Clinical Neurology and Neurosurgery 184 (2019) 105405

Contents lists available at ScienceDirect

Clinical Neurology and Neurosurgery

journal homepage: www.elsevier.com/locate/clineuro

Minimally invasive approach to non-missile penetrating spinal injury with resultant retained foreign body: A case report and review of the literature

Krisztina Moldovan[a,*], Albert E. Telfeian[a], Jared S. Fridley[a], Ziya L. Gokaslan[a], Daniel Aghion[b], Adetokunbo A. Oyelese[a]

[a] Department of Neurosurgery, Rhode Island Hospital, Alpert Medical School of Brown University, 593 Eddy Street, APC-6, Providence, RI 02903, United States
[b] Department of Neurosurgery, Memorial Healthcare System, 3501 Johnson Street, Hollywood, FL 33021, United States

ARTICLE INFO

Keywords:
Non-missile penetrating spine injury
Minimally invasive spine surgery
Spinal cord injury
Spinal stab wound
Retained foreign body

ABSTRACT

Non- missile penetrating spinal injury (NMPSI) is a rare entity in North America and as a result there is no clear treatment paradigm. According to the literature, NMPSI causes serious acute neurological deficits and can also lead to devastating delayed complications in cases of untreated retained foreign bodies (RFB).

In this report we present an acute case of NMPSI to the thoracic spine resulting in RFB treated by operative removal using minimally invasive fluoroscopic technique.

While in prior published cases of NMPSI operative intervention was accomplished through laminectomy, our case presents an alternative, less invasive approach which may results in shorter recovery time.

We also review the literature on NMPSI, including reports on both acute cases and chronic presentation due to RFBs.

Based on this review, we conclude that NMPSI associated with RFB should be managed with operative intervention.

1. Introduction

Non-missile penetrating spinal injury (NMPSI) is a relatively rare phenomenon in North America where most spinal cord injuries are due to blunt trauma from falls or motor vehicle collisions. Furthermore, in cases of penetrating spine trauma, the overwhelming majority of cases are due to missile forces from gunshot wounds rather than non-missile forces such as knife wounds [22]. NMPSI with resultant retained foreign body (RFB) is even more rare. For this reason, despite multiple case reports in the literature, there is still uncertainty in management approaches to this condition [5,14,17,24].

The predominant experience and knowledge about NMPSI in the literature comes from several large case series from South Africa where due to a combination of sociopolitical factors an unusually large proportion of spinal cord injuries were from stab wounds. These studies show that NMPSI disproportionately affects young males in their 20 and 30 s and result in serious neurological deficits. Approximately 20% of patients suffercomplete SCI, 40–50% suffer incomplete SCI, with only 30% remaining neurologically intact [14,19].

There is still considerable variability in treatment approaches to NMPSI cases, with the decision to pursue operative exploration largely dependent on institutional tradition and surgeon preference. In general, most centers pursue operative intervention in cases with worsening neurological status, incomplete injury with evidence of compressive lesion, or persistent CSF leak with or without resultant infection. The likelihood of improvement after surgery is not consistent in available case series. Complications of surgery include extended hospital stay, CSF leak, infection and/or meningitis, and worsening in neurologic condition due to intraoperative nerve or spinal cord injury (SCI) [5].

In this paper we present an acute case of NMPSI to the thoracic spine with RFB which was treated by operative removal of the foreign body using a minimally invasive fluoroscopic technique. In previous reported cases, operative intervention for RFB was achieved through laminectomy. As such, our report describes a novel treatment approach for cases of NMPSI with RFB. We also review the literature on both acute and delayed presentations of NMPSI and discuss treatment approaches and outcomes.

Abbreviations: ASIA, American Spinal Injury Association; CSF, cerebral spinal fluid; GSW, gunshot wound; MIS, minimally invasive surgery; MISS, minimally invasive spine surgery; NMPSI, non-missile penetrating spinal injury; RFB, retained foreign body; SCI, spinal cord injury

* Corresponding author at: Department of Neurosurgery, Rhode Island Hospital, 593 Eddy Street, APC-6, Providence, RI 02903, United States.
E-mail addresses: kmoldov1@gmail.com, kmoldovan@lifespan.org (K. Moldovan), atelfeian@lifespan.org (A.E. Telfeian), jared.fridley@lifespan.org (J.S. Fridley), ziya.gokaslan@lifespan.org (Z.L. Gokaslan), daghion@gmail.com, daghion@mhs.net (D. Aghion), aoyelese@lifespan.org (A.A. Oyelese).

https://doi.org/10.1016/j.clineuro.2019.105405
Received 18 February 2019; Received in revised form 23 June 2019; Accepted 29 June 2019
Available online 01 July 2019
0303-8467/

