Nonmissile penetrating spinal injury

Case report and review of the literature

KIARASH SHAHLAIE, M.D., DONGWOO JOHN CHANG, M.D., F.R.C.S.(C), AND JOHN T. ANDERSON, M.D.

Departments of Neurological Surgery and Surgery, University of California at Davis Medical Center, Sacramento, California

✓ Nonmissile penetrating spinal injuries (NMPSIs) are rare, even among the population of patients treated in large trauma centers. Patients who present with retained foreign body fragments due to stab wounds represent an even smaller subset of NMPSI, and their optimal management is unclear.

The authors report the case of a 42-year-old man who presented to the University of California at Davis Medical Center with a retained knife blade after suffering a stab wound to the lower thoracic spine. They discuss this case in the context of a literature review and propose management options for patients with NMPSIs in whom fragments are retained.

A search of PubMed was undertaken for articles published between 1950 and 2006; the authors found 21 case reports and eight case series in the English-language literature but discovered no published guidelines on the management of cases of NMPSI with retained fragments.

After clinicians undertake appropriate initial trauma evaluation and resuscitation, they should obtain plain x-ray films and computerized tomography scans to delineate the anatomical details of the retained foreign body in relation to the stab wound. Neurosurgical consultation should be undertaken in all patients with an NMPSI, whether or not foreign body fragments are present. Surgical removal of a retained foreign body is generally recommended in these patients because the fragments may lead to a worse neurological outcome. Perioperative antibiotic therapy may be beneficial, but the result depends on the nature of the penetrating agent. There is no documentation in the literature to support the use of steroid agents in patients with NMPSIs.

KEY WORDS • thoracic spine • stab wound • spinal cord injury • foreign body

NONMISSILE penetrating spinal injury is rare outside of South Africa, where the largest series were reported by Lipschitz,24 Lipschitz and Block,25 and Peacock, et al.,34 decades ago. In North America, most cases of spinal injury result from nonpenetrating injuries sustained during MVAs and falls. Penetrating injuries are typically due to missile objects, most often gunshot wounds. Nonmissile penetrating spinal injury, therefore, occurs infrequently; in most large trauma centers only a few cases are treated each year. Management guidelines for these rare injuries are not well established.

Most cases of NMPSIs affect the lower cervical or upper thoracic regions in young males who are assaulted from behind. The weapon is typically a knife that is withdrawn after the assault and results in varying degrees of neurological deficit. Spinal stability is rarely compromised following an NMPSI, and most patients undergo nonoperative treatments.

More uncommonly, victims of NMPSI present to the emergency department with the weapon retained in the spine. Management of these cases is often challenging because removal of the retained weapon or fragment introduces the risk of neurological compromise. Careful transport to the emergency department, detailed radiographic studies, and neurosurgical consultation prior to manipulation of retained fragments in patients with central or peripheral nervous system involvement are important principles in the treatment of NMPSIs. Other aspects of management, including removal of the foreign body, surgical exploration, and perioperative care, however, are not as well established.

We report the case of a 42-year-old man who presented after an altercation and in whom a knife blade was retained in the T-10 VB. On admission he was neurologi-
Nonmissile penetrating spinal injury

...ckily intact. He was successfully treated with open surgical removal (without laminectomy) and close postoperative surveillance. A review of the literature on missile and NMPSIs was performed to propose options for the management of a fragment-retained NMPSI.

Case Report

Examination. This 42-year-old man was brought to the emergency department after suffering stab wounds to the sternum and left flank during an altercation. He reported pain at both sites but no shortness of breaths/minute, abdominal pain, or motor or sensory deficits. He was breathing comfortably with a respiratory rate of 18, blood pressure of 122/80 mm Hg, and heart rate of 90 bpm. A detailed neurological examination revealed no deficits. There was no sphincter disturbance or saddle block anesthesia.

Emergency chest and thoracic CT scans revealed a retained 11.5-cm knife blade in the lower thoracic region. The blade entered the left T-10 pedicle, extended through the right anterolateral aspect of the VB and through the superior endplate, with the tip lying in the T9–10 intervertebral space (Figs. 1 and 2). The convex, sharp surface of the blade penetrated approximately 2 mm within the central canal, resulting in minimal thecal sac/cord impingement (Figs. 2 and 3). A left paraspinal hematoma and small hemothorax were also identified. There was no evidence of hemorrhage in the central canal (that is, no epidural or subdural hematoma). After consultation between the trauma and neurosurgical services, it was decided that the patient should undergo removal of the knife blade without laminectomy or dural exploration.

