ICU Care for the Spine Patient

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Spine patients in the intensive care unit (ICU) generally include two groups of patients: postoperative patients after elective spine surgery and patients who have acute spinal cord injury (SCI). Patients are more likely to require critical care services after spine surgery if they have advanced age, increased comorbidity burden, increased surgical invasiveness, and development of postoperative complications [1]. Patients with SCI are more likely to need admission to the ICU if they have high cervical SCI, complete SCI, advanced age, history of cardiopulmonary disease, and need for significant respiratory support [2]. Every spine patient in the ICU has critical care needs specific to their individual comorbidities, their expected clinical course based on their admitting diagnosis, and their potential to develop complications. Comprehensive critical care is provided using a system-based approach. This chapter will discuss these systems in separate sections.

Neurological System

Neurological Exam

Spine patients in the critical care unit receive serial neurological evaluations. New-onset neurologic deficits require attention and further evaluation with imaging to rule out acute spinal cord compression or nerve root compression to assess if surgical intervention is needed [3, 4]. In the postoperative spine patient these evaluations

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include level of consciousness, orientation, and bilateral upper and lower extremity motor/strength and sensation testing. In patients with SCI, the International Standards for Neurological Classification of Spinal Cord Injury represents the gold standard assessment for documentation of the level and severity of a spinal cord injury [5]. This was formulated as a result of collaboration between the International Standards Committee of the American Spinal Injury Association (ASIA) and the International Spinal Cord Society. The assessment is a detailed strength and sensory exam to evaluate the level of the neurological injury, complete or incomplete injury, the ASIA Impairment Scale (AIS) Grade, and the zone of partial preservation. A proper neurologic assessment always includes a rectal examination because sacral sparing has prognostic significance in the patients with SCI [6]. Acute cerebral ischemia and seizures can also occur in both groups of spine patients given the acute change in medical condition which requires intensive care in addition to individual predisposing comorbidities.

In patients with SCI, there are additional considerations for the neurological exam. Traumatic brain injury can occur concurrently with SCI. Spine immobilization should be maintained until definitive treatment. There is no evidence to recommend the routine use of steroids in order to improve functional recovery in this setting [4, 7].

Pain Management

Patients who undergo spine surgery typically require intensive pain management for acute postoperative pain in the setting of preexisting chronic pain. Patients who have preexisting chronic pain may have tolerance to narcotics and non-narcotic analgesics, complicating pain management. Immediately after spine surgery, there is often intense acute pain for the first three days. Adequate pain management in this period has been shown to correlate well with improved functional outcome, early ambulation, early discharge, and prevention of the development of chronic pain [8]. A multimodal pain regimen combining opioids and non-opioid analgesics can effectively control pain [8]. Opioids may be administered on a scheduled regimen, as needed, or utilizing a patient-controlled analgesia (PCA) pump. Common choices for non-opioid analgesics include muscle relaxants, nonsteroidal anti-inflammatory drugs (NSAIDs), acetaminophen, gabapentinoids (gabapentin/pregabalin), and ketamine. Continuous wound infiltration and/or epidural delivery of local anesthetics can also be utilized to reduce postoperative pain [8–10].

In addition to treatment of somatic and neuropathic pain with a multimodal regimen similar to that mentioned above, patients with SCI require treatment of spasticity. Oral baclofen and tizanidine are recommended as first treatments in SCI related spasticity, with intrathecal baclofen shown to also reduce autonomic dysreflexia [11, 12]. Orthoses, daily passive muscle stretching, and exercises to strength the muscle groups can aid in the management of spasticity, given the concern for spasticity to develop into chronic contractures [13].

Mobility, Therapy, and Rehabilitation

Physical and occupational therapists work with spine patients to evaluate mobility, balance, ambulation, and to assess for assistive device needs. Additionally, these therapists work with patients to perform their activities of daily living. Assessment of home layout and evaluation of caregiver support availability are completed prior to discharge from the hospital. Mobility during the daytime contributes to normal sleep-wake cycles, thus reducing delirium. It also decreases the risk of development of atelectasis, venous thromboembolic (VTE) disease, pressure sores, and musculoskeletal problems related to prolonged bedrest [13–16].