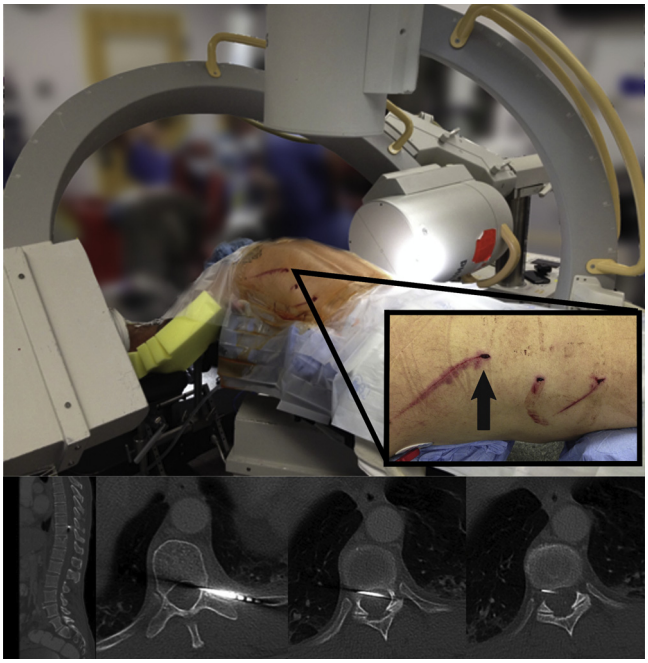

Fig. 1. OR set up and visualized stab wounds: (Top) Patient positioned on Jackson Table with positioning biplanar C-arm fluoroscopy system in place. Multiple stab wounds to the left flank are visible (inset) but the retained foreign body (knife blade) is not externally visible. (Bottom) Sagittal and axial CT images of thoracolumbar spine showing foreign body extending from extrapleural location inferior to the 10th rib, coursing through the left T10 pedicle and cephalad through the anterior aspect of the spinal canal terminating medial to the contralateral T9 neural foramen.

2. Patient and methods

2.1. Case description

A 49-year-old male presented to the emergency department after a domestic altercation with a family member having sustained multiple stab wounds to the left flank and back with what the patient reported to be a pair of scissors. The patient reported pain and the feeling that something was in his back. He otherwise denied neurologic symptoms including weakness, numbness or bowel or bladder dysfunction with the exception of a baseline chronic right foot drop.

On physical examination the patient had multiple stab wounds visible on his left flank and posterior thoracic region but there were no foreign objects visible on initial inspection (Fig. 1). On neurological examination the patient was at his baseline level of neurologic function with right foot drop but otherwise intact.

CT scan of the thoracolumbar spine was performed revealing a foreign body, presumed to be scissor blade, extending from an extrapleural location inferior to the 10th rib, traversing the anterior aspect of the spinal canal with the tip of the blade terminating at the contralateral T9 neural foramen (Fig. 1).

2.2. Operative technique

With the above findings on CT, the decision was made to take the patient to the operating room for removal of the RFB. This was accomplished through a minimally invasive approach. Biplanar fluoroscopy was used to localize the knife blade and plan a 25-mm incision just adjacent to one of the stab wounds to avoid accessing the spinal canal through a previously contaminated tract.

A K-wire was inserted through the incision and passed forward under fluoroscopic visualization until the point of the retained blade was contacted (Fig. 2C, D). Serial dilators were then used to create a corridor to access the foreign body. (Fig. 3). A 21 mm minimally invasive tubular retractor (Spotlight, Depuy-Synthes Spine, Raynham, MA) was inserted over the foreign body and the dilators were removed (Fig. 4A, B).

The blade appeared to be firmly lodged in bone. To avoid excessive manipulation of the blade, needle driver forceps were used to firmly grasp the blade and carefully pull it loose from the bone. The blade was removed in one smooth motion maintaining its trajectory. Fluoroscopy was used to verify that there was no further RFB lodged within the spine (Fig. 4C, D).

Upon removal of the blade brisk CSF flow was noted. This was readily controlled with insertion of Gelfoam. The port system was then removed and the wound closed in multiple layers. The patient's stab wounds were cleaned and closed. After removal, the foreign body was noted to be a knife blade with serrated edge broken off at the handle, rather than a scissor blade (Fig. 5C).

After the operation the patient was admitted to the trauma service. He later had to undergo an exploratory laparotomy for repair of a traumatic hernia. The patient tolerated his procedures well and was discharged from the hospital on post-op day 4 with stable neurologic exam and no CSF leak or signs of infection.

