Goldman [6,7] describes nine variables that predispose a patient to cardiac complications. These variables are (1) S3 gallop or jugular venous distension, (2) myocardial infarction in past 6 months; (3) premature ventricular contractions (more than 5/minute); (4) rhythm other than sinus on preoperative electrocardiogram (EKG); (5) age over 70 years; (6) emergency surgery; (7) intraperitoneal, intrathoracic, or aortic surgery; (8) suspected critical aortic stenosis; and (9) poor general medical condition. Patients over age 40 years with cardiovascular risk factors should have a resting EKG before surgery. If ischemic changes are noted, a stress test is required. Because patients undergoing THR are usually unable to exercise, a thallium-dipyridamole scan is an alternative. The decision to proceed to a cardiac catheterization should be made by a cardiologist.

Other important risk factors include obesity, smoking, and malnutrition. In an Australian cohort, up to 71% of patients undergoing THR had one or more serious medical problems preceding surgery [8]. Useful prophylactic measures are smoking cessation, weight reduction, breathing exercises, and correction of nutritional deficiencies.

Anesthesia considerations

General and regional anesthesia affects the pulmonary and cardiovascular systems in different ways. General anesthesia decreases lung compliance, depresses cough reflex, increases pulmonary secretions, and alters mucociliary clearance. Preexisting pulmonary disease magnifies these effects. The duration of general anesthesia also plays a role in the incidence of postoperative respiratory problems. Procedures lasting longer than 3 hours have a threefold higher rate of pulmonary complications [9]. On the other hand, regional anesthesia has been shown to reduce postoperative pulmonary morbidity. A randomized trial comparing general and regional anesthesia in elderly patients undergoing THR showed a significant drop in the postoperative PaO_2 in the general anesthesia group [10].

Regional anesthesia compared with general anesthesia reduces the incidence of thromboembolic events, probably because of reduced venous stasis [11,12], and is preferred in patients with difficult airways, such as concomitant unstable rheumatoid spine.

General anesthesia tends to depress cardiac contractility, whereas regional anesthesia has minimal effects on the myocardium. Regional anesthesia lowers peripheral vascular resistance, however. Few studies have compared anesthetic techniques and cardiac complications after THR. One retrospective study found fewer cardiac complications after spinal anesthesia [13]. In another prospective study, there were no cardiac complications in the regional anesthesia group, compared with a high rate of postoperative hypoxemia and one death from myocardial infarction after general anesthesia [10].

Peripheral vasodilatation that occurs during regional anesthesia leads to hypotension with a concomitant reduction in blood loss. A mean arterial blood pressure of 60 mm Hg was found to be optimal, maximizing beneficial effects while avoiding neurologic injury and tissue ischemia [14]. Deliberate hypotension requires invasive cardiac monitoring and may be contraindicated in patients with ischemic or valvular disease [7].

Cardiopulmonary complications

Pulmonary complications are among the most common problems encountered in the perioperative period. Atelectasis is common after general anesthesia. Its incidence has been estimated to be between 2% and 7% [15–17].

Postoperative pneumonia occurs in as many as 10% of elderly patients [18]. Colonization of the upper respiratory tract, particularly after protracted ventilatory support, occurs in nearly 100% of these cases. Initial empiric broad-spectrum antibiotic coverage can be readjusted based on culture results.

Acute respiratory distress syndrome (ARDS) characterized by intrapulmonary shunting, mismatch of the ventilation/perfusion ratio (V/Q), and decreased lung compliance with subsequent respiratory insufficiency has been described after major orthopedic operations. Numerous causes have been implicated, including sepsis and fat embolism syndrome (FES). Mechanical ventilation with the use of positive end-expiratory pressure (PEEP) may be necessary to improve gas exchange [19]. Limiting the tidal volume to 5 to 7 mL/kg reduces mortality from ARDS [20]. Efforts should be made to identify and treat confounding problems such as sepsis, multiorgan failure, and cardiac failure [19,21].

Cardiac complications after THR occur at a rate of 2% to 10% [18]. The incidence of ischemic heart disease, including angina pectoris and myocardial infarction, is between 0.59% and 1.37% after THR [16,22]. Myocardial infarction following noncardiac surgery is associated with a mortality rate as high as 70% [23]. Chest pain is reported in 50% of these patients and may be masked by the administration of narcotics or sedatives. Postoperative EKG changes of unknown significance occur in 20% of patients [24]. Elevation of the creatinine phosphatase isoenzyme (CPK-MB) should not be attributed to the trauma of hip surgery. Troponin assays are sensitive markers for cardiac ischemia [25].