Delirium

Delirium has been noted to affect as many as 87% of patients in the ICU, and the incidence of postoperative delirium after spinal surgery ranges from 0.49% to 21% [17–19]. Predisposing patient factors for the development of delirium include older age, cognitive impairment, functional dependence, alcohol and drug abuse, and significant underlying comorbidities such as sensory impairment, diabetes, anemia, and malnutrition [17–21]. For those who undergo spine surgery, intraoperative factors include increased duration of surgery and the need for blood product transfusion [16, 17]. Furthermore, any acute change in medical status, especially one requiring ICU admission, can increase risk of developing delirium. Examples include hemodynamic instability, cardiopulmonary insufficiency, abnormal laboratory data, need for blood transfusion, and iatrogenic administration of certain medications such as opioids, benzodiazepines, and anticholinergics [16, 18, 19, 22]. Overall, early recognition of patients at an increased risk for delirium increases providers' ability to institute timely preventative and treatment strategies.

Effective treatment of delirium is mostly non-pharmacologic and includes maintaining a consistent family presence, decreasing polypharmacy, and encouraging a normal sleep-wake cycle. Patients should participate in activity during the day and minimize disruptions at night [16, 22, 23]. Correcting abnormal laboratory values and treating dehydration also reduces the incidence of delirium [19, 23]. In patients who require mechanical ventilation, daily spontaneous awakening trails, daily spontaneous breathing trials, and overall reduction in sedative use allows for early mobility with therapy services. This is associated with better clinical outcomes and a reduction in delirium [19, 24].

Cardiovascular System

Patients may have underlying comorbidities which predispose them to the development of arrhythmias or hemodynamic lability. Such baseline conditions include chronic hypertension, diabetes, coronary artery disease, congestive heart failure, and chronic/paroxysmal arrhythmias. The physiological stress of surgery also increases the risk of hypotension, hypertension, new-onset arrhythmia, heart failure, and myocardial injury [25]. The goals of hemodynamic optimization are to preserve spinal cord perfusion, minimize postoperative surgical bleeding, and provide adequate end-organ perfusion. While hypertension can increase the risk of surgical site bleeding, it also increases myocardial demand and the risk for stroke. Conversely, hypotension increases the risk of ischemia to the spinal cord and end organs.

All patients in the critical care unit are monitored with continuous telemetry and serial blood pressure evaluations as the standard of care. Blood pressure is monitored either continuously using an arterial line or serially from a non-invasive blood pressure pneumatic cuff. Adequate perfusion is evaluated with serial neurological exams, serial laboratory tests, and frequent urine output. Further hemodynamic components that are routinely monitored and optimized include intravascular volume status, cardiac output, and global oxygen delivery.

Postoperative Cardiac Considerations After Spine Surgery

Protocol-based blood pressure goals have been shown to improve outcomes after elective spine surgery [25–27]. While there is not a consensus for an overarching post-spine surgery blood pressure target, the hemodynamic goals should take into consideration individual comorbidities, spinal cord perfusion, organ perfusion, and complications arising from both hypotension and hypertension [25].

Perioperative cardiac events are the leading cause of death following non-cardiac surgery. Major adverse cardiac events (MACEs) include myocardial infarction, cardiac arrhythmias, and cardiac arrest [28]. The postoperative median time period to develop myocardial infarction after elective spine surgery is approximately two days, affecting 1%–2% of patients [29]. Patients who are male with comorbidities of advanced age, obesity, diabetes mellitus, hypertension, anemia, chronic renal insufficiency, and a history of cardiac disorders are more likely to develop MACEs after spine surgery [30–32]. Intraoperative risk factors include larger surgeries with at least two levels of spinal fusion and intraoperative blood transfusion [30, 31]. MACEs can present with dyspnea and angina, abnormalities in continuous telemetry, acute electrocardiogram changes, and cardiac enzyme elevation. Transthoracic and transesophageal echocardiography can provide further information on the etiology and response to treatment. Although individual patient factors must be considered, the general treatment strategy for acute postoperative myocardial infarction includes administration of oxygen, nitroglycerin, morphine, beta blockade, and aspirin. The decision to proceed with emergent coronary revascularization with cardiac catheterization should take into consideration the need for periprocedural anticoagulation and postrevascularization antiplatelet therapy, both of which can increase the risk of postoperative bleeding [33].