2.3. Follow up

The patient was seen in follow-up in the neurosurgery clinic 2.5 years after his injury. He reported that he had been doing well with no complaints other than some baseline lumbar back pain. The patient did not report any issues with wound healing and denied any new neurological deficits. On physical exam he remained at his neuro baseline with no new weakness. His flank incision appeared well healed. (Fig. 5A, B).

2.4. Review of literature

We performed a literature search for reports about NMPSI. We identified 22 case reports and 8 larger case series on the subject, with findings discussed in detail below.

3. Discussion

3.1. Patient characteristics

NMPSI is rare in North America, with only a few cases documented per year even at busy trauma centers [22,24]. Most of our knowledge about the acute presentation and management of NMPSI comes from large case series published in South Africa in the 1960-70 s. During this time, due to a number of factors including poor housing, gang violence and limited access to firearms, NMPSIs were much more common, making up 25% of all SCIs in the country. In 1962 Lipschitz & Block reported on 130 cases of stab wounds to the spine, while in 1977 Peacock published the largest series on the topic with 450 cases [14]. Eighty-four percent of victims were men, and 70% under the age of 30. These patient characteristics are consistent across the literature, including recent reports form the past decade [5,9,19]. Knives were the most common weapon used (84%) followed by axes and screwdrivers [19].

Location of injury was most frequently upper thoracic or lower cervical, a finding explained by the fact that injuries were most frequently sustained during assault, with attackers stabbing the victims from behind and given that the cervicothoracic region is most frequently at the assailant's arm level. In Peacock's series 63.8% cases were thoracic, 29.6% cervical and 7% lumbar; this is overall consistent across the literature [9,19,22,24].

The proportion of NMPSI cases resulting in RFB is highly variable across studies, a discrepancy most likely attributable to differences in detection rate. Lipschitz & Block's 1962 study only reported 2.3% of

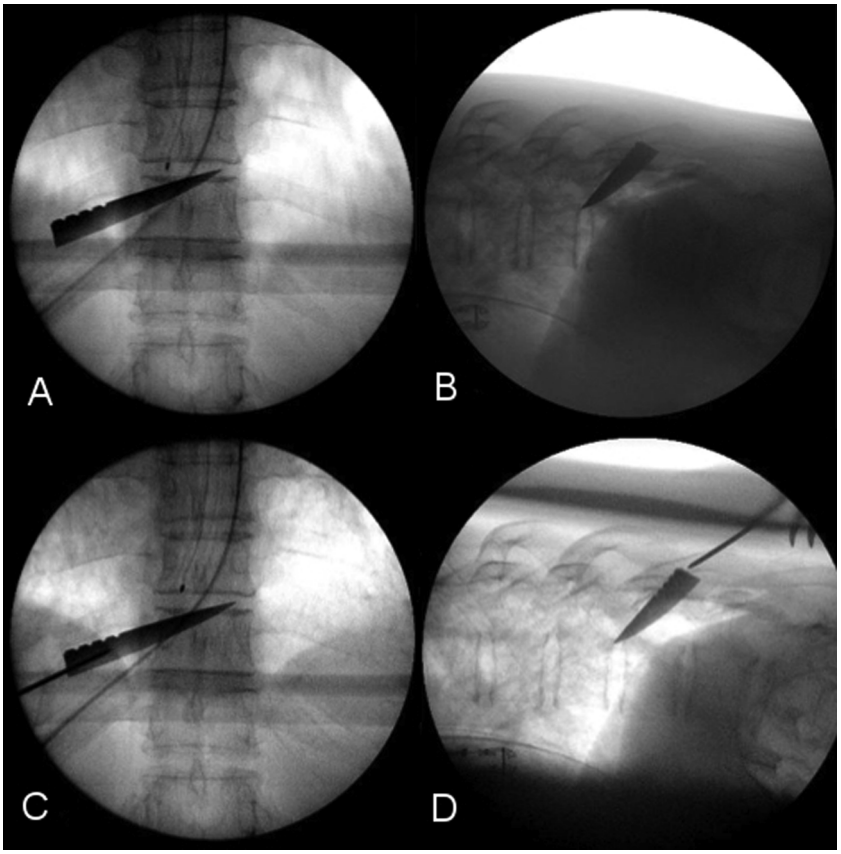

Fig. 2. (A, B) Initial intraoperative localization of the RFB using biplanar fluoroscopy. This was also used to plan the skin incision and access trajectory. A K-wire is inserted through an approximate 25 mm incision and advanced under biplanar fluoroscopy until retained the blade is contacted (C, D).

NMPSI patients with RFB [14]. In comparison, an 11 patient case series published in 1991 by Thakur reports 36% with RFB, whereas a 1999 study of 9 patients by Moyed reports a rate of 33% [17,24]. In a more recent series published in 2015 by Enricker, again based in South Africa, 49% of 105 NMPSI patients were reported as having RFBs [5].