Congestive heart failure (CHF) is common in patients with preexisting cardiac disease who receive large amounts of fluids and blood products. Finally, cardiac arrhythmias are common reasons for ICU care. The incidence of supraventricular tachycardia is estimated at 4.8% after THR [26] and is more likely to occur in older patients with a previous cardiac or pulmonary history.

Pulmonary embolism

Among patients admitted to the hospital, those with multiple traumas or undergoing elective major joint replacement are at greatest risk for DVT [27]. The risk of thromboembolism increases with age, the extent and duration of surgery, the type of anesthesia, the duration of immobilization, and the severity of comorbidities [28,29]. Up to 50% of patients with lower extremity fractures develop DVT, with 10% progressing to pulmonary embolism (PE), and 2% dying from massive PE [30]. Of those confirmed cases, 11% die within the first hour, and 8% will suffer a fatal PE despite adequate anticoagulation [31]. Because of the lack of uniformity among studies, the actual incidence of DVT and PE after THR remains controversial. A recent study evaluated the risk of DVT after THR to be between 10% and 25%, with a fatal PE rate of 0.15%

[32]. Haake and Berkman [33] reported a cumulative incidence of fatal PE of 0.06% to 6.7% compared with 3.6% to 12.9% following hip fractures. The true incidence of thromboembolism after THR is probably underestimated because of limitations in diagnostic tools.

Prophylaxis against thromboembolism in orthopedic surgery is paramount. The Sixth American College of Chest Physicians Conference on Thromboembolism has made detailed recommendations for prophylaxis after joint replacement [34]. For THR, low molecular weight heparin (LMWH) or adjusted-dose warfarin, with a target international normalized ratio (INR) of 2.5, should be started preoperatively or immediately after surgery. Other prophylactic regimens have been advocated.

The test most commonly used to diagnose DVT is duplex ultrasonography. It can be safely performed at the bedside and has almost 100% sensitivity and 99% specificity for proximal DVT [35].

Suspicion of PE must remain high in patients undergoing THR [36]. A ventilation/perfusion scan is less likely to be useful in patients with respiratory complications. A spiral computed tomographic (CT) scan with intravenous contrast infusion is a useful alternative. It has an estimated sensitivity of 70% and a specificity of 81 to 100%. Spiral CT has limited ability to detect peripheral emboli [37]. Pulmonary angiogram remains the criterion standard, but it is greatly underutilized [38]. Guidelines on the treatment of thromboembolism have been published elsewhere [39].

Most patients with pulmonary embolism do not need admission to ICU unless they are experiencing cardiopulmonary instability requiring monitoring, respiratory support, or hemodynamic augmentation. Patients with shock after PE are at greatest risk of death. Thrombolytic therapy has been advocated in this setting. It has been proven superior to heparin in the resolution of PE as assessed by pulmonary angiogram, lung scan, and hemodynamic derangement [40]. It is associated with a significant risk of bleeding, however, and might be contraindicated in the immediate postoperative period. Finally, patients with PE and contraindications to anticoagulation should be considered for an inferior vena cava filter [41].

Fat embolism

Fat embolism is a well-recognized complication of orthopedic surgery [42–44]. Fat embolism syndrome is a triad syndrome, and fat embolism is a subclinical form of FES. A review of the literature reveals a wide variation on the prevalence of FES. The occurrence of fat embolism after major trauma with long bone involvement has been estimated to be 90% [45,46]. The prevalence of FES in these trauma cases is believed to be underestimated. The operations most commonly associated with FES are THR, total knee replacement (TKR), and intramedullary nailing of the shaft [47,48]. Although not reported in the literature, the actual incidence of FES with these operations is believed to be high.

There are two theories for the pathogenesis of FES: a mechanical theory and a biochemical theory [49]. The mechanical theory proposes that bone marrow contents enter the pulmonary vasculature through the venous system. Intraoperatively, this process could result from pressurization and manipulation of long bone intramedullary canals [50]. Small fat droplets ranging in size from 7 to 10 microns in diameter may circulate through the pulmonary capillaries and into the systemic circulation, terminating in the brain or other organs. Another mode of entering the systemic vasculature is through a patent foramen ovale [51]. Up to 10% of the adult population has a patent foramen ovale [52].