Cardiac Considerations After Spinal Cord Injury

In order to ensure adequate spinal cord perfusion, current guidelines recommend maintaining a mean arterial blood pressure >85–90 mmHg for at least the first week after an acute SCI, past the time when spinal cord edema and vascular congestion are expected to be maximum [4, 34, 35]. Patients with SCI are at risk for spinal shock, neurogenic shock, and autonomic dysreflexia. Patients with SCI above the splanchnic sympathetic outflow (T5–T6) have pooling of blood within the venous system and decreased cardiac return, resulting in systemic hypotension. SCI above the level from which the cardiac accelerator nerves arise (T1-T4) directly contributes to decreased cardiac output and hypotension. Hypotension can also occur due to hemorrhage, pneumothorax, myocardial injury, pericardial tamponade, sepsis, abdominal injury, adrenal insufficiency, and other traumatic insults. These patients may present with bradycardia or arrhythmias due to direct loss of sympathetic input to the heart [4, 6]. In addition to managing the direct cause of hemodynamic instability, the Consortium for Spinal Cord Medicine guidelines suggest that cervical and thoracic injuries through T6 should be treated with vasoactive mediations that provide inotropy, chronotropy, and vasoconstriction. Either dopamine or norepinephrine are suggested as first-line vasoactive agents [4, 36, 37].

Orthostatic hypotension is common in patients with SCI and can be addressed with both nonpharmacologic and pharmacologic interventions. Nonpharmacologic treatment includes lower limb compression with graduated elastic stockings and elastic wraps, abdominal binders, adequate hydration, and gradual attainment of an upright position. Medication regimens can include fludrocortisones, midodrine, or ephedrine. Orthostatic hypotension should be aggressively managed as it impedes mobilization, rehabilitation, and recovery [6, 38].

Respiratory System

The respiratory system consists of the upper respiratory tract and the lower respiratory tract. The upper respiratory tract includes the airway structures of the nasal passages, oropharynx, and larynx above the vocal cords. The lower respiratory tract includes the larynx below the vocal cords, trachea, bronchi, bronchioles, and alveoli. Spine patients in the ICU can have difficulty with oxygenation and ventilation due to pathology in the upper respiratory tract, the lower respiratory tract, or both. Standard monitoring in the intensive care unit includes continuous pulse oximetry. To further evaluate the respiratory system, arterial blood gases and chest imaging are commonly utilized.

Airway Compromise After Spine Surgery

Patients can have baseline conditions that predispose them to upper respiratory tract complications after spine surgery. These include advanced age, morbid obesity, prior smoking, obstructive sleep apnea, pulmonary disease, cervical myelopathy, and prior anterior cervical spine surgery [39, 40]. Intraoperative anesthetic and surgical events can increase the likelihood of postoperative upper respiratory tract complications. These include difficult airway, multiple intubation attempts, more than 300 mL of blood loss, prolonged procedures more than five hours, the type of surgical method, exposing more than three vertebral levels, and surgery that includes C2, C3, or C4 [39–41].

A rare but potentially lethal complication after anterior cervical spine surgery is respiratory compromise from airway obstruction. This is most likely to occur in the first 12–72 hours postoperatively. It may require emergent reintubation and has been reported to occur in 6.1% of patients following anterior cervical spine surgery [41]. Although airway obstruction is most likely due to the development of laryngopharyngeal edema, wound hematoma, abscess, cerebrospinal fluid collection, vocal cord dysfunction, and construct failure can also contribute. If there is concern for airway compromise, then an endotracheal tube cuff leak test or fiberoptic bronchoscopy can further assess airway patency prior to extubation. An endotracheal tube exchanger can be used as a placeholder in the trachea at the time of extubation to facilitate reintubation if necessary [39].