Operation. General anesthesia was induced. The patient was placed prone and the left flank entrance wound was closely examined. A localizing needle was used to identify the location and trajectory of the knife blade because it was not visible at the skin surface. A counterincision was fashioned over this area and dissection was extended through the muscle layers. The proximal end of the blade was encountered in the musculature. Maintaining its alignment, the blade was firmly grasped and pulled back without incident. After removal, the blade was closely inspected to ensure that it was physically intact distal to its separation/break point from the knife handle (Fig. 4). There was no significant bleeding following removal, and the wound was copiously irrigated with saline. Because the sternal stab wound was found to be superficial, it was treated with irrigation, debridement, and local wound care.

Postoperative Course. The patient was neurologically intact after awakening from anesthesia, and he was admitted to the intensive care unit for close monitoring. Postoperative radiographic studies demonstrated no evidence of foreign fragment(s). The patient underwent serial neurological examinations for 24 hours postoperatively, and no evidence of deficit(s) was observed. He was then transferred to the floor where the remainder of his hospital stay was uneventful. The patient received no antibiotic agents postoperatively, and there were no signs of infection. He was discharged from the hospital to home on postoperative Day 4 neurologically intact and is doing well as an outpatient.

Discussion

Background of NMPSI

In an extensive review of the English-language literature published between 1950 and 2006, we found 21 individual case reports (Table 1) and eight case series (Table 2) of patients with NMPSI. The largest number of cases were reported from South Africa more than 40 years ago by Lipschitz,24 Lipschitz and Block,25 and Peacock, et al.34 At Conradi Energy Hospital in Cape Town, South Africa, Peacock and associates44 treated 450 patients in whom stab wounds had resulted in SCI between 1963 and 1976. These cases accounted for 25% of all SCI admissions during that period, a trend attributed to high gang activity, poor housing, prohibition of alcohol, poor street lighting, limited access to firearms, and lesser prison sentences for perpetrators of assault—all resulting in paralysis (that would effectively incapacitate an enemy rather than kill him/her).25,34 Although the distribution of SCI in South Africa has changed over time—most cases are now due to gunshot wounds (35%) and MVAs (30%)—stab wounds still account for a disproportionate number of injuries (26%) and provide valuable insight for centers outside of this region.39

At trauma centers outside of South Africa typically fewer than five cases of NMPSI are treated annually.41,46 At an institute in Texas, for example, Simpson and colleagues41 reported 18 cases of NMPSI treated in a 6-year period. Similarly, Thakur and associates46 reported 11 cases of nonmissile spinal trauma at their hospital in India during a 10-year period. At our Level 1 trauma center in northern California there is a similar low incidence of NMPSI: four patients were seen at the University of California at Davis Medical Center in the past 10 years.

Fig. 1. Scout film from a CT scan revealing an 11.5-cm retained knife blade at the T-10 vertebra. The blade appears to enter the VB at the left inferior endplate and lie with its tip at the right superior endplate.
In most cases NMPSI occurs in young men, although traumatic injuries in women have been increasing over the past three decades. Most victims are stabbed once (incidence 65%) and the weapon is typically a knife (incidence 72–84%). In the largest series from South Africa, assaults with axes, screwdrivers, bicycle spokes, scissors, garden forks, sickles, and sharpened broomsticks were also reported. Authors outside of South Africa have reported stab wounds from a pencil, stingray spine, fencepost modified into a spear, splinter, sewing machine thread-holding rod, and a gimlet. In general, penetrating objects/ weapons are withdrawn by the attacker, rarely breaking (at the handle or blade) or wedging into bone to present as a retained foreign body.

Nonmissile penetrating spinal injury is typically inflicted from behind at the victim’s thoracic (incidence 54–63%) and cervical (incidence 27–30%) regions and, less frequently, in the lumbosacral spine (incidence 7%). This distribution likely reflects two aspects of these assaults: assailants typically aim for the neck or chest, and the cervicothoracic region is within the “natural sweep of the arm [of the attacker].” As a result, NMPSI typically results in varying degrees of neurological deficit. In the South African series, 21% of the patients presented with complete SCI and 55% with a modified Brown–Séquard syndrome. This trend is echoed by authors outside of South Africa, reporting incomplete SCI as the most typical manifestation; the second most common manifestation is a complete injury with no deficits. In a review of 18 cases of NMPSI due to stab injury, Simpson and associates reported 14 incomplete (78%) and four complete SCIs treated between 1980 and 1986. Thakur, et al., reviewed the cases of 11 patients with stab injuries to the spine and reported eight with deficits and three without. Interestingly, the rate of recovery from SCI due to a stab wound is higher than the incidence of recovery after other injuries; in a review of 551 patients with NMPSI the authors reported significant neurological recovery in 61% of the patients after stab wounds, 44% after MVAs, and only 32% after gunshot wounds.