3.2. Acute presenting symptoms and clinical outcomes

NMPSIs may be associated with significant neurological deficits. In Peacock's series of 450 patients there were 93 (21%) cases of complete SCI with the rest of the patients having incomplete lesions and 248 presenting with a Brown-Sequard type syndrome [19]. CSF leak occurred in only 4% of cases and resolved without intervention. A similar breakdown was seen in Heary's series of patients from New Jersey and Pennsylvania, with Brown-Sequard syndrome seen in 45% of patients and complete SCI in 25% [9]. In Simpson's series, 78% had complete SCI (likely because this study also included GSW) [22]. In Enicker's 2015 study, 24% of NMPSI patients were identified as having ASIA A complete SCI, 41% ASIA B, C or D and 35% were ASIA E or neurologically intact [5]. The degree of clinical improvement reported in patients with acute NMPSI is variable in the literature. In Lipschitz series, only 4.6% of patients improved clinically, while Peacock noted that recovery was good in 65.6% of patients (able to ambulate without assistance or with minimal support), fair in 17.1% (required major support to ambulate), and no recovery was noted in 17.3% [14,19]. In Velmahos' 1995 series of 143 South African patients, 61% made significant recovery [26]. In Enicker's series, no improvement was noted in ASIA A and B patients, and only 4 patients with incomplete SCI recovered to ASIA E status.

3.3. Indications for surgery and surgical approaches

Indications for surgical intervention are somewhat variable across the handful of case series which explore acute management of NMPSI. In Peacock's original large series laminectomy was performed in 4% of cases and the indication was always RFB [19]. In Lipschitz's study operative intervention was undertaken in those with RFB or sepsis/abscess [14]. In a series from Texas which included both missile and non-missile cases (18 out of 142 were NMPSI), criteria for surgery included incomplete deficit, worsening neurological status and associated visceral perforation. Twenty-three percent of patients received laminectomy with no difference in outcome between the surgical and non-surgical groups [22]. This study did note, however, that meningitis, CSF leak, and wound infection were complications more frequently found in the surgical group. Again, it is hard to generalize these findings to patients with NMPSI since the above study did not differentiate between missile and non-missile injury when looking at outcomes following surgery. In Enicker's study surgery was undertaken for all patients with RBF, 92% of whom required laminectomy to remove retained fragment, while in 8% the fragment was extracted without bony decompression [5]. Forty patients (78%) had dural tears which were primarily repaired; 24% had lumbar drain inserted. Major complications of surgery included 4 patients (8%) with post-op sepsis and meningitis.

3.4. Delayed presentation

Interestingly, while the acute presentation and management of NMPSI is discussed in many of the previously mentioned larger case series, the literature also has many examples of delayed presentation of NMPSI with RFBs. In these case reports, patients who were originally asymptomatic after their injury present with varying severity of