Lower Respiratory Tract Complications After Spine Surgery

Lower respiratory tract complications after spine surgery include acute respiratory failure, atelectasis, pleural effusion, pneumonia, pleural effusion, and pneumothorax [42–44]. Patients may have inherent comorbidities that predispose them to pulmonary complications in the lower respiratory tract after spine surgery. These comorbidities include advanced age, scoliosis causing restrictive lung disease, history of smoking, chronic obstructive pulmonary disease, asthma, pre-operative oxygen dependence, obstructive sleep apnea, poor baseline functional status, and diabetes [42, 43, 45]. There are procedure-related factors that may increase the risk of pulmonary complications following spine surgery. For example, a prolonged duration of surgery is associated with an increased risk. Furthermore, corrective surgery for spinal deformities can utilize a technical approach that invades the thoracic cavity. This invasion of the thoracic cavity can lead to lobar collapse. Diaphragmatic manipulation or irritation during surgery can cause postoperative pleural effusions. Intraoperative blood transfusions and aggressive volume resuscitation can lead to fluid shifts resulting in pulmonary edema. Prolonged surgical immobility and postoperative pain can increase atelectasis. The combined immobility from both the intraoperative period and the postoperative period increases the risk of pulmonary embolism (PE). Early mobilization and aggressive respiratory care can reduce several of these postoperative pulmonary complications [46–48].

Respiratory Care in Spinal Cord Injury

Patients with acute SCI require significant respiratory care and are at a high risk for respiratory complications. Baseline respiratory parameters should be obtained and monitored continuously. Standard respiratory care for patients with SCI includes frequent suctioning, using manually-assisted coughing to augment weak accessory muscles to expel retained secretions, pulmonary hygiene, and mechanical insufflation-exsufflation [4].

If intubation is necessary, then spine immobilization must be maintained if spinal cord instability is present [6]. Up to 100% of patients with cervical SCI require intubation and mechanical ventilation [6, 49]. Additional risk factors for intubation include advanced age, underlying respiratory pathology, and tachypnea on admission [2]. Weak or absent cough reflex, loss of accessory respiratory muscle function, diaphragmatic dysfunction, and weakness of abdominal muscles leads to aspiration, reduced tidal volumes, atelectasis, mucus plugging, and pneumonia. Additionally, patients with SCI can develop pleural effusions, pneumothorax, acute respiratory distress syndrome (ARDS), acute lung injury (ALI), transfusion-related acute lung injury, and pulmonary thromboembolism.

In patients without ALI or ARDS, larger tidal volumes may be utilized to titrate to a patient's respiratory mechanics, reduce atelectasis, and progress with weaning trials. Patients who develop ARDS or ALI should utilize mechanical ventilation with a lower tidal volume and a lower plateau pressure to reduce mortality [35, 50, 51]. Readiness for weaning from mechanical ventilation is indicated by sufficient vital capacity, improved secretions, ability to cooperate, upper airway patency, chest radiography without acute findings, and an improving mechanical ventilation support requirement [52]. Patients with complete SCI, especially cervical SCI, and those with significant concurrent injuries are more likely to undergo a tracheostomy given the increased likelihood of prolonged mechanical ventilation [35].

Renal System

Spine patients may have baseline comorbidities that mandate closer monitoring of their renal function, including advanced age, diabetes mellitus, hypertension, chronic kidney disease, and end-stage renal disease. During any surgical procedure, patients can develop hypotension from anesthetic medication effects, blood loss, and insensible free water losses. These can be exacerbated in prolonged spinal surgery procedures or those with significant intraoperative or postoperative bleeding. Accordingly, patients may present with acute kidney injury, urinary retention, and electrolyte derangements that require frequent serum chemistry evaluation and close monitoring of urine output.

Acute Kidney Injury

Acute kidney injury (AKI) is a common complication in hospitalized patients, with an incidence of 3–10% [53–57]. Patients who develop AKI have in-hospital mortality rates as high as 30–70% [54, 58–60]. In general, AKI can result from prerenal, intrinsic renal, and postrenal etiologies. The most common causes of these include renal hypoperfusion, administration of nephrotoxic medications, and urinary tract obstruction respectively. Close monitoring of urine output ensures a more appropriate volume status and has been associated with improved detection of AKI and reduced 30-day mortality in patients experiencing acute kidney injury [61]. Adequate urine output is typically defined as 0.5–1 ml/kg/hr to ensure perfusion, although each patient's comorbidities should be evaluated closely to individualize this target [62]. Over-resuscitation can result in volume overload, hypertension, hypoxemia, and exacerbation of congestive heart failure.

