Penetrating injuries to the spinal cord constitute less than 15% of new spinal cord injuries (SCIs) each year in the United States. These injuries rank as the third leading cause of SCI, after motor vehicle accidents and falls. They may result from missile or stabbing injuries, and predominantly occur in areas with a high rate of violent crime.

Most of the early experience with neurosurgical management of penetrating spinal cord injury was gained during wartime. During World War I, the overall mortality rate from a missile injury to the spinal cord was 71.8%. Victims of penetrating injury with complete myelopathy rarely survived, as was the case at that time for complete myelopathy of any cause. The optimal treatment of these patients, including resuscitation, surgical intervention, and postoperative care was unknown. An operative mortality of 62% discouraged most surgeons from attempting intervention. Neurosurgical treatment usually consisted of laminectomy, in the case of incomplete myelopathy, or debridement of entry and exit wounds, in the case of complete myelopathy.

Numerous medical advances have since been made that have greatly lengthened the life expectancy of SCI victims. Many of these breakthroughs, including antibiotic therapy and advanced trauma life support, occurred during or after World War II. The mortality of penetrating spinal cord injury in the second war decreased to between 7.4 and 14.5%. Surgeons, however, remained pessimistic about operative intervention for these injuries until the Korean War. During this conflict, most penetrating spinal injuries underwent surgical exploration, with reports of improvement in some cases.

The number of penetrating injuries to the spinal cord among civilians has sadly increased over the past several decades. Among the industrialized nations, gunshot wounds are vastly more common in the United States. Stabbing injuries, less common in the United States, are observed more frequently in South Africa, where they account for 25% of all SCIs.

An understanding of the pathophysiology of this disease continues to evolve, although the available treatments remain quite limited.

**Patient Selection**

**Physical Examination**

Once the patient has been stabilized, a thorough history must be obtained. A detailed neurological examination must follow. Information about the mechanism of injury, associated trauma, and type and caliber of weapon should be sought. This is important prognostically and therapeutically. High-velocity bullets, most often used by the military, may cause injury by passing near the spinal cord, creating damaging shock waves. These bullets may therefore damage the spinal cord by a concussive effect, direct entry into the canal, or associated vascular injury. Some of these spinal cord injuries, notably the concussive injuries caused by shock waves, may improve. Lower-velocity bullets, the type most commonly seen in civilian injuries, tend to cause damage by direct violation of the spinal cord. This usually results in an all-or-none effect with these weapons: those who do suffer spinal cord injuries tend to be complete. The prognosis, consequently, with myelopathy created by a low-velocity bullet is poor.

One must document immediately the level of spinal cord injury and American Spinal Injury Association (ASIA) grade. Fifty percent of penetrating injuries occur in the thoracic region. Twenty percent are cervical, and the other 30% occur in the thoracolumbar area. Over 50% of gunshot wounds to the spinal cord that cause SCIs result in a complete SCI. This percentage is higher in the thoracic spine. Entry and exit wounds must be inspected, with careful attention paid to the presence of obvious contamination or leakage of fluid from the wounds.

**Radiological Assessment**

Standard anter ior/posterior and lateral roentgenograms of the spine are mandatory and must be obtained as soon as possible. Notation should be made of the location of the bullets and/or other objects. The alignment of the spine and presence of fractures can also be evaluated at this time. A computed tomographic (CT) scan through the involved
Penetrating spinal injuries may: traverse the spinal cord completely (a), enter the spinal canal and lodge in the cord (b), or miss the cord altogether and damage only the spine or meninges (c).

The use of magnetic resonance imaging (MRI), in cases of retained missile in the vicinity of the spinal cord, remains controversial. Despite the presence of metallic artifact, valuable information can be gained. This must be weighed against the risk of fragment migration, which could be catastrophic for an intact patient. The exact risk remains unknown, but series do exist of patients undergoing MRI, with retained spinal bullets, without untoward consequences. Myelopathy, after penetrating injury, may result from a compressive hematoma, a surgically treatable lesion. It is difficult to visualize a hematoma with any other study, although CT-myelogram may be utilized. MRI and myelogram may also be needed at later times if a cerebrospinal fluid (CSF) fistula is suspected.