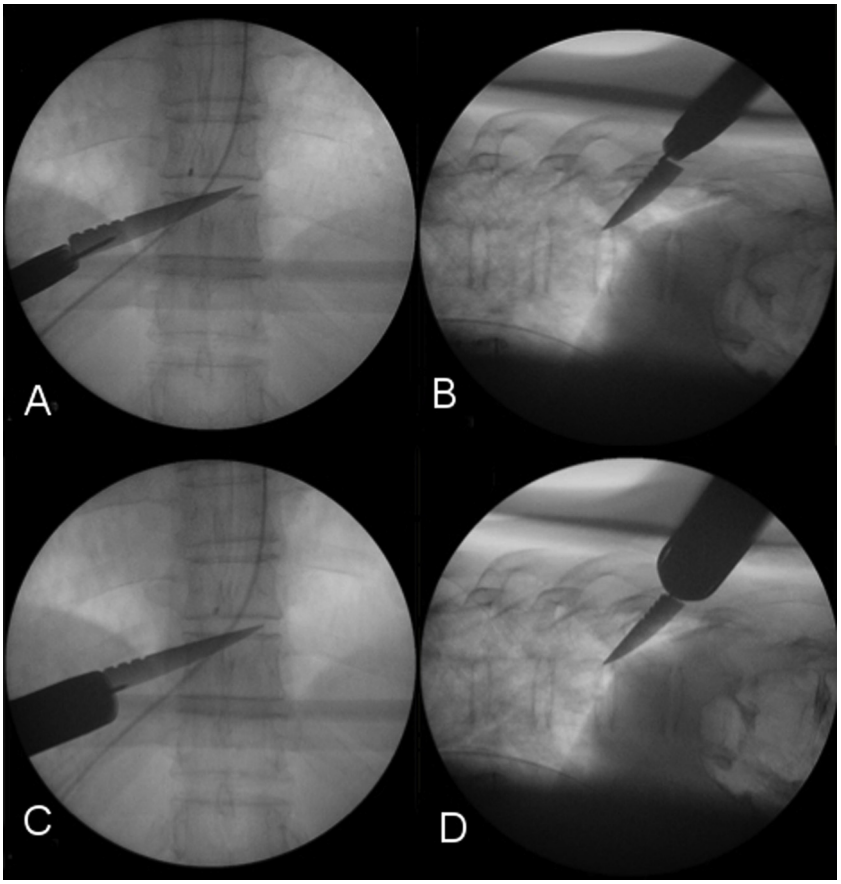

Fig. 3. Serial MIS dilators are passed over the K-wire using biplanar fluoroscopy and creating a corridor of access through the soft tissues to the retained blade as seen in AP (A, C) and Lateral (B, D) planes.

symptoms weeks, years and even decades after their initial trauma. In most of these cases, due to inadequate or incomplete imaging, RFBs (most frequently knife blades) were missed on patients' presentation only to be found years later when individuals came to medical attention due to the development of neurological dysfunction. For example, Wolf in 1973 reported on a case of a 35-year-old man stabbed in the back with initially only transient paresthesia in one leg followed by complete recovery and lack of symptoms for 21 years [27]. After a minor motor vehicle collision, the patient developed progressive myelopathy which eventually progressed to a Brown Sequard type syndrome with T7 sensory level. The patient was found to have a knife blade at T6 level which had apparently transfixed the cord with the knife tip buried in the vertebral body. After removal of the RFB the patient experienced significant improvement in symptoms.

Altogether, there are 23 such case reports found in the literature on our review dating from 1943 to 2014 with the delay between initial trauma and presentation of symptoms ranging from 1 day to 21 years (Table 1). Fifteen patients had thoracic level injuries while 6 had cervical and 2 had lumbar level injuries. Most patients underwent operative removal of foreign body after delayed presentation, with 12 patients experiencing some degree of clinical improvement after intervention, 2 resulting in deaths and the rest remaining clinically unchanged.

In acute SCI in the setting of non-missile penetrating forces, the mechanisms of injury include direct transection of the cord, nerve roots, arterial injury and compression injury from bony fragments or hematoma. In cases of delayed presentation, however, different mechanisms are at play, which are thought to include infection, delayed CSF leak, fibrosis/scarring or syrinx formation from metallic blade fragments causing inflammatory reaction in the cord. It is interesting to note that in multiple case studies of late onset neurologic deficit after NMPSI with RFB patients develop delayed symptoms after a second minor trauma [10]. This may be due to foreign body migration or disruption of previously formed scar tissue involving the cord/ or nerve roots caused by the repeat trauma [3,10,29].

Intraoperative findings in some of the case studies presented in the literature help to support the above theories regarding the pathophysiology of delayed presentation of NMPSI with RFB.

In a report by Ehni, a patient presenting with progressive paraparesis and urinary frequency was found to have scissor tips in the thoracic spinal canal from an injury the patient could not recall. During removal of the RFB the surgeons noted scar formation with attachments to the dura, subarachnoid thickening and a cystic cord with mucinous material [3]. Similar findings were noted during pathologic examination in other case studies including one by Wu and Jones [10,29].

3.5. Minimally invasive approach to removal of retained foreign body in case of NMPSI

Considering both the acute and delayed complications of a RFB, we believe there is clear evidence in the literature that removal of RFB associated with NMPSI is indicated. Prior case series and case reports have described posterior soft tissue dissection and bony decompression through laminectomy as the operative approach to removing RFBs. In our report we describe retrieval of a RFB though a minimally invasive approach with the use of fluoroscopy. This approach has potential benefits for the patient. Due to minimal dissection and bony decompression there is less damage to musculature/soft tissue and bone structure, decreasing the chance of destabilizing the spine structurally and also leading to speedier and less painful recovery for the patient