Electrolyte Disorders

Electrolyte disorders are common in patients in critical care and can cause increased morbidity and mortality [63, 64]. Patients are at an increased risk for electrolyte disorders if they have underlying diabetes, hypertension, and chronic renal insufficiency. Periprocedural blood loss requiring transfusion, various types of intravenous fluid resuscitation, and osmotic diuretics affect the physiologic electrolyte balance. Overall, electrolyte disorders increase the risk for the development of delirium, seizure, coma, cardiac arrhythmias, respiratory failure, gastrointestinal dysmotility, and cardiac arrest [63, 65, 66].

Urinary Retention

Postoperative urinary retention (POUR) is the most frequently reported genitourinary complication after spine surgery, with an incidence ranging from 5–38%. Patients are more likely to develop POUR if they are older, male, have a history of AKI, urinary tract infection (UTI), benign prostatic hypertrophy, hypertension, or diabetes mellitus. POUR can lead to the development of UTI, sepsis, and increased length of stay [67]. Indwelling urinary catheters can relieve bladder distention and are useful to closely monitor urinary output. Once close monitoring of the urine output is no longer necessary, the indwelling urinary catheter should be removed because their prolonged use can increase the risk of UTI. Intermittent catheterization of the bladder can be initiated if necessary following removal of the indwelling catheter.

Patients with SCI can have neurogenic bladder due to the loss of reflex activity in the lower genitourinary tract. This loss of ability to spontaneously void leads to urinary retention, with bladder distention being one of most common causes of autonomic dysreflexia [4, 68]. Similar to patients with POUR, the use of indwelling urinary catheters can relieve bladder distention but should be removed when close monitoring of urinary output is no longer necessary [68].

Gastrointestinal System

Spine patients can have dysmotility in the upper and/or lower gastrointestinal tract. This commonly presents with nausea, vomiting, ileus, or diarrhea. Further evaluation may be necessary to rule out more significant causes for dysmotility such as infection, mechanical obstruction, acute colonic pseudo-obstruction, hemorrhage, and peritoneal wall rupture. Adequate nutrition and appropriate blood sugar control are vital to ensure wound healing and decreasing the risk of infection.

Dysphagia

Spine patients with dysphagia are at increased risk of pulmonary aspiration. These patients may be unable to swallow altogether or have trouble swallowing food and managing their secretions. Risk factors for spine patients to develop dysphagia include advanced age, weak or absent cough, anterior cervical spine surgery, cervical SCI, and prolonged respiratory failure [4, 69, 70]. It is imperative to identify dysphagia early in order to initiate timely evaluation and intervention by speech pathologists. These efforts can reduce the risks of aspiration, chemical pneumonitis, and pneumonia [4, 69]. Speech therapists can evaluate for dysphagia with a bedside swallowing examination, videofluoroscopic swallowing study, and fiberoptic endoscopic examination of swallowing.

Postoperative Ileus

Ileus is a relatively common postoperative finding after elective spine surgery, occurring in approximately 3.5% of patients undergoing lumbar spine surgery [46, 71]. Preoperative risk factors include chronic anemia, alcohol abuse, chronic lung disease, fluid/electrolyte disorders, and recent weight loss [71]. Intraoperative surgical factors that increase the risk and duration of postoperative ileus include multiple fusion levels, increased surgical blood loss, and increased intestinal manipulation from an anterior approach [71, 72]. In addition, all types of anesthesia have an effect on bowel motility [73, 74]. The use of postoperative opioids for analgesia has an inhibitory effect on gastric motility [74]. Providing medications for symptom management, correcting abnormal serum electrolytes, and minimizing agents that exacerbate symptoms can prevent or reduce the more significant complications of aspiration, underfeeding, and decreased mobility [75]. Early ambulation has been postulated to have a prokinetic effect on the gastrointestinal system, and this may also help to reduce rates of delirium, atelectasis, and VTE [13–16, 22, 23, 46, 76].