The biochemical theory of FES suggests that circulating free fatty acids directly affect the pneumocytes. The source of free fatty acids may be multifactorial. C-reactive protein, which may cause chylomicrons to coalesce and form fat globules, is elevated after trauma and sepsis. Catecholamines promote the release of free fatty acids and are also elevated after trauma [53]. The two mechanisms are believed to act synergistically [45]. The presence of fat throughout the pulmonary vasculature may lead to pulmonary hypertension, right heart strain, hypotension, hypoxia, and significant cardiopulmonary compromise. Patients who are vulnerable to clinical compromise are those with reduced cardiopulmonary reserve, pathologic fractures, and a right-to-left shunt [54]. Surgical techniques may have a significant effect on the severity of fat embolization [42]. For example, careful intramedullary lavage before placement of the prosthesis will decrease the amount of debris available for embolization [55].

Fat embolism syndrome is a diagnosis of exclusion that depends on the clinician's index of suspicion. Gurd [56] described major and minor features for diagnosing FES. The major features are respiratory insufficiency, cerebral signs, and petechial rash; the minor features are pyrexia, tachycardia, retinal involvement, jaundice, renal involvement, and fat macroglobulinemia. The diagnosis of FES requires at least one major and four minor criteria. Signs and symptoms usually become apparent within 24 to 48 hours after insult; however, they may appear immediately.

The classic clinical triad for FES is pulmonary insufficiency, neurologic derangement, and petechial rash [57,58]. Pulmonary insufficiency is always present is and usually the first manifestation of the syndrome. Neurologic derangements occur in up to 86% of patients with FES; they manifest as headache, lethargy, irritability, delirium, stupor, convulsions, and coma [59]. Preservation of normal muscle tone and reflexes suggests a favorable prognosis. Nonreactive pupils and depressed deep tendon reflexes that do not resolve after correction of hypoxemia are suggestive of ischemia and microscopic hemorrhage in association with emboli in the brain [11]. Petechiae occur in 20% to 50% of cases; these lesions represent fat globules lodged in dermal capillaries. They are usually seen on the head, neck, anterior chest, axilla, oral mucous membrane, and conjunctivae.

Although thrombocytopenia is common in FES, petechiae may be present in the absence of thrombocytopenia; these lesions usually resolve within 5 to 7 days [58,60]. Bronchoalveolar lavage seems to be unreliable in the detection of fat embolism because normal, control patients have fat-containing alveolar macrophages ranging from 5% to 95% in alveolar samples. Pulmonary artery catheterization with frozen section of aspirated blood may be useful when the cause of respiratory failure is equivocal. The overall mortality rate is high (5% to 33%) despite adequate resuscitation. The cause of death is usually related to the severity of the respiratory problem. Long-term morbidity associated with FES is caused by cerebral complications [59]. Treatment for FES is supportive, consisting primarily of mechanical ventilation for respiratory compromise and hemodynamic stabilization. There are no data supporting the use of heparin or corticosteroids in FES.

Cement-related issues

Complications occurring during cemented arthroplasty have been reported since the early 1970s. In early studies, the incidence of polymethylmethacrylate (PMMA)-related hypotension was between 33% and 100%. More recent studies have shown a lower incidence. One study noted acute hypotension in 4.8% of cemented THR compared with 0% after insertion of noncemented stems [61].

The cause of cement-related hypotension is still controversial. Initially methylmethacrylate monomers were implicated as a causative factor. Intravenous administration of methylmethacrylate in animal studies produces profound peripheral vasodilation. Anaphylatoxin release (complement fractions C3a and C5a), prostaglandins [62], and cement-related myocardial depression [63] have also been suggested as other possible mechanisms.

Finally, abundant experimental evidence now implicates pulmonary embolization of marrow contents (air, fat, and bone marrow) as the cause of cement-related hypotension. These emboli contribute to hypotension through a mechanical effect and the initiation of a chemical cascade [64]. Intraoperative transesophageal echocardiography (TEE) performed during cemented THR demonstrates a snow flurry of echogenic material in the right atrium after component insertion. This phenomenon was attenuated by placement of a venting hole in the shaft of the femur, thus preventing the rise of pressure in the medullary space [65].

Clinical changes during cemented THR occur after 30 minutes [66]. The most common clinical finding is a transient decrease in arterial oxygen tension. Pulmonary shunting has been calculated to be 28%, a finding that persists for 48 hours [67]. Venting of the femoral shaft to prevent intramedullary pressure and embolization of marrow contents has resulted in lower drops in arterial oxygen tension [68]. Significant hypotension occurs less commonly, in about 5% of cases. Cardiac arrest has also been reported [69].

Those at risk are elderly patients with malignancy, cardiac, and pulmonary disease [66]. Insertion of a long-stem femoral component in an unoperated canal is also a predisposing factor. Modern techniques such as high-volume, pulsatile lavage of the femoral canal with combined pressurized cement insertion have been shown to eliminate significant reduction in arterial oxygen tension as well as pulmonary shunt [55].