In general, it seems wise to avoid MRI in neurologically intact patients with a fragment near the spinal cord. Complete patients presenting acutely, however, may benefit from early identification and removal of a compressive hematoma. As such, MRI should be considered for these patients, if not otherwise contraindicated. The potential benefit of MRI, either acutely or delayed, in a patient with incomplete myelopathy must be carefully weighed against the theoretical risk of further injury from missile migration. Most incomplete patients do not require MRI. The cause for their myelopathy can often be determined from other studies.

**Indications for Surgical Treatment**

Reasons to consider surgery after penetrating injuries to the spine include restoration of neurological function, prevention or treatment of infection, correction of spinal instability, and prevention or treatment of CSF fistulas. In the acute setting, it is most important to remember that ~67% of patients with a penetrating spinal injury have an associated visceral injury. Attention to these other organs often supersedes attention to the spine. Acute spinal surgery after penetrating injury is also associated with an increased incidence of infection and complication; this risk diminishes after about 1 week from the injury. It therefore seems prudent to delay surgery if possible. Perhaps, the only urgent surgery in this scenario is the rapid evacuation of a compressive lesion from an incomplete, yet deteriorating, patient.

Spinal instability is rarely compromised after penetrating injuries to the spine. It must be considered, however, that these patients may have sustained other types of trauma, such as physical beating or vehicular trauma, which may have imparted upon them additional spinal injuries. In regard to management of spinal instability, the penetrating aspect of the injury is of less importance from a surgical perspective than the combinatorial degree of instability. Furthermore, penetrating spinal injury is not itself a contraindication to closed cervical traction.

Cauda equina lesions have a better prognosis for functional recovery after penetrating injuries. These should be surgically decompressed acutely, when appropriate. Isolated nerve root injuries may be decompressed if they cause long-term problems; acute surgery is rarely warranted.

**Preoperative Preparation**

SCI patients are trauma patients and should be managed at a trauma center whenever possible. They may have other life-threatening injuries and require immediate evaluation by an experienced trauma team. The airway must first be secured. Endotracheal intubation, if necessary, should not be delayed. Respiration, arterial oxygen saturation, heart rate, and arterial blood pressure must then be rapidly assessed and treated, if necessary. All of these factors affect spinal cord perfusion and are of primary importance in preserving neurological function. Hypotension is a common finding in patients with spinal cord injury, and the etiology may be difficult to ascertain. High thoracic and cervical spinal cord injuries may lower blood pressure by the diminution of sympathetic tone. Victims of gunshot wounds may also present with hypotension resulting from blood loss or cardiovascular compromise. Hypotension resulting from volume loss characteristically produces tachycardia. Hypotension resulting from spinal cord injury, however, most often causes a bradycardia. Initial management of hypotension after SCI mandates aggressive fluid resuscitation followed by the judicious use of vasopressors. Blood products should be administered as necessary. If indicated, Swan-Ganz catheterization and other types of invasive hemodynamic monitoring should not be delayed.
The available data suggest that treatment with corticosteroids is relatively contraindicated. All types of penetrating injuries were excluded from the National Acute Cord Injury Study (NASCIS) trials. Other studies have evaluated the use of corticosteroids for penetrating spinal cord injuries and have found no benefit. This lack of proven efficacy, coupled with the potential for steroids to inflict harm, provides a relative contraindication to steroid administration in victims of penetrating spinal cord injury.

Prophylactic antibiotics should be given. The ideal length of administration is not known, but it seems prudent that most surgeons continue treatment for at least 1 week. The agent should be chosen based on the other regions of the body injured and local hospital bacterial sensitivities. Tetanus immunization status should be documented on admission, and prophylaxis should be given if any doubt remains.

Finally, penetrating objects take an unpredictable course through the tissue they enter. The importance of maintaining a high index of suspicion for associated injuries and maintaining a close collaboration with the trauma team members cannot be overstated.

