RESEARCH ARTICLE

Laminectomy for Penetrating Spinal Cord Injury with Retained Foreign Bodies

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Background: Penetrating spinal cord injury (PSCI) with retained foreign bodies (RFB) is rarely observed in clinics and may result in a complete or incomplete neurological deficit. This study was performed to appraise the treatment effect of laminectomy for PSCI with RFB.

Case Presentation: This study presented three patients referred to a tertiary hospital between August 2011 and October 2018 due to PSCI with RFB and receiving laminectomy. The first patient was a 25-year-old female with a butcher’s knife piercing the T9 lamina and T10 vertebral body obliquely; the second was a 49-year-old male who suffered a perforating wound of the cervical spinal canal and injury of vertebral artery from foreign glass, while the third was a 60-year-old male with a wooden stick penetrating stomach and terminating in the L1 lamina. The first and second patients immediately underwent laminectomy for debridement and removal of RFB, while the third received two-staged operations to remove the retained stick thoroughly. Unfortunately cases 1 and 3 eventually resulted in total paralysis and case 2 revealed no improvement in myodynamia. Then, Medline/PubMed, Embase and the Cochrane Library were systematically searched, and 23 articles involving 25 additional cases with this kind of injury were included for analysis.

Conclusions: The optimal treatment strategy for penetrating spinal cord injury with retained foreign bodies remains challenging and should be assessed case-by-case. If possible, surgical removal of foreign bodies by laminectomy is preferred immediately to prevent delayed presentation and persistent contamination. Meanwhile, a multidisciplinary team is needed to address concomitant injuries.

Key words: Laminectomy; Penetrating spinal cord injury; Retained foreign body; Systematic review

Introduction

The overwhelming majority of spinal cord injuries cases are due to blunt trauma from falls or traffic accidents, and those secondary to penetrating injury are rarely observed in the clinical setting. Penetrating spinal cord injury (PSCI) disproportionately affects young males in their 20s and 30s, and may result in severe neurological deficits. Up to now, most of our knowledge and experience about PSCI comes from several large case series from South Africa published in the 1960–70s. When referring to the emergency room, those with retained foreign bodies (RFB) are even rarer. These foreign bodies can enter the spinal canal via the interlaminar space or through the intervertebral foramen and lodge in the vertebral bodies, laminae, or pedicles, posing a tough challenge for surgeons about the initial care of the patient, evaluation of the potentially affected structures and the appropriate sequence of therapeutic interventions.

Although multiple case series have been published, there is still controversy in the management paradigm for PSCI with RFB. Laminectomy is usually indicated to facilitate the complete removal of foreign bodies lodged in the spinal canal. This article reported three cases of PSCI with RFB in a tertiary hospital manifesting incomplete or complete neurological deficits and receiving laminectomy. Meanwhile, a systematic review of relevant literature was provided to summarize the clinical characteristics of PSCI with RFB.

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and appraise the treatment effect of laminectomy. We hope that this case report and systematic review will help clinicians to identify the optimal treatment regimen for this kind of injury and improve therapeutic efficacy.

**Case Presentation**

**Case 1**

A 25-year-old female was stabbed with a sharp knife in the lower back during an altercation. On admission, a knife was obliquely plugged in the left paraspinal region at the thoracic level with the handle sticking out (Figure 1(A)). Physical examination revealed apparent paralysis similar to Brown–Séquard syndrome: loss of myodynamia in the left leg, muscular weakness and loss of sensation to a pinprick in the right leg, as well as bowel and bladder incontinence, which rendered an American Spinal Injury Association (ASIA) score of C. CT revealed that a 10 cm hyper-dense foreign body piercing the right T9 lamina, traversed the thoracic spinal cord and penetrated the T10 vertebral body with the tip terminating in the left chest cavity (Figure 1(B),(C)).

After general anesthesia, the course taken by the knife was traced. The blade penetrated the left paraspinal muscles, pierced the interspinous ligaments and entered the T9 vertebral body through its left pedicle. To obtain sufficient surgical vision, subperiosteal dissection and subsequent drilling were performed around the insertion point of the knife. Laminectomy of the T9-T10 vertebrae was performed and it could be noticed that the blade transected the left part of the thoracic spinal cord. The knife was removed smoothly under direct vision to maintain its trajectory and then the lacerated spinal duramater was carefully sutured. Fluoroscopy verified that there was no residual debris lodging within the spine, the incision was sutured layer by layer. Besides the routine drainage tube, a chest drainage tube was placed by a cardiothoracic surgeon to address the hemothorax.

The patient tolerated her surgery well and was followed up clinically 3 years after injury. No complications were observed but unfortunately this patient lapsed to total paraplegia ultimately (ASIA score of A).