Maintenance of arterial oxygenation and adequate volume replacement are essential during surgery. Patients at risk benefit from invasive monitoring and vasopressors at the time of cement insertion. Consideration should also be given to placement of a venting hole into the femoral component.

Noncemented hip arthroplasty was developed in response to evidence that cement promotes bone loosening and prosthetic failure. Although the incidence of cardiac complications is lower with noncemented stems, cemented hip arthroplasty remains the standard in elderly patients. Noncemented prosthesis is reserved to patients under the age of 60 years or those undergoing surgical revision. In many centers, hybrid THR is now the preferred technique. It consists of a cemented femoral stem with a noncemented acetabular cup [70].

Local complications

Complications related to wound healing range from prolonged wound drainage to perhaps the most dreaded complication after THR, deep wound infection. Factors that predispose to poor wound healing should be identified preoperatively: rheumatoid arthritis, chronic steroid administration, diabetes mellitus, advanced age, and malnutrition [71].

Prophylactic antibiotics, meticulous surgical techniques, and control of the intraoperative environment are critical in the prevention of infections. The infection rate after THR is 5.8% when THR is performed in a regular operating room without antibiotic coverage, 1.3% for a regular operating room with preventive antibiotics, 0.7% for a laminar flow room without antibiotics, and 0.6% for a laminar flow room with antibiotics [72].

Early deep wound sepsis can be defined as deep infection of the surgical wound as well as the prosthetic components. Supportive care in the ICU may be indicated, in the setting of fulminant sepsis or septic shock, but the treatment remains essentially surgical. The most widely advocated plan of care consists of aggressive débridement of the wound, retention of the prosthetic components, and antibiotics targeted at gram-positive organisms. This approach had a 71% success rate in one series [73]. Failure of treatment will necessitate more extensive procedures, such two-stage exchange arthroplasty.

Fortunately, neurovascular injuries are uncommon, but they are certainly devastating for the patient and the surgeon. The incidence of vascular injury is quite low, in the range of 0.1% to 0.2% [74]. The most serious injuries affect the iliac and femoral vessels and require immediate surgical correction. Delayed injury to the iliac vessels has been reported as a result of implant migration [75].

The incidence of nerve palsy after primary THR ranges from 0% to 3% and from 2.9% to 7.6% after revision. Most of those injuries are to the sciatic nerve [76]. The causes are diverse, including direct trauma, ischemia, injury from the heat of the cement, compression by a hematoma, or dislocation of the prosthesis [77]. The prognosis is variable, with at least some recovery unless the nerve was transected.

Other complications

Gastrointestinal complications range from 1.2% to 4.6% following THR [16,22]. The most common is postoperative paralytic ileus. Gastrointestinal bleeding can also complicate the postoperative course. Patients at risk for gastrointestinal bleeding after THR include those with a history of peptic ulcer disease and the use of nonsteroidal anti-inflammatory drugs (NSAIDS) [78]. Perioperative management consists of administration of histamine 2 (H2) receptor antagonists, proton-pump inhibitors, and cessation of NSAIDS. Postoperative management will require ICU admission, fluid resuscitation, antiulcer therapy, and endoscopy.

Electrolyte imbalances, most commonly hyponatremia, can complicate the postoperative course. After THR, the incidence of hyponatremia is 4.4% [79]. Patients may be asymptomatic or exhibit symptoms ranging from lethargy to coma. Hyponatremia occurs in the setting of low total body sodium and water (in patients taking diuretics) or administration of hypotonic fluids after surgery [80]. Rapid correction of severe hyponatremia carries the risk of cerebral edema.

One of the most common problems after THR is urinary retention requiring bladder catheterization. Its incidence varies from 1% to 35% [81]. Urinary retention predisposing to urinary tract infection after THR can have serious consequences. Patients requiring bladder catheterization have a 6.2% incidence of deep hip infections [82]. Most authors recommend insertion of a short-term indwelling catheter after surgery.

Knee

It is estimated that about 150,000 TKRs are performed yearly in the United States [83]. Major complications include pulmonary embolism, myocardial infarction, and infections. Careful preoperative evaluation is critical. The type of anesthesia is critical, with epidural anesthesia the preferred choice. Intraoperative monitoring includes the use of a Swan-Ganz catheter in selected unilateral and in most bilateral cases.