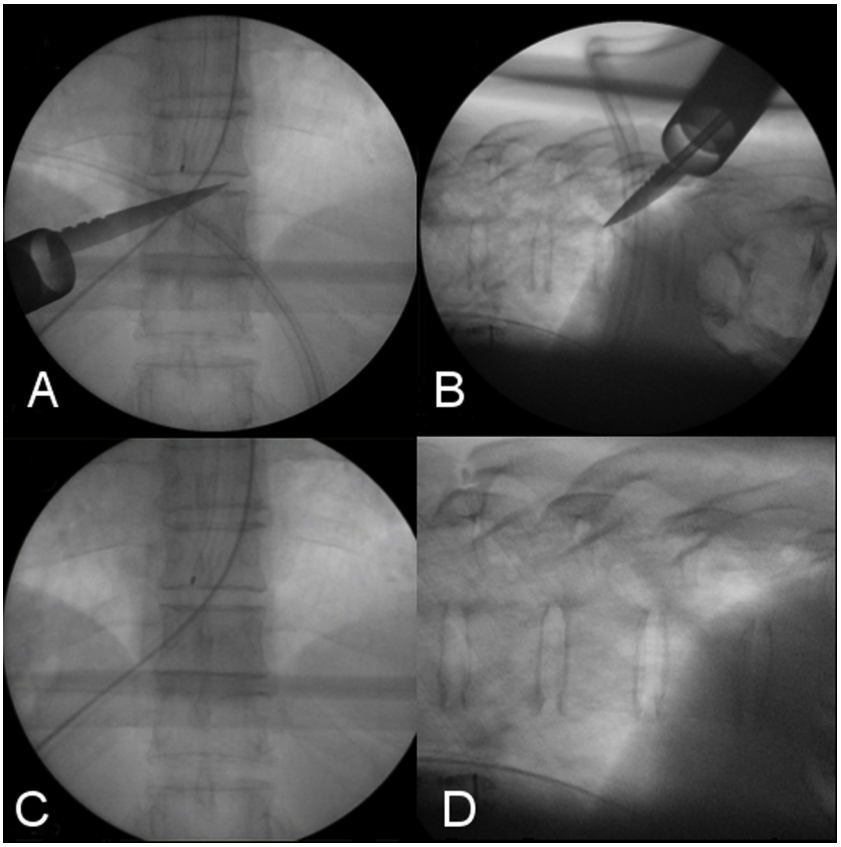

Fig. 4. A 21 mm MIS tubular retractor is inserted and the dilators are removed. The RFB is localized on AP (A) and lateral (B) fluoroscopy. A needle driver is used to grasp and withdraw the broken knife blade. AP (C) and lateral (D) fluoroscopy images confirm removal of the retained blade.

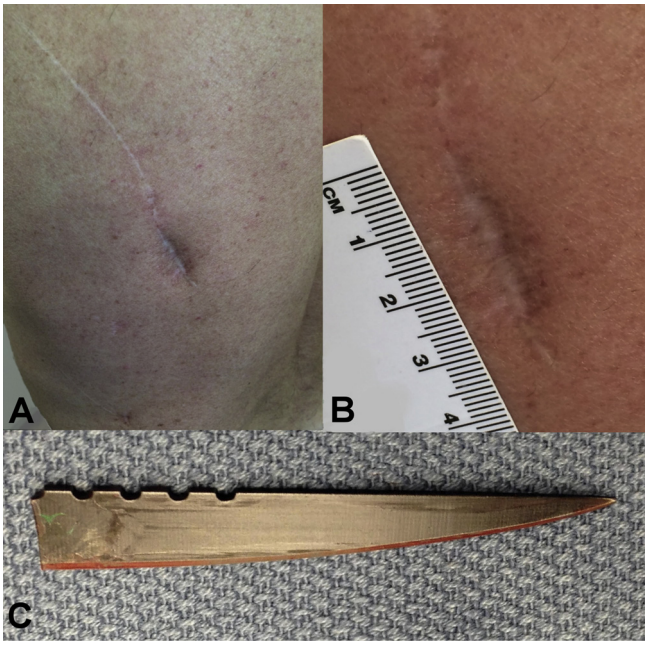

Fig. 5. (A) Patient with well-healed left flank incision at 2.5-year follow-up after minimally invasive surgery for removal of RFB from NMPSCI. (B) Close-up view showing 2.5 cm incision (C) Knife blade after it had been surgically removed form patient's back measuring 6.5 cm in length.

with shorter hospital stay. The minimal skin opening may also decrease the risk of infection and meningitis by minimizing access to the original contaminated tract through which the RFB was introduced. Decrease in manipulation of the foreign body and maintenance of original angle of entry would also potentially decrease further injury to nerves and spinal cord and may decrease the risk of intraoperative CSF leak. It is important to note that a more minimally invasive approach through a tubular retractor could make operative complications such as bleeding or epidural hematoma evacuation more difficult to manage, potentially requiring the surgeon to convert the case to a traditional open approach. However, as the blade was not in close proximity to the aorta, life-threatening bleeding was less of a concern. Similarly, in cases of significant dural injury and CSF leak which cannot be readily controlled with packing, a minimally invasive tubular approach would limit the surgeon's ability to access and repair the leak, necessitating conversion to traditional open surgery. It is also important to mention, that successful and safe utilization of a minimally invasive tubular approach to the spine requires an experienced surgeon and staff, and should not be undertaken by those without sufficient exposure to this technique. Finally, biplanar fluoroscopy results in greater radiation to the staff and surgeon. However, in the modern era, this may be mitigated by intraoperative CT imaging and navigation. These tools were not available at our medical center at the time the procedure was performed.