**Case 2**

A 49-year-old male suffered a posteriorly penetrating injury to his cervical spine after falling from a window. The myodynamia of the right upper limb was grade 3/5; in the left upper and both lower limbs, the myodynamia was grade 0/5, while his bowel and bladder function remained intact. CT of the cervical spine indicated that foreign glass penetrated the right side of the spinous process with a left and downward trajectory and entered the spinal canal at the C4 level (Figure 2(A),(B)). CT angiography (CTA) revealed incomplete occlusion of the left vertebral artery at the C5 level. The therapeutic plan included endovascular repair of potential vertebral artery injury, stabilization of cervical vertebrae, and removal of the foreign glass. The posterior midline approach was taken to expose the bilateral C2-C6 laminae. C4-C5 laminectomy was performed to make it easier to retrieve the glass and exploration revealed that the spinal cord was locally lacerated. The posterior wall of the C4-C5 laminectomy and PSCI with RFB

![Fig. 1](image1.png) Case 1 (25-year-old female). (A) the patient was assaulted with a sharp knife; (B) three-dimensional CT reconstruction and (C) coronal CT revealed a foreign body extending through the spinal canal and terminating in the thoracic cavity

![Fig. 2](image2.png) Case 2 (49-year-old male). (A) and (B) CT of the cervical spine indicated that foreign glass entered the spinal canal at the level of C4; (C) after removing the foreign glass, no more hemorrhage was induced and (D) laminectomy and internal fixation with lateral mass screws
left transverse foramen was excised to expose the vertebral artery. No hematoma or active bleeding surrounding the vertebral artery was observed and after removing the foreign glass, no more hemorrhage was induced (Figure 2(C)). Meanwhile, a small piece of bone block was found to have been separated from the C5 vertebra by the foreign glass. Both the bone block and glass crushed the vertebral artery in the foramen transversarium of C5. After confirming that there was no compression for the spinal cord, the lacerated spinal dura matter was repaired and internal fixation with lateral mass screws was carried out (Figure 2(D)).

The patient had an uncomplicated hospital stay and was discharged at 14 days postoperatively. However, at the 6-month postoperative follow-up, no recovery of myodynamia or sensation were observed (ASIA score of C).

**Case 3**

When a 60-year-old man was sawing wood, a wedge-shaped wooden stick flew out and penetrated his body from the right lower abdomen (Figure 3(A)). Sensation and motor functions in both lower extremities were completely lost, rendering an ASIA score of A. MRI and CT scan revealed an injury to the left lobe of the liver, inferior vena cava, left kidney and the L1 vertebra (Figure 3(B),(C)).

Immediately after admission, he underwent laparotomy through an oblique incision following the costal margin on the right side. After the hematocoele in the abdominal cavity was cleared, it was seen that a wooden stick penetrated the chest wall, entered the liver through the left inner lobe, and exited the liver from the calot’s triangle; subsequently, the stick pierced the inferior vena cava and the L1 vertebra. The wooden stick was first cut along the chest wall; then the inferior vena cava was blocked, and the rest of the stick was pulled out. Prolene sutures were used to suture the inferior vena cava and liver fissures.

After the first operation, the patient accepted conservative treatment for 3 weeks. During the second procedure, a posterior midline incision was performed, centering at the level of the L1 vertebra. It was noticed that there was a residual part of the wooden stick coming up from the interlaminar space between L1-L2. After the pedicle screws were inserted on both sides of the T12 and L2 vertebrae, the spino- nous process and lamina of the L1 vertebra were excised to expose the spinal canal. It could be seen that the wooden stick penetrated the spinal cord cone and L1 vertebral body, rendering contusions of the cauda equina and dural sac. Then the stick was removed smoothly and the surrounding wood chips were cleaned up (Figure 3(D)). After thorough irrigation, the lacerated spinal dura mater was sutured and the spinal rods were firmly fixed. However, postoperative follow-up for 3 years revealed no recovery of the lower extremity paralysis. The patient maintained an ASIA score of A.

**Systematic Review and Discussion**

According to the PRISMA statement, three electronic databases (PubMed, Embase, and the Cochrane Library) were searched for entries recorded from the time of database inception to March 1, 2021, using a combination of keywords including “penetrating spinal injury,” “retained foreign body” and “laminectomy.” Meanwhile, bibliographies of relevant articles were also hand-screened to retrieve additional records. Studies included in the systematic review need to meet the following criteria: (i) participants, patients admitted for PCSI with RFB; (ii) intervention, laminectomy; (iii) outcome, adequate data could be extracted to assess the prognosis; and (iv) study design, case reports or case series. Requisite data were extracted and recorded to standardized excel files.