Thromboembolism

Deep vein thrombosis after TKR occurs in approximately 50% of unilateral cases and as many as 75% of bilateral cases when no prophylaxis is used [84,85]. Although most authors agree that DVT occurs mainly in calf veins and is probably of little consequence, it should be regarded as a harbinger of proximal clots with serious consequences. Hass et al [86] found that 50% of patients had thrombosis of the calf veins and 8% had thrombosis of the proximal veins. Of those, 4.5% had documented positive lung scans. Symptomatic PE occurred in 1.1%. Prophylaxis for DVT remains a prudent decision after TKR. Commonly used prophylaxis includes LMWH, warfarin, heparin, aspirin, and compression devices.

Fat embolism

Fat embolism may be unrecognized as the cause of transient postoperative confusion or hypoxia mimicking PE. The exact prevalence after TKR has not been reported in the literature. In a review, Monto et al [87] reported 19 cases with 9 deaths, mostly associated with long-stem cemented prostheses.

The use of a pneumatic tourniquet does not protect against fat embolism. During tourniquet deflation, the absorption of fat and surgical debris into the medullary sinusoids might result in a sudden embolic load to the lungs. Transesophageal echocardiography has demonstrated echogenic material in the right heart chambers in most patients following tourniquet deflation [88,89]. Fortunately, clinical manifestations are rare [90].

Local complications

Tourniquets are used to control blood loss during lower extremity procedures. Inappropriate usage has been associated with both neurovascular and tissue damage. Tissues directly beneath are subject to ischemia and to compressive and shearing forces. To minimize complications, the lowest pressure that prevents capillary blood flow should be used, around 250 mm Hg in the lower extremities. Tourniquet time should not exceed 2 hours. If longer use is necessary, the tourniquet should be deflated for 10 minutes before reinflation.

Arterial complications are rare [91,92]. In 1987, Rush et al [93] reported 13 cases of arterial complications. The authors suggested that thrombosis was caused by local pressure from the tourniquet and recommended not using a tourniquet in the presence of proximal artery calcifications and poor peripheral pulses. If there is any doubt, a vascular surgeon should be consulted preoperatively [93].

Among neurologic complications, peroneal nerve palsy remains infrequent but worrisome. Mont et al [94] found a cumulative prevalence of 0.58% in the literature. Recovery is usually excellent when the palsy is initially incomplete [95].

Finally, wound drainage and delayed wound healing are of concern because they can mask a deep infection. Some authors advocate open débridement if drainage continues after 5 days of appropriate therapy.

Spine

Spinal surgery is widely performed for a variety of indications including pain, degenerative disease, deformity, and fracture. The great variations in the types of procedures performed make comparison of outcomes difficult. Procedures can be simple or involve fusion with or without instrumentation. The rates of fusion for similar indications vary widely among centers and specialties [96,97]. The specific approach to the spine can be anterior or posterior, and much debate remains concerning the merits of each approach. Some patients undergo procedures involving both approaches, either in the same anesthesia session (combined procedures) or a few days apart but during the same hospitalization (staged procedure).

Intubation considerations

In patients undergoing cervical spine surgery, intubation often poses a challenge. Those with degenerative disease of the spine usually have limited extension of the neck. Patients with rheumatoid arthritis might have various forms of atlantoaxial subluxation, temporomandibular ankylosis reducing the mouth opening, and chronic cricoarytenoiditis that predisposes to acute airway obstruction during intubation and extubation. Direct laryngoscopy should be avoided with known posterior and vertical atlantoaxial subluxations, whereas anterior, lateral, and rotatory subluxations can tolerate direct laryngoscopy after stabilization of the neck [98].

Awake intubation of a sedated patient is preferred, because intubation of the unconscious patient predisposes to greater risk of hypoxic injury. Nasotracheal intubation is usually easier than oral intubation, because the nasopharynx, oropharynx, and glottis are commonly in the same axis [99]. Nasotracheal intubation, however, is associated with a high risk of sinusitis in patients requiring prolonged periods of ventilatory support [100]. Fiberoptic intubation is preferred to a blind approach: Analysis of 128 cases undergoing posterior cervical spine fusion showed that the frequency of postoperative respiratory complications and reintubations was significantly lower in patients intubated with fiberoptic assistance [101].

Determinants of need for critical care

Most patients undergoing spinal surgery do not require intensive care. Harris et al [102] attempted to identify clinical factors associated with unexpected critical care management and prolonged hospitalization after elective cervical spine surgery. They reviewed their center's experience with 109 cases performed between 1995 and 1999. Their data suggest that multilevel decompression, preexisting myelopathy, pulmonary disease, cardiovascular disease, hypertension, and diabetes are separately linked to the unanticipated need for critical care and longer hospitalization. In a similar study, Nahtomi-Schick et al [103] attempted to determine if intraoperative fluid management in spine surgery can predict ICU LOS. They divided their patients into three groups: those who did not require ICU care, those requiring 1 day of ICU care, and those requiring more than 1 day. Significant variations in the type and complexity of the operations limited the comparison between the study groups. Patients with longer ICU LOS, however, required more transfusion with blood products and fluid replacement with crystalloids intraoperatively. The authors concluded that ICU admission can be predicted based on the type of surgery and amount of crystalloid administration.