Operative Procedure

Surgery for Missile Injuries

An aggressive effort should be undertaken to establish the exact etiology of spinal cord injury. Compressive hematomas should be evacuated without delay in incomplete patients because the potential exists for functional improvement if addressed promptly. The benefit of evacuating intramedullary hematomas is unknown but may be performed at the discretion of the surgeon (Fig. 36–2). The indication to acutely remove compressive bony fragments remains unresolved as well. If not performed acutely, delayed decompression of bone or disk from the spinal cord may be attempted in cases of incomplete myelopathy. Delayed decompression of bone, in the case of complete myelopathy, will not restore neurological function, but some have suggested that this procedure may help prevent development of a syrinx. Injuries involving direct traverse-ment of the spinal cord by a missile are unlikely to benefit from any type of surgery. Durotomy and myelotomy do not, by themselves, improve the likelihood of recovery after SCI.

Bullets rarely contaminate. Their removal has not been demonstrated to reduce the incidence of infection. Heavy metal poisoning from lead or copper bullets remains a very rare phenomenon; therefore, surgery is not indicated for this reason alone. Surgery is also not indicated solely to prevent fragments from migrating.

Surgery for Knife and Other Stab Wounds

The risk of infection after stabbing injuries is greater than that for missile injuries. These wounds should, therefore, perhaps undergo debridement and irrigation. The wound cavity must undergo careful inspection, and retained foreign bodies should be removed whenever feasible. Knives and stabbing weapons usually enter the spinal canal in the interlaminar aperture between the spinous processes and facet joints; this anatomical configuration tends to prevent the weapon from crossing midline. The classic deficit is the Brown-Séquard syndrome. Their prognosis is superior to that for missile injuries; in some series, 67% of patients regain ambulatory capability.

Surgical Approach and Logistics

Once surgery has been decided upon, the specific approach depends on the location of pathology and the surgeon’s preference. Choice of anesthetic agent should reflect the necessity of avoiding hypoperfusion of the spinal cord, particularly in the case of acute SCIs. Most necessary surgeries in these situations may be approached through a dorsal midline incision (Fig. 36–3). If not already initiated, antistaphylococcal antibiotics should be given prior to incision. Laminectomy may be used for decompression (Fig. 36–4). The need for durotomy is usually determined at the time of surgery. If the spinal cord must be accessed, as in the case of an intramedullary hematoma, the dura mater may be opened in the midline and held open with retention sutures (Figs. 36–5 and 36–6). In some cases, the dura may already be lacerated. The laceration may be elongated, if necessary.
Figure 36–3  Dorsal exposure of the spinal column.

Figure 36–4  Laminectomy begun over the site of injury.

Figure 36–5  A midline durotomy is performed.

Figure 36–6  Dorsal exposure of the spinal cord after penetrating injury.
Postoperative Management, Including Possible Complications

General Care

Long-term care of patients with spinal cord injuries has significantly lowered the morbidity and mortality rates of this condition. Protection of skin with visual inspection and frequent turning, pulmonary toilet, and prophylaxis against deep vein thrombosis should be instituted upon arrival to the hospital and maintained permanently. Gastrointestinal prophylaxis and bowel regimens should begin without delay.

Fragment Migration

Late migration of fragments occurs infrequently. If the patient suffers from symptoms, fragment removal may be appropriate.

Chronic Pain

Chronic pain may present after penetrating spinal cord injuries as it may after any type of spinal cord injury. It may be dealt with by medications, physical therapy, and other types of chronic pain treatments. In cases of severe refractory pain, surgical options, such as a dorsal column stimulator, may be discussed.

Management of Paralysis

Long-term care algorithms for patients with spinal cord injury have significantly extended their life expectancy. Meticulous skin protection with frequent turning, physical rehabilitation, deep venous thrombosis prophylaxis, and regular bowel and bladder regimens greatly enhance the quality of life for these patients.

Conclusion

Penetrating injuries of the spine occur less frequently than do injuries arising from blunt trauma. Their incidence, however, has increased over recent decades. Once seen only on the battlefield, these injuries are now routine at trauma centers nationwide.

The primary management for these patients involves resuscitation, intervention as needed by trauma surgeons, and critical care nursing. Spinal surgery is not required in the majority of cases; even less commonly is it required emergently. When appropriate, the specific surgery may be tailored by the surgeon to address the pathology present.

In general, the acute medical and chronic care management of these injuries is identical to that of all other types of spinal cord injury. Although the likelihood of late recovery of neurological function in these cases remains bleak, the refinement of prevention and treatment algorithms should improve the outlook in the future.