Spinal cord or nerve root injury may occur immediately after the traumatic incident or in a delayed fashion. Immediate injury is caused by physical damage to neural tissue from the penetrating weapon, in-driven bone frag-
Nonmissile penetrating spinal injury

Fig. 3. A and B: Three-dimensional reconstructed CT scans revealing a knife blade entering the T-10 VB at the left lower end-plate in a trajectory parallel and adjacent to the 11th rib. C: Three-dimensional reconstructed CT scan (caudocranial perspective) obtained at the T11–12 interspace. The convex knife blade surface is visualized in the central canal as an irregular artifact (arrow).

Injuries may be associated with airway compromise or hemodynamic shock secondary to tracheal or large vessel damage of the neck. Similarly, thoracic NMPSI may be associated with bronchial, cardiac, or aortic injuries, and abdominal NMPSI may present in conjunction with injuries to the bowel, solid organs, or vascular structures.

Embedded foreign objects associated with neurological damage should not be removed by paramedics or emergency staff prior to neurosurgical consultation because closed removal (and manipulation) is associated with an increased risk of bleeding, neurological damage, and infection. This recommendation dates back to the management of arrow wounds from the nineteenth century, when it was found in autopsies that “. . . wounds in the vessels were plugged perfectly by the arrow shafts.”

According to this publication, Dr. Joseph H. Bill recommended that wounded soldiers in the American Indian–Fighting Army be seen by a surgeon before removal of the arrow, a recommendation still critical in treating individuals with injuries due to penetration.

After appropriate initial trauma assessment and resuscitation, radiographic studies should be obtained to determine if retained fragments are present. Failure to do so may result in undiagnosed retained objects that can have adverse long-term consequences. Harmit, et al., for example, reported on a 22-year-old man whose wound was simply sutured closed to stop profuse bleeding and who presented 8 months later with pain; investigators then discovered that a 5-cm-long blade tip had been retained in the wound. Retained fragments may also result in the delayed development of neurological deficits. For instance, Jones and Woosley reported on a 46-year-old man who presented after cursory treatment of a thoracic stab wound 8 years later with progressive leg weakness, leg numbness, and bowel and bladder disturbances. The surgeons discovered that the knife remained in situ; the patient experienced significant improvement following its removal. Although significant improvement is reported in most cases in which foreign body objects are removed after a delayed discovery, some patients experience permanent neurological dysfunction as a result of the retained foreign body. Kulkarni and associates, for example, reported the case of a 31-year-old man with a retained knife blade from a T-11 stab wound who presented 4 weeks later with progressive leg numbness/weakness and difficulty walking; he experienced no significant improvement after the blade was surgically removed.

Emergency Department Management

All patients with a history of NMPSI are at risk of harboring a retained foreign body in or around the spinal canal. Retained material is more evident in cases of impalement injuries because a portion of the penetrating agent is often visible to the naked eye. In some cases of impalement injury and other NMPSI, however, a retained fragment is often not visible to the paramedic or emergency department physician on initial evaluation. Because failure to diagnose a retained fragment can have adverse consequences, it should be assumed that patients who have sustained an NMPSI harbor foreign objects until this is radiographically proven otherwise.