Risk factors for complications

Complications of spine surgery can be linked to procedure- and patient-related factors. In two separate, large cohort studies based on hospital discharge records in the State of Washington, Deyo et al [104,105] demonstrated a significantly higher complication rate when fusion was performed than for surgery without fusion. This increased rate of complications resulted in 2.2 times greater nursing home placement, 1.5 times higher hospital charges, and 2.0 times greater 6-week mortality. Also, they found that operations for conditions other than herniated disc were associated with greater use of resources and more complications, particularly when arthrodesis was performed.

In a retrospective review, Fujita et al [106] compared the complication rates between cervical and thoracolumbar spine fusion in patients older than 60 years. They found that mean blood loss, operative time, and hospital LOS were greater with thoracolumbar procedures than with cervical procedures. In a separate study, McDonnell et al [107] reviewed the hospital records of 447 patients undergoing anterior spinal fusion, excluding cervical operations. They found that a thoracic approach takes less time to perform, and more blood is lost when a lumbar approach is performed, but neither approach is significantly superior in terms of complications. The same is true when thoracic and lumbar approaches are compared with thoracolumbar approaches. Multivariate analysis also showed a greater risk of major complications with a combined procedure than with staged procedures and anterior procedures. The number of levels involved in the procedure increases complication risks. More extensive procedures are associated with higher blood volume loss, more tissue edema, and greater cardiovascular stress. Data comparing anterior and posterior approaches to the spine are limited.

The most important patient-related factors are age and preexisting comorbidities. In a review of 1223 anterior spinal fusions of the thoracic and lumbar spine in adults, Faciszewski et al [108] found an increased risk of complications for patients over age 60 years, women, and patients with multiple preexisting health problems. Their finding that women are at an increased risk of complications has not been duplicated in any subsequent study. In fact, larger cohort studies suggest that women undergoing these operations tend to be older and more likely to survive, although they require nursing home care more often [105]. The age factor has been well established in many studies, as has the effect of the number of comorbid conditions. Some studies suggest a linear correlation between the number of comorbid conditions and complication rates, whereas others found an increased risk only when two or more comorbidities were present. The most frequently cited comorbid conditions include cardiovascular disease, pulmonary disease, hypertension, and diabetes. Preexisting myelopathy in the operated patient carries a higher risk of complications.

Major and minor complications

Major complications are more likely to be associated with longer hospital stay and need for intensive care. These complications include pneumonia, respiratory failure, prolonged postoperative intubation, cardiac arrest, shock, arrhythmia, congestive heart failure, stroke, delirium, prolonged use or need for reinsertion of chest tube, upper gastrointestinal bleeding, wound infection requiring débridement, diffuse intravascular coagulopathy, thromboembolic disease, injury to great vessels, monoplegia, and ureteral obstruction.

The syndrome of inappropriate secretion of antidiuretic hormone (SIADH) reportedly occurs in 5% of patients undergoing spinal fusion. It is more likely to occur in patients with spinal deformity and large intraoperative blood loss [109]. Therapy includes fluid restriction while maintaining appropriate intravascular status.

After spinal surgery, DVT and thromboembolic disease occur at a very low rate, estimated at 0.3%, but can contribute disproportionately to mortality [110]. The risk increases with LOS and immobilization. No anticoagulation is required perioperatively unless there is a history of thromboembolic disease. Appropriate preventive measures include use of compressive stockings and sequential compression devices. Other minor complications include transient hypoxia, ileus, necrosis of edge of wound, need for multiple transfusions, dural tear, transient confusion, dysethesia, atrial fibrillation, cystitis, urticaria, impotence, and retrograde ejaculation.

Intraoperative complications are usually related to the specific approach and the structures involved in the dissection field. These complications are often addressed in the operating room. The most serious is a laceration of the great vessels, such as carotid, aorta, or vena cava.

Intraoperative positioning is associated with specific complications. The sitting position increases the risk of air embolism, hypotension, and spinal hypoperfusion. The prone position may raise intraabdominal pressure, leading to ventilatory impairment and increased bleeding from epidural veins, and predispose to an epidural hematoma [99].