Neurogenic Bowel Dysfunction

Patients with SCI commonly have loss of colonic motility control. The presence or absence of the bulbocavernosus reflex indicates upper motor neuron versus lower motor neuron bowel dysfunction. Early in the treatment course, a bowel regimen should be created and titrated to the needs of each patient depending on the presentation of constipation or diarrhea. The goal is to have one bowel movement per day, with a combined regimen of oral medications, suppositories, and digital stimulation [4, 77]. Constipation and impaction are some of most common causes of autonomic dysreflexia in patients with SCI at level T6 or above. If a patient presents with diarrhea, a rectal tube may be a useful temporary measure while the etiology is evaluated, which may include medication effect, electrolyte abnormality, or infection [4].

Glycemic Control and Nutrition

Hyperglycemia, diabetes, and malnutrition have been associated with adverse outcomes in both patients after elective spine surgery and those with SCI. Patients with diabetes have been reported to have an increased risk of infection, including surgical site infections, ventilator associated pneumonia, and catheter-related bacteremia. There is increase in adverse complications especially in patients who have serum blood sugars >200 mg/dL [4, 78–81]. The goal of glycemic management is euglycemia, targeting blood glucose values <180 mg/dL. Early enteral nutrition should be initiated in both patients with SCI and those after elective spine surgery to reduce complications and improve outcomes [4, 82–84]. In patients with SCI, this has been associated with an improvement in wound healing, reductions in infectious complications and gastric stress ulceration, and a lower incidence of hyperglycemia [4, 84].

Hematologic System

In spine patients, there is a need to balance pathologic bleeding and increased thromboembolic risk, both of which are associated with morbidity and mortality. Bleeding can cause or exacerbate neurological deficits, MACEs, hemodynamic instability, and progressive coagulopathy. VTE disease can cause morbidity from post-thrombotic syndrome involving local tissues from deep venous thrombosis (DVT) or increase mortality rates from PE.

Hematologic Considerations After Spine Surgery

The incidence of VTE after spine surgery has been reported to occur in up to 31% of patients, with the rate of DVT ranging from 0.3–15.5% and the rate of PE ranging from 0.06–18%. Fatal PEs represent about 6% of all PEs that occur after spine surgery [85–87]. Patients are at an increased risk of VTE if they are male, older, obese, have baseline dependent functional status, or have a history of malignancy, hypertension, transient ischemic attack, or stroke. Longer operative time, perioperative blood transfusions, and lumbar spine surgery further increase the risk of postoperative VTE [88–92]. Prolonged postoperative immobilization increases the risk of VTE, while early ambulation can decrease the incidence of VTE [46, 88]. Mechanical and chemical thromboprophylaxis interventions include the use of intraoperative and postoperative elastic stockings on the legs, intermittent pneumatic compression devices, early mobility, and administration of unfractionated heparin or low molecular weight heparin [93].

Conversely, patients who undergo spine surgery can experience morbidity and mortality due to acute anemia blood loss, coagulopathy, hemodynamic instability, and MACEs. Formation of an epidural hematoma can require emergent surgical evacuation and risks permanent neurological damage. For these reasons, the risk of bleeding should be balanced with the risk of VTE for each patient's comorbidities, surgical procedure, and postoperative needs.

Hematologic Considerations in Spinal Cord Injury

Patients with SCI are at a high risk of developing VTE within the first week of injury. Advanced age, malignancy, and concurrent injuries increase the risk of developing VTE [35]. Early administration of thromboprophylaxis within 72 hours of the initial injury is recommended after SCI if there are no contraindications. This includes mechanical and chemical thromboprophylaxis interventions such as intermittent pneumatic compression and low molecular weight heparin or unfractionated heparin [4, 6].

Potential contraindications to the administration of chemical thromboprophylaxis include inadequate hemostasis, intracranial bleeding, neuraxial hematoma, or hemothorax. If patients have active bleeding for more than 72 hours, then inferior vena cava filter placement may be needed. Once hemostasis is achieved, then chemical thromboprophylaxis should be initiated as soon as possible [4]. Inferior vena cava filters are not recommended as a routine prophylactic measure in SCI patients. These filters can be utilized in patients who have VTE despite anticoagulation and for those with contraindications to mechanical and chemical thromboprophylaxis [6].