Careful transportation to the hospital and delivery of basic trauma care upon arrival are essential for the optimal management of NMPSI. The presence of a retained or impaled object should not obviate the undertaking of a complete trauma assessment because these patients are at risk of serious associated injuries. For example, cervical

Radiographic/Neuroimaging Studies

Most authors recommend plain radiography and CT scanning for evaluating patients with NMPSI in whom fragments may remain. Metallic fragments, such as a retained knife blade, are well documented by conventional radiography and CT scanning. Computerized tomography scans are also ideal for identifying subtle hematomas typically missed on angiograms and bone fragments that may lie along the path of penetration. Metal fragments may produce an artifact that can obscure the quality of CT studies, but identification of the characteristic adjacent streak artifact, which occurs along the same axis as the blade, can be used to determine the location of the blade tip with high accuracy.
Magnetic resonance imaging has been advocated by some authors for neurodiagnostic workup of cases of NMPSI. Moyed and colleagues, for example, reported their experience with preoperative MR imaging in nine patients with NMPSI; they obtained three sagittal and two axial MR images through the injury region. The authors found that MR imaging was a “powerful tool” for identifying the injury tract, cord or root lesions, and associated lesions including hematomas, disc herniation, and bone fragments. In one patient in their series, a 25-year-old man who had been stabbed in the lower region of the neck on the right side, there was MR imaging evidence of a “magnetic susceptibility artifact” from a metal fragment adjacent to the central canal that was not seen on radiographs or CT scans. The high sensitivity of MR imaging to retained foreign material, along with its ability to better characterize ligamentous and vascular injuries, has underscored its utility in the workup of patients with an NMPSI. This is somewhat controversial, however, because there is an increased risk of heating, movement, and induction of currents in ferromagnetic or conductive materials when placed in an external magnetic field.

**Surgical Management**

The surgical management of NMPSI is a controversial topic that reflects differences in surgeons’ preferences; it is not surprising then, that no published management guidelines exist. In the series by Peacock and colleagues involving 450 patients, for example, only 20 (4.4%) underwent laminectomy. In a more recent report from South Africa by Velmahos and coworkers, the authors reported a higher rate of surgical treatment—22 operations (15.4%) in 143 patients with stab wound–related SCIs. In a review of 11 patients with NMPSI, Thakur, et al., on the other hand, reported that surgical intervention was undertaken in nine patients (81.8%); seven of these patients underwent laminectomy for removal of foreign bodies and dural repair and two underwent simple surgical exploration and wound irrigation. In a review of 16 patients with stab wound–inflicted SCIs and resulting neurological deficits, however, investigators found no significant difference in outcome in patients with complete and incomplete SCIs managed surgically. Reports on gunshot wounds to the spine (that is, missile PSIs) are similarly controversial and contradictory; some authors have advocated surgery, whereas others have questioned its value. Consequently, the rates of surgical intervention vary among institutions.

There is consensus among many authors, however, that surgical exploration should be considered in patients with progressive neurological deficits, incomplete SCI when there is radiographic evidence of neural compression (due to retained foreign material, bone fragment, or soft tissue), or persistent CSF leakage. It remains unclear, however, if patients need or benefit from surgery in these situations. For example, in their original series of 450 patients, Peacock and colleagues documented 18 cases (4%) of CSF leak that were successfully managed nonoperatively; the leaks “stopped spontaneously and laminctomy and dural repair were not necessary.” Cerebrospinal fluid leaks that do not resolve spontaneously, however, may cause pseudomeningoceles and/or low-pressure headaches to develop over time. For this reason, some clinicians have advocated surgery in all patients with CSF leakage whereas others have recommended surgical intervention to halt leaks that persist beyond 96 hours.

Because it is unclear if removal of fragments results in reversal of deficits, the management of retained foreign material is also controversial. However, documented marked improvement in a 21-year-old man after he underwent urgent surgical removal of a knife blade embedded in the thoracic spine. Neurological improvement has also been described in patients who have undergone delayed removal of retained fragments. Groen and coworkers, for example, reported the case of a patient who was stabbed with a stingray spine that was retained in the T-8 VB. Four weeks postinjury the patient underwent surgical removal of the stingray spine (which had been left in place due to “absence of neurosurgical expertise”); the patient experienced complete resolution of pain and paresthesia and “only discrete” hypertonia and hypalgesia of the right leg at 7 months after surgery. Manzone, et al., reported a similar case in which significant neurological improvement occurred after a retained knife blade was extricated 7 months after the initial assault. Removal of retained foreign material, therefore, may prove efficacious both acutely and in cases of delayed presentation.

Removal of a retained foreign body may also benefit patients presenting without neurological deficits because delayed-onset myelopathy has appeared to 36 years later in patients with mild deficits as well as those who are initially neurologically intact. Harmit and associates, for instance, reported on a 22-year-old man who presented with persistent back pain and neurological deficits and who underwent surgical removal of a knife blade that had been retained in the thoracic spine for 8 months since the initial injury. Karim, et al., reported a case of delayed-onset radiculopathy and foot drop in a patient who was initially neurologically intact; radiography demonstrated evidence of foreign body migration from T11–12 to L4–5, and symptoms improved following surgical removal of the foreign body.