Infections

Patients undergoing spinal fusion are at particularly increased risk for infection. Conventional lumbar discectomy with antibiotic prophylaxis has a low infection risk, less than 1% [111]. Microdiscectomies may have a higher infection rate [112,113]. Percutaneous lumbar discectomy might have a slightly lower rate; however, the numbers reported are limited [114]. The incidence of infection increases with fusion and instrumentation. Fusion has been demonstrated to increase the infectious risk of discectomy from 1% to 3% to 6% to 8% [115]. This increase is related to larger dissection fields, greater tissue damage, longer operative time, and more significant disruption of tissue vascularity. The addition of implants also raises infection rates proportionately to the increase in operative time. These rates vary with specific operations and implants. Implants rarely act as a source of infection but more often constitute a safe harbor for bacteria. In general, cervical spine operations carry a slightly lower risk of infection than lumbar or thoracic spine operations [116].

Specific patient-related risk factors have been determined as a cause of increased infection risk. These risk factors are more easily addressed when the operation is nonemergent. Diabetics have a higher incidence of postoperative complications, two thirds of which are infectious in nature. In a study of 1548 patients in a surgical ICU, Van den Berghe et al [117] demonstrated that intensive insulin therapy to maintain blood glucose at or below 110 mg/dL reduced the mortality rate from 8.0% with conventional treatment to 4.6%. The greatest reduction in mortality involved deaths from multiple-organ failure with a proven septic focus. Intensive insulin therapy also reduced the overall in-hospital mortality rate by 34% and bloodstream infections by 46%. Patients were less likely to require prolonged mechanical ventilation and intensive care.

Other contributing factors are tobacco smoking [118], malnutrition, obesity, and cachexia. In two separate reviews, the majority of patients with spine infections were considered malnourished. Indicators include weight loss of more than 10 pounds, serum albumin less than 3.4 g/dL, total lymphocyte count less than 1500 cells/mL, skin test anergy, and arm circumference less than 80% of normal [119]. Rheumatoid arthritis, chronic steroid therapy, previous infections, coexisting infections (pneumonia, urinary colonization, ulcers, and so forth), and neoplasm are also known to increase the rate of infectious complications. Emerging data indicate that nasal carriage of *Staphylococcus aureus* is a significant risk factor for septicemia, and that eradication with topical antibiotics could reduce nosocomial pneumonia, wound infection, and sepsis [120].

Longer perioperative hospitalization leads to increased rates of wound infection. The rate of infection doubles with each additional week of stay. Most patients admitted to an ICU are colonized by hospital pathogens within 2 weeks of admission. The problem is compounded by antibiotic administration that increases rates of resistance. The use of surgical adjuncts such as methyl methacrylate, bone substitutes, and hemostatic agents may contribute to infection rates.

Neurologic complications

Neurologic complications occur in 0.3% of patients undergoing anterior spine decompression and fusion. These complications usually manifest as myelopathy, radiculopathy, or myeloradiculopathy. Frequently, the offending process is intrusion of graft or instrumentation material into the spinal canal. In kyphosis/scoliosis cases, factors that increase the risk of postoperative neurologic complications include congenital deformities, large curves, kyphosis, postradiation deformity, intraoperative correction exceeding the preoperative bending correction, passage of sublaminar wires in the thoracic and lumbar spine, and surgeon's lack of expertise [121].

In the recovery room and during the immediate postoperative period, checks should be performed regularly at short intervals to detect neurologic deterioration. When such a finding is noticed, immediate investigation should be performed to determine the cause and reversibility of the process. Initial steps in management include cervical spine radiograms to check for proper vertebral alignment and, when available, MR imaging to detect extrinsic spinal cord compression by bone, intramedullary swelling, or hematoma. When a significant clot is suspected, the patient should be returned immediately to the operating room. When no compression is identified, immobilization measures such as cervical collar should be used, and spinal cord perfusion should be maintained by normotension and intravenous fluid administration. Based on data from spinal cord injury, the use of intravenous methylprednisolone is justified at a bolus dose of 30 mg/kg over 1 hour followed by 5.4 mg/kg over the next 24 hours [122].

Delayed neurologic injury can occur. Such injury has been described in patients with Down syndrome undergoing upper cervical spine fusion for atlantoaxial instability [123]. Delayed neurologic injury has also been described after instrumentation of narrow segments of the spine, presumably related to edema compromising blood supply [124].

Graft- and instrument-related complications

Graft extrusion and instrumentation failure can occur in the perioperative period. Posterior extrusion of the graft can result in myelopathy and needs surgical intervention. Anterior extrusion is more likely to be clinically significant at a cervical level because of the potential for tracheal obstruction, dysphagia, neurologic injury, and kyphosis. The incidence of graft extrusion is between 1% and 13%. Good surgical technique and anterior plating can prevent it.