4. Conclusion

NMPSI is relatively uncommon but may result in significant neurological deficits both acutely and in delayed fashion which provides an indication to surgically remove the RFB. Our case provides an alternative treatment approach to traditional open laminectomy employing the principles and techniques of MISS with the potential benefit to patients of a more rapid recovery, and a potential decrease in risk of infection.

Table 1
Case Reports of NMPSI with Retained Foreign Body.

Author	Age at diagnosis	Level	Weapon	Time btw injury and symptom onset	Presentation	Treatment	Outcome
Jones [11]	43	T9-10	Knife	18 yrs.	Spastic paraparesis	Removal	No improvement
Castillo and Kahn [2]	20	T4	Knife	19 yrs.	Monoparesis	Removal	Improved
Adornato and Collis [1]	50	C7	Knife	13 yrs.	RUE weakness	Removal	Improved
	36	T7	Knife	16 yrs.	LLE weakness	Removal	Worsened
Wolf [27]	38	T6	Knife	21 yrs.	Spastic paraparesis	Removal	Improved
Jones and Woosley [10]	38	T6	Knife	8 yrs.	Brown Sequard	Removal	Improved
Ehni [3]	41	T8	Scissors	Unknown	Spastic paraparesis	Removal	No improvement
	9 mo	Entire length of spine	Broom straw	Unknown	Recurrent meningitis	Non-operative/ antibiotics	No improvement; death by 1 year of age
Harmit et al. [8]	22	T12	Knife	8 mo	Pain	Removal	Improved
Wu [29]	24	L3-4	Glass	1.5 day	RLE weakness	Removal	No improvement
Fung and Ng [6]	53	T2	Scissors	14 yrs.	LLE weakness	Removal	Improved
Karlins et al. [12]	21	T7	Knife	0	Brown Sequard	Removal	Partial improvement
Kulkarni et al. [13]	31	T11	Knife	4 wk	RLE weakness	Removal	No improvement
Tokushige et al. [25]	66	L5	Steel rod	0	LLE paralysis	Removal	Death from sepsis
Manzone et al. [15]	22	T5	Knife	6 mo	Paraparesis	Removal	Improved
Rubin et al. [20]	18	C1	Knife	0	Tetraplegia	Removal	No improvement
Groen et al. [7]	17	T7	Stingray spine	4 wks.	Paraparesis	Removal	Improved
Meltzer et al. [16]	18	C3	Pencil	Since childhood	Pain	Removal	Improved
Simsek et al. [23]	32	T11	Knife	0	Paraplegia	Removal	No improvement
Elgamal [4]	42	C2	Knife	0	Quadriparesis	Removal	Improvement
Shahlaie et al. [21]	42	T10	Knife	0	None	Removal	No improvement
Nath and McGonigal [18]	20	C2	Knife	4 days	L weakness	Non-op	No improvement
Wu et al. [28]	24	T10	Bamboo stick	4 yrs.	Myelopathy	Removal	Improved
Zaldivar-Jolissaint et al. [30]	30	C6	Pocket knife	10 days	Radiculopathy	Removal	Partial improvement

RLE-right lower extremity; LLE-left lower extremity; C-cervical; T-thoracic; L-lumbar.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