Delayed development of neurological deficits may result from foreign body migration, infection, repeated trauma, and posttraumatic syrinx formation. Some cases have also been attributed to inflammatory reactions to metallic fragments in the central nervous system. Copper, for example, is associated with severe scarring and necro-
<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Cases</th>
<th>Age (yrs), Sex</th>
<th>Weapon</th>
<th>Retained</th>
<th>Location</th>
<th>Signs/Symptoms</th>
<th>Time to Treatment</th>
<th>Op Treatment</th>
<th>Symptom Outcome</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Castillo &amp; Kahn, 1950</td>
<td>1</td>
<td>43, M</td>
<td>knife</td>
<td>yes</td>
<td>T-4</td>
<td>monoparesis for 3 yrs</td>
<td>23 yrs</td>
<td>removal</td>
<td>improved</td>
<td>passed through central cord</td>
</tr>
<tr>
<td>Adornato &amp; Collis, 1972</td>
<td>2</td>
<td>50, M</td>
<td>knife</td>
<td>yes</td>
<td>C-7</td>
<td>RUE weakness &amp; numb- ness for 6 mos</td>
<td>13 yrs</td>
<td>removal, duratomy repair</td>
<td>near complete resolution</td>
<td>2 ops, CSF leak</td>
</tr>
<tr>
<td>Wolf, 1973</td>
<td>1</td>
<td>68, M</td>
<td>knife</td>
<td>yes</td>
<td>T-6</td>
<td>progressive monoparesis</td>
<td>30 yrs</td>
<td>removal</td>
<td>significant improvement</td>
<td>MVA 21 yrs after NMPSI</td>
</tr>
<tr>
<td>Horowitz, et al., 1985</td>
<td>1</td>
<td>27, M</td>
<td>steel rod</td>
<td>yes (impaled)</td>
<td>L2–3</td>
<td>paraparesis, sensory loss</td>
<td>acute removal</td>
<td>persist L-3 paraplegia</td>
<td>abscess 3 wks postop</td>
<td></td>
</tr>
<tr>
<td>Fung &amp; Ng, 1992</td>
<td>1</td>
<td>53, M</td>
<td>iron scissors</td>
<td>yes</td>
<td>T-2</td>
<td>LLE weak, numbness for 3 yrs</td>
<td>removal</td>
<td>significant improvement</td>
<td>paraspinal granuloma</td>
<td></td>
</tr>
<tr>
<td>Karlins, et al., 1992</td>
<td>1</td>
<td>21, M</td>
<td>knife</td>
<td>yes</td>
<td>T7–8</td>
<td>Brown–Séquard syndrome</td>
<td>acute</td>
<td>removal thoracotomy</td>
<td>minimal weakness</td>
<td>preop CT for planning</td>
</tr>
<tr>
<td>Schule, et al., 1995</td>
<td>1</td>
<td>50, F</td>
<td>screwdriver</td>
<td>no</td>
<td>C-5</td>
<td>tetraplegia</td>
<td>NA</td>
<td>nonop</td>
<td>minimal improvement, died of PE at 3 mos</td>
<td>autopsy w/ hair, foreign material</td>
</tr>
<tr>
<td>Kulkarni, et al., 2000</td>
<td>1</td>
<td>31, M</td>
<td>knife</td>
<td>yes</td>
<td>T-11</td>
<td>recurrent, progressive</td>
<td>4 wks</td>
<td>removal</td>
<td>no significant change</td>
<td>initially self-resolved wound infection</td>
</tr>
<tr>
<td>Tokushige, et al., 2000</td>
<td>2</td>
<td>66, M</td>
<td>steel rod</td>
<td>yes (impaled)</td>
<td>L5–S1 (transrectal)</td>
<td>LLE paralysis</td>
<td>acute removal</td>
<td>began to improve, died of sepsis stable, intact</td>
<td>penetrated retroperitoneum</td>
<td></td>
</tr>
<tr>
<td>Adams, et al., 2001</td>
<td>1</td>
<td>18, M</td>
<td>screwdriver</td>
<td>no</td>
<td>T-9</td>
<td>headache, diplopia</td>
<td>5 wks</td>
<td>blood patch resolved/intact</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manzoni, et al., 2003</td>
<td>1</td>
<td>22, M</td>
<td>knife</td>
<td>yes</td>
<td>T5–6</td>
<td>paraparesis</td>
<td>6 mos</td>
<td>removal</td>
<td>significant improvement</td>
<td>initially closed w/o removal</td>
</tr>
<tr>
<td>Groen, et al., 2002</td>
<td>1</td>
<td>17, M</td>
<td>stingray spine</td>
<td>yes</td>
<td>T7–8</td>
<td>paraparesis, paresthesia</td>
<td>4 wks</td>
<td>removal</td>
<td>no improvement</td>
<td>no bone injury</td>
</tr>
<tr>
<td>Meltzer, et al., 2004</td>
<td>1</td>
<td>18, M</td>
<td>pencil (graphite)</td>
<td>yes</td>
<td>C-3 (transoral)</td>
<td>cervical pain (delayed)</td>
<td>“since childhood”</td>
<td>removal, C-3 verte-brectxomy</td>
<td>significantly improved</td>
<td></td>
</tr>
<tr>
<td>O’Neill, et al., 2004</td>
<td>1</td>
<td>13, M</td>
<td>fencepost spear</td>
<td>no</td>
<td>“mid cervical”</td>
<td>C-4 sensory, C-5 motor</td>
<td>NA</td>
<td>nonop</td>
<td>significant improvement</td>
<td>4 mos inpatient rehab</td>
</tr>
<tr>
<td>Simsek, et al., 2004</td>
<td>1</td>
<td>32, M</td>
<td>knife</td>
<td>yes</td>
<td>T11–12</td>
<td>paraplegia</td>
<td>acute</td>
<td>removal, aorta repair</td>
<td>no improvement</td>
<td></td>
</tr>
</tbody>
</table>