Eventually, 23 articles published between 1950 to 2021 involving 25 patients were included. Plus three cases presented in the current article, 28 patients with this kind of injury were analyzed (Table 1). The search flow diagram is shown in Figure 4. The included patients’ ages ranged from 11 to 74 (mean 38.9) with a male prevalence of 85.7% (24/28), consistent with previous observations that PCSI mainly affects young males in their 20s and 30s. The most frequent clinical presentation was lower limb paresis and the most commonly seen RFB were knife blades. Six patients have an injury at the cervical level, 16 at the thoracic level and six at the lumbar level. Ten patients developed delayed presentations with an interval between initial injury and onset of symptoms ranging from 1 day to 21 years. Two
patients remained neurologically intact. All patients received laminectomy to remove the RFB and 67.86% (19/28) of them revealed postoperative improvement of neurologic symptoms. One patient died eventually at the end of the follow-up.

According to Lipschitz et al.’s study of 130 patients with non-missile PSCI, the proportion of lodged weapons was deficient, but in a more recent case series published in 2015, this rate reached up to 49% (51/104). The discrepancy could be explained by the advancement of imaging techniques. In the most extensive series on this topic reported by Peacock et al., the location of injury was most frequently at the upper thoracic (54–74%) or lower cervical (18–30%) level; only 7–8% involved the lumbosacral area. Meanwhile, concomitant pneumothorax and artery injuries were observed in nearly 16% cases. In the current article, besides the spinal cord, RFB resulted in injuries to the thorax, liver, kidney and inferior vena cava. The manifestation of PSCI with RFB may be presented in an acute or delayed way. After PSCI, most patients immediately exhibit various degrees of neurological deficits, the most common being Brown–Séquard syndrome (45–55%).

In most of these cases, RFB failed to be spotted immediately due to inadequate imaging, and a minor trauma might lead to migration of RFB or disruption of previously formed scar tissue adjacent to the spinal cord and/or nerve roots.

Following stab wounds, these patients were managed according to the Advanced Trauma Life Support (ATLS) principles. A complete physical examination involving myodynamia, muscular tension, reflexes and sensation is necessary. Careful consideration of PSCI must be made using X-ray and CT to identify the number, location and trajectory of lodged fragments. If a delayed neurological deficit occurs, patients should be overhauled to determine whether there is a residual foreign body or a new onset of operation-related complications. For case 3, a critical step was to prevent hemorrhage upon extraction of the foreign body. The vascular injury could be ruled out with CTA. Spinal MRI is not routinely performed due to the possibility of in situ ferromagnetic materials but could be used if there is evidence of neurological deterioration, spinal abscess, empyema, hemorrhage or epidural hematoma after removing the blade.

Immediate removal of the RFB and decompression are indicated, and the surgical options include laminectomy and minimally invasive fluoroscopic technique. The latter was
associated with minor damage, shorter hospital stays as well as speedier rehabilitation, but also a lower chance to achieve thorough debridement. Until now, decompressive laminectomy and watertight closure of spinal dura mater remain the mainstream choice for these cases. For patients suffering PSCI with RFB, it is advisable to promptly initiate broad-spectrum antibiotics until the lumbar drain is removed and there is no concern for CSF leakage. Meanwhile, glucocorticoid use is now not recommended for its adverse outcome and limited benefits. Conservative methods such as fluid infusion, blood transfusion and physiotherapy are important components of the treatment regimen. In Lipschitz et al.’s case series, only 4.6% of patients improved clinically, while In Enicker et al.’s report, none of those ASIA A or B grade cases showed clinical improvement and only four patients with incomplete SCI recovered to ASIA E status. As to the three patients admitted to our center, cases 1 and 3 were categorized as ASIA C and A grade respectively after initial injury but unfortunately, both ended with ASIA A grade. Meanwhile, case 2 revealed no improvement in myodynamia after the operation. A surprisingly satisfactory recovery (67.86%) of laminectomy was achieved for the case reports included in the systematic review, possibly due to a publication bias.

**Conclusion**

The optimal treatment strategy for penetrating spinal cord injury with retained foreign bodies remains challenging for surgeons and should be assessed case-by-case. If possible, surgical removal of foreign bodies by laminectomy is preferred immediately to prevent delayed presentation and persistent contamination. Meanwhile, a multidisciplinary team is needed to address concomitant injuries.

**Author Contributions**

All authors have read and approved the manuscript. Each author has contributed individually and significantly to the development of the manuscript. P.Z. was the main contributor to drafting the manuscript. X.L. and D.Z. performed literature search and analysis. Q.Z. designed the study.
performed the manuscript review and contributed to the intellectual content of the study.

Declaration

All authors listed meet the authorship criteria according to the latest guidelines of the International Committee of Medical Journal Editors and all authors are in agreement with the manuscript.

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