[1] D.C. Adornato, J.S. Collis, Stab wounds of the spinal cord, Int. Surg. 57 (2) (1972) 147–150.
[2] R. Castillo, E.A. Kahn, Asymptomatic transfixion of spinal cord by a knife blade; report of a case, J. Neurosurg. 7 (2) (1950) 179–182.
[3] G. Ehni, Occult foreign bodies in the spinal canal. Report of two cases, N. Engl. J. Med. 308 (16) (1983) 947–949.
[4] E.A. Elgamal, Complete recovery of severe quadriparesis caused by stab wound at the craniocervical junction, Neurosurg. Rev. 28 (1) (2005) 70–72.
[5] B. Enicker, S. Gonya, T.C. Hardcastle, Spinal stab injury with retained knife blades: 51 Consecutive patients managed at a regional referral unit, Injury 46 (9) (2015) 1726–1733.
[6] C.F. Fung, T.H. Ng, Delayed myelopathy after a stab wound with a retained intraspinal foreign body: case report, J. Trauma 32 (4) (1992) 539–541.
[7] R.J. Groen, E.A. Kafiluddin, H.L. Hamburger, E.J. Veldhuizen, Spinal cord injury with a stingray spine, Acta Neurochir. (Wien) 144 (5) (2002) 507–508.
[8] S. Harmit, V. Singhal, V.P. Bansal, Intraspinal, extradural stab injury of the spine without neurological deficit. A case report, Int. Orthop. 9 (4) (1985) 277–278.
[9] R.F. Heary, A.R. Vaccaro, J.J. Mesa, R.A. Balderston, Thoracolumbar infections in penetrating injuries to the spine, Orthop. Clin. North Am. 27 (1) (1996) 69–81.
[10] F.D. Jones, R.E. Woosley, Delayed myelopathy secondary to retained intraspinal metallic fragment. Case report, J. Neurosurg. 55 (6) (1981) 979–982.
[11] W. Jones, Old stab wounds of spinal cord with subsequent widespread pigmentation of spinal cord and base of the brain, J. Am. Med. Assoc. 121 (13) (1943) 1004–1006.
[12] N.L. Karlins, G. Marmolya, N. Snow, Computed tomography for the evaluation of knife impalement injuries: case report, J. Trauma 32 (5) (1992) 667–668.
[13] A.V. Kulkarni, M. Bhandari, S. Stiver, K. Reddy, Delayed presentation of spinal stab wound: case report and review of the literature, J. Emerg. Med. 18 (2) (2000) 209–213.
[14] R. Lipschitz, J. Block, Stab wounds of the spinal cord, Lancet 2 (7248) (1962) 169–172.
[15] P. Manzone, V. Domenech, D. Forlino, Stab injury of the spinal cord surgically treated, J. Spinal Disord. 14 (3) (2001) 264–267.
[16] H.S. Meltzer, P.J. Kim, B.M. Ozgur, M.L. Levy, Vertebral body granuloma of the cervical region after pencil injury, Neurosurgery 54 (6) (2004) 1527–1529 discussion 1529–1530.
[17] S. Moyed, K. Shanmuganathan, S.E. Mirvis, A. Bethel, M. Rothman, MR imaging of penetrating spinal trauma, AJR Am. J. Roentgenol. 173 (5) (1999) 1387–1391.
[18] D.S. Nath, M.D. McGonigal, A missed cervical cord injury caused by a stab wound to the neck, J. Trauma 62 (2) (2007) 529–531 discussion 531.
[19] W.J. Peacock, R.D. Shrosbree, A.G. Key, A review of 450 stabwounds of the spinal cord, S. Afr. Med. J. 51 (26) (1977) 961–964.
[20] G. Rubin, D. Tallman, L. Sagan, M. Melgar, An unusual stab wound of the cervical spinal cord: a case report, Spine (Phila Pa 1976) 26 (4) (2001) 444–447.
[21] K. Shahlaie, D.J. Chang, J.T. Anderson, Nonmissile penetrating spinal injury. Case report and review of the literature, J. Neurosurg. Spine 4 (5) (2006) 400–408.
[22] R.K. Simpson, B.H. Venger, R.K. Narayan, Treatment of acute penetrating injuries of the spine: a retrospective analysis, J. Trauma 29 (1) (1989) 42–46.
[23] O. Simşek, C. Kilincer, H. Sunar, M.K. Hamamcioğlu, S. Canbaz, S. Cobanoğlu, et al., Surgical management of combined stab injury of the spinal cord and the aorta—case report, Neurol. Med. Chir. (Tokyo) 44 (5) (2004) 263–265.
[24] R.C. Thakur, V.K. Khosla, V.K. Kak, Non-missile penetrating injuries of the spine, Acta Neurochir. (Wien) 113 (3–4) (1991) 144–148.
[25] J. Tokushige, A. Inokuchi, H. Kawaguchi, Impalement injuries involving the spinal canal, J. Orthop. Sci. 5 (6) (2000) 614–617.
[26] G.C. Velmahos, E. Degiannis, K. Hart, I. Souter, R. Saadia, Changing profiles in spinal cord injuries and risk factors influencing recovery after penetrating injuries, J. Trauma 38 (3) (1995) 334–337.
[27] S.M. Wolf, Delayed traumatic myelopathy following transfixion of the spinal cord by a knife blade. Case report, J. Neurosurg. 38 (2) (1973) 221–225.
[28] Q.H. Wu, W.S. Chen, Q.X. Chen, Delayed myelopathy after stab injury with intraspinal nonmetal foreign body granuloma, Chin. J. Traumatol. 11 (2) (2008) 126–128.
[29] W.Q. Wu, Delayed effects from retained foreign bodies in the spine and spinal cord, Surg. Neurol. 25 (3) (1986) 214–218.
[30] J.F. Zaldivar-Jolissaint, L. Bobinski, Y. Van Dommelen, M. Levivier, C. Simon, J.M. Duff, Delayed presentation of deep penetrating trauma to the subaxial cervical spine, Eur. Spine J. 24 (Suppl. 4) (2015) S540–S543.