Infectious Disease Considerations

Spine patients in the ICU can have infectious disease considerations affecting the spine as well as other organ systems. The former includes incisional and soft tissue infections, deep infections, vertebral osteomyelitis and discitis, central nervous system abscesses, and spinal hardware infections. The latter includes pneumonia, urinary tract infections, line-associated infections, bacteremia, infectious colitis, and pressure ulcers.

All spine surgical procedures carry a risk of post-procedural infection. Postoperative spine infection rates have been reported to be up to 20% of spine surgeries. Patients with advanced age, diabetes, developmental delay, immunosuppression, obesity, smoking, and malnutrition are at an increased risk of infection. Spine surgeries for trauma/SCI, instrumentation placement, increased blood loss, and a prolonged operative time further increase the risk of infection [78, 94–97].

Patients with an infection at the site of the surgical procedure will present with persistent, progressive back pain out of proportion to the physical findings. The pain may radiate to the buttock, thigh, leg, groin, perineum, or abdomen. Constitutional symptoms are not consistently present. Superficial, skin, and soft tissue infections may present with redness, swelling, or purulent drainage at the incision site, however less than 10% of surgical incisions will present in this manner [78, 94]. The presence of a neurologic deficit should raise suspicion for an epidural abscess. Postoperative infections after anterior cervical procedures may present with painful swallowing due to development of a retropharyngeal abscess [78]. Further evaluation including laboratory, imaging, and surgical exploration may be necessary to delineate between the different differential diagnoses [94].

Infectious Disease Evaluation

Laboratory evaluation often includes a complete blood count with differential, erythrocyte sedimentation rate, C-reactive protein, and blood cultures. Serial assessment of these parameters may help providers identify an evolving infection and monitor the effectiveness of their treatment. Blood culture data can help direct appropriate antimicrobial therapy based on local infectious patterns [78, 97, 98].

Imaging modalities include plain radiographs, computerized tomography (CT) scans, and magnetic resonance imaging (MRI). Negative plain radiographic findings do not exclude infection [78]. Spine CT can show bony destruction, soft tissue collections, erosive changes at the endplates, and loss of intervertebral disc space [78, 94]. MRI with gadolinium enhancement is the preferred imaging modality to visualize postprocedural spine infections and is able to clearly delineate epidural, subfascial, and subcutaneous abscesses [78, 94, 96–98].

Infectious Disease Treatment Principles

Effective treatment of post-neurosurgical infections requires that antimicrobials penetrate the blood-brain and blood-CSF barriers. Certain antimicrobials are reportedly effective in the in vitro setting but should not be used in practice as they do not adequately penetrate the CNS. Additionally, biofilms on hardware are more difficult for antimicrobial medications to penetrate [94]. Tissue biopsy or needle aspiration of purulent material can aid in providing a microbiological diagnosis to direct antimicrobial therapy [78, 94]. Treatment length is based on clinical, laboratory, and radiographic responses.

As discussed previously, other infectious disease considerations can include pneumonia, UTIs, line-associated infections, bacteremia, and pressure ulcers. The risk of pneumonia can be reduced with pulmonary toilet, respiratory therapy, monitoring for aspiration, and early mobilization [42–44, 46–48]. The majority of UTIs occur in the setting of POUR and indwelling urinary catheters [67]. Removal of lines and catheters as soon as possible can reduce the risk of UTIs and other line-associated infections. Pressure ulcers and foot drop injuries can be mitigated with frequent turning, orthoses, and early mobility [13]. Finally, early administration of appropriate antibiotics, infectious source control, and intravascular volume resuscitation are crucial to improve morbidity and mortality in patients with sepsis and septic shock [99].

Conclusion

Overall, spine patients in the intensive care unit represent a complex, heterogeneous patient population. Diligent monitoring, early recognition, and timely management of complications are essential. Providers should consider a systematic evaluation of patients' care needs given the potential for morbidity and mortality.

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