* LLE = left lower extremity; NA = not applicable; PE = pulmonary embolism; RLE = right LE; RUE = right upper extremity.
sisk, silver with a marked inflammatory response, nickel and lead with more intermediate responses, and gold and platinum with minimal responses. Stainless steel incites a variable response, depending on its particular composition. Oxidation of metallic fragments has also been reported to result in deposition of rust particles.

Laminectomy and dural exploration may be of benefit in some patients who have sustained an NMPSI. Adams, et al., for example, reported the case of an 18-year-old man stabbed with a screwdriver at T-9; he presented to the emergency department neurologically intact. After reviewing a plain x-ray film, the emergency physicians removed the screwdriver and discharged the patient home; he returned 5 weeks later with a postural headache, right sixth cranial nerve palsy, and MR imaging evidence of a sixth cranial nerve palsy. He was treated with an autologous epidural blood patch and his symptoms completely resolved. Patients in whom surgical dural exploration is required following foreign body removal, therefore, should be identified by qualified spine surgeons.

Nonmissile penetrating spinal injuries are generally stable, and internal fixation should be considered only when extensive bone destruction is documented on imaging studies. Connell, et al., reviewed data obtained in 27 patients with penetrating spinal trauma, 10 of whom were assaulted with sharp weapons. They concluded that spinal immobilization is not indicated for fully conscious patients (that is, those with a Glasgow Coma Scale score of 15) who are neurologically intact because their spines can be cleared by clinical assessment alone.

**Perioperative Care**

Intravenous steroid agent administration does not improve neurological function in patients with penetrating SCI and may be associated with an increased risk of infection. It is therefore not recommended as a management option.

Spinal infections are generally rare in cases of penetrating injuries to the spine, but extraspinal infections predisposing to septic complications may occur. Patients with an increased risk of infection may be identified based on the mechanism of NMPSI. For example, objects with a blunt or open tip are more likely to deposit small amounts of foreign material along the stab wound path; a stab wound created by a screwdriver, for example, may be associated with deposition of hair and textile fibers along the mechanism of NMPSI. For example, objects with a blunt or open tip are more likely to deposit small amounts of foreign material along the stab wound path; a stab wound created by a screwdriver, for example, may be associated with deposition of hair and textile fibers along the stab wound path. Magnetic resonance imaging revealed a 1×1-cm lesion in the C-3 VB that was found to represent infection with granuloma formation around retained pencil lead; his pain resolved following corpectomy and surgical fusion. Pa-