Instrument failure occurs at a rate of 5% to 17%. Known risk factors include age greater than 70 years, low bone mineral density, revision operations, and long plates [121].

Site-specific complications

After cervical fusion, carotid injury, upper airway edema, recurrent laryngeal nerve injury, and vertebral artery laceration can occur. Recurrent laryngeal nerve injury is less likely with a left-sided approach. Horner-Bernard syndrome caused by injury to the stellate ganglion has been described after high dissection involving T1 and T2 levels [108]. Thoracic and thoracolumbar approaches usually require chest tube placement. Pneumothorax, pleural effusion, and persistent pain syndrome are common in this setting. Thoracolumbar and lumbar operations can cause abdominal hernia, retroperitoneal lymphocele, ureteral laceration, lumbar plexus injury, postsympathectomy neuralgia, and femoral nerve palsy.

Donor site-related complications

When autogenous bone grafting is performed, the donor site should be evaluated for signs of infection, bleeding, and neurologic injury, particularly when the iliac crest is harvested. Arrington et al [125] reported an incidence of 5.8% of major complications and 10% of minor complications at the donor site. Major complications included vascular injuries, deep hematomas, neurologic deficits, deep infection, iliac wing fracture, and abdominal herniation. Fracture of the iliac crest occurs more often in women and is usually treated with conservative non–weight-bearing measures. Pelvic instability can also occur after posterior iliac crest harvest and is thought to be caused by injury to the superoposterior sacroiliac ligaments. Multiparous women might be at an increased risk of this complication.

Special considerations in scoliosis surgery

Scoliosis is a progressive disease in which severity is related to the angle of the curvature. A curvature less than 60° is unlikely to be associated with pulmonary dysfunction. The earliest manifestations consist of a restrictive ventilatory pattern with reduction in the vital capacity. Gas exchange is also affected by ventilation/perfusion mismatch, alveolar hypoventilation, increased dead space ventilation, and widened A-a gradient. This impairment of gas exchange results in pulmonary hypertension and hypercapnea, eventually leading to respiratory failure. Patients with scoliosis have respiratory muscle weakness leading to inadequate cough, limited ability to handle secretions, and greater predisposition to infection. Surgery is usually performed to limit the progression of the disease and prevent complications. There is some debate about the long-term effect of surgery on lung function and gas exchange. There is evidence, however, that lung function might deteriorate acutely during surgery and the postoperative period.

Complications can arise after rapid correction of extreme deformities because of interference with the circulation to the spine leading to anterior spinal artery syndrome. When a thoracotomy is performed, a left-sided approach is preferred, because it is easier to handle the thick-walled aorta than the relatively vulnerable vena cava on the right. Deliberate hypotension is a technique used during scoliosis surgery to reduce blood loss; it is associated with greater risk of spinal cord ischemia. Agents used to achieve hypotension include nitroprusside, which is associated with methemoglobenemia. Anesthesia in scoliosis patients could cause hyperkalemia, cardiac arrhythmia, and malignant hypertension [126,127]. The intensivist should be alert to these complications.

Preoperative respiratory impairment predicts the need for postoperative mechanical ventilation. Some patients might require a tracheostomy. Patients in whom a thoracotomy or a thoracoabdominal approach is used have a significantly higher number of pulmonary complications. Scoliosis patients are quite sensitive to respiratory suppressants, and care should be taken to avoid heavy sedation perioperatively.

Another common complication of scoliosis surgery is the development of a paralytic ileus. Therefore a nasogastric tube is usually inserted and left in place until bowel function is recovered.

Other aspects of postoperative care

Some medications should be avoided in the perioperative periods including NSAIDs, especially ketorolac, because it has been shown to inhibit and delay bone formation, resulting in a fivefold increase in the rate of pseudoarthrosis in instrumented spinal fusion [128]. Also, many agents used for the treatment of rheumatoid arthritis should be avoided. Methotrexate is known to inhibit growth of rapidly regenerating tissue by inhibiting DNA synthesis, and thus its use should be discontinued in the perioperative period [129].

Summary

Complications of orthopedic and spine operations can be life threatening. Proper patient selection, careful planning of patient care, and prophylactic measures are important determinants of a successful outcome. After elective orthopedic surgery such as total joint replacement, the intensivist should be aware of potential systemic complications common to any major surgical intervention (pneumonia, pulmonary embolism, sepsis, myocardial infarction) and also of procedure-specific problems (cement-related cardiac events, fat embolism) and local complications (neurovascular injuries). Patients undergoing spine procedures should have close neurologic monitoring for immediate and delayed deficits.