---

**TABLE 2**

*Summary of case series of NMPSI published between 1950 and 2006*

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Cases</th>
<th>Study Period</th>
<th>Weapon</th>
<th>Retained</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lipschitz &amp; Block, 1962</td>
<td>130</td>
<td>1955–1959</td>
<td>“any sharp instrument”</td>
<td>2.3%</td>
<td>1st large South African series; mostly young males stabbed in thoracic spine; 70% incomplete deficits; op only in those w/ retained fragments or sepsis/abscess; over all 4.6% improved clinically</td>
</tr>
<tr>
<td>Peacock, et al., 1977</td>
<td>450</td>
<td>1963–1976</td>
<td>84.2% knife</td>
<td>yes, NQ</td>
<td>largest South African series; mostly young males stabbed in thoracic (63.8%) or cervical (29.6%) spine; 79.1% incomplete deficits; 4.4% underwent op for retained fragments, persistent CSF leak, infection; overall outcome good in 65.6%, fair in 17.1%, unchanged in 17.3%, death in 3.6%</td>
</tr>
<tr>
<td>Simpson, et al., 1989</td>
<td>18</td>
<td>1980–1986</td>
<td>NP</td>
<td>yes, NQ</td>
<td>series from TX; mostly young males stabbed in thoracic (54%) or cervical (27%) spine; 78% complete deficits; 33% underwent op w/ no significant improvement</td>
</tr>
<tr>
<td>Thakur, et al., 1991</td>
<td>11</td>
<td>1978–1988</td>
<td>72% knife</td>
<td>36%</td>
<td>series from Chandigarh, India; mostly young males stabbed in upper thoracic &amp; cervical spine (72%); deficits in 72%; patients w/ retained fragments underwent op; outcome unclear</td>
</tr>
<tr>
<td>Velmahos, et al., 1995</td>
<td>143</td>
<td>1988–1992</td>
<td>varied</td>
<td>NQ</td>
<td>updated South African series documenting a decrease in SCI due to stab wounds &amp; an increase due to gunshot wounds; overall 15.4% underwent op &amp; 61% made significant recovery</td>
</tr>
<tr>
<td>Heary, et al., 1996</td>
<td>20</td>
<td>1979–1994</td>
<td>95% knife</td>
<td>NQ</td>
<td>series from NJ and PA; mostly young males stabbed in thoracic (75%), thoracolumbar (15%), or lumbar (10%) spine; 45% w/ Brown–Séquard syndrome &amp; 25% w/ complete deficits; improvement was better in stab wound than in gunshot wound victims during same period</td>
</tr>
<tr>
<td>Moyed, et al., 1999</td>
<td>9</td>
<td>NP</td>
<td>89% knife</td>
<td>33%</td>
<td>series from MD; mostly young males (78%) stabbed in cervical spine (78%); details of clinical presentation &amp; outcomes NP; presented role of MRI in evaluation</td>
</tr>
</tbody>
</table>

* NP = not provided; NQ = not quantified.
Nonmissile penetrating spinal injury

tients with wounds created by high-risk penetrating items and those that are significantly contaminated, therefore, may benefit from a course of broad-spectrum antibiotic therapy with or without surgical debridement.

Conclusions

Patients presenting with PSI with retained foreign material should be recommended for surgical removal of the material and exploration in the acute phase of injury. Retained foreign fragments can lead to both acute and chronic neurological and infectious consequences. The preponderance of published reports to date suggest that neurological deficits are improved and progressive deficits prevented by surgical removal of the material and irrigation of the wound. All patients should be closely monitored postoperatively for evidence of delayed neurological deficits, particularly those in whom complete radiographic documentation was not achieved and/or dural exploration was not performed. Broad-spectrum antibiotic therapy may be beneficial in preventing infectious complications, particularly in patients at increased risk of infection due to the mechanism of NMPSI and cleanliness of wounds. Radiographic studies, particularly radiographs and CT scans, obtained prior to and immediately after surgery are important for identifying the presence of retained foreign material, even after initial surgical exploration.

Acknowledgment

We thank Kathleen MacColl for providing statistical information from the trauma databank at the University of California at Davis Medical Center.

References


407

Manuscript received September 2, 2005.
Accepted in final form February 13, 2006.
Address reprint requests to: Dongwoo John Chang, M.D., F.R.C.S.(C), Department of Neurological Surgery, University of California at Davis Medical Center, 4860 Y Street, Suite 3740, Sacramento, California 95817. email: dongwoo.chang@ucdmc.ucdavis.edu.

K. Shahlaie, D. J. Chang, and J. T. Anderson