Microsurgical repair of severed thoracic spinal cord and clinical outcome: technical case report

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Abstract

Background: This report describes a case of successful repair of severed thoracic spine in a young man who presented with a penetrating stab injury to spine resulting in Brown-Séquard syndrome. Surgical technique and post-operative management is discussed.

Case presentation: A 34-year-old fit and well healthy man was admitted with a history of stab injury to the thoracic spine at thoracic T2/3 level with ASIA impairment score (AIS) score D with an incomplete spinal cord affecting his left lower limb with complete paralysis and right lower limb paresis with impaired sensation below T6 level to L5. Neuroimaging confirmed a penetrating knife injury traversing the T2/3 level causing hemi-section of the spinal cord confirmed intraoperatively. He underwent an urgent exploratory surgery of his spine and a T2/3 laminectomy was performed to aid removal of the knife. The dura was noted to be contused and severed spinal cord was noted to be severed with associated cord oedema. A microsurgical repair of the severed cord was performed with duroplasty followed by intense neuro-rehabilitation. On a 3 month follow up his AIS score is E with lower limb power is 5/5 bilaterally and he is able to mobilise independently up to 8–10 steps without any supportive aid and with crutches he is independently functional and mobile.

Conclusion: This is the first documented case of microsurgical repair of severed thoracic spinal cord secondary to traumatic knife injury. In the management of such scenario, apart from the removal of foreign body, repair of the cord with duroplasty should be carefully considered. The role of spinal neuroplasticity in healing following timely repair of the spinal cord along with intense rehabilitation remains the key. This had resulted in a good clinical and functional outcome with in a 18-month follow up.

Keywords: Spinal injury, Stab injury, Penetrating injury to spinal cord, Spinal cord repair ASIA score, Brown-Séquard syndrome

Background

Spinal cord injury (SCI) is a severe neural trauma and depending on the damaged segment and severity of the trauma, it is classified into complete and incomplete SCI. SCI is also a debilitating neurological condition with tremendous socioeconomic impact on the affected individuals and the health care system. Etiologically, more than 90% of SCI cases are traumatic and caused by incidences such as traffic accidents, violence, sports or falls [1–3]. Adults older than 60 years of age whom suffer SCI have considerably worse outcomes than younger patients, and their injuries usually result from falls and age-related bony changes [3, 4]. In this report, a young and healthy male presenting with a penetrating stab injury to his thoracic spine and the management...
outcome is described with an emphasis on the surgical technique.

Case presentation
A fit and well 34-year-old man was admitted to the emergency service with multiple stab injuries to posterior thorax and occiput with a retained knife in his interscapular area. He remained haemodynamically stable and neurological examination revealed normal power in upper limbs and a 4/5 power in his right lower limb, 0/5 power in his left lower limb. Sensory examination revealed an intact pin prick and light touch from C2-T4, altered sensation T5, absent sensation to pin prick and light touch from T6-S2 with intact perianal sensation. He had a Motor incomplete- ASIA impairment score (AIS) D score. A CT spine was confirmed trajectory of the knife traversing the superior T2 right lamina into left inferior posterior T2 vertebral body. There was no associated vascular injury associated (Figs. 1, 2).

Surgical technique
A thoracic T2 and T3 laminectomy and removal of foreign body was performed within 3 hours of presentation. The knife was noted to be retained in the right paraspinal region with a trajectory of the knife tip to the midline (Figs. 3, 4). A 10 cms midline incision made and connecting the oblique right paraspinal wound. The paraspinal muscles dissected and laminae of T2/3 expose and T2/3 laminectomy completed with high speed drill.
Intra operative findings
Under microscopic guidance, the knife was removed following the laminectomy with minimal manipulatory movement. Care was taken not to move the knife perpendicularly to the cord to avoid further damage. The tip of the knife penetrated the right side of the cord causing more than a hemisection (60% of the lateral cord diameter and 100% of anterior posterior diameter on the right side) of the cord landing in the vertebral body and penetrating the posterior longitudinal ligament. The dura appeared contused and severed (Fig. 5). 8 mgs dexamethasone was administered intravenously after the knife was removed from the cord. The torn right hemi cord was sutured with continuous 7/0 prolene (Fig. 6, 7). The pia arachnoidal layer was included in the suturing procedure in a circumferential manner to oppose the torn cord. Haemostasis secured with Floseal®. Dural margins were trimmed and a watertight duroplasty was performed Duraguard™ with 3/0 prolene. Tissee fibrin glue was used to seal the duroplasty margins. Wound closed in layers. No post-operative surgical complications were encountered.

As this procedure was carried out as an emergency out of hours, neurophysiological monitoring was not utilised.

Post-operative course
He was treated in the intensive care unit and was noted to have complete loss of power in both legs for 8 days and a power of 1/5 noted in his left extensor hallucis longus that improved to 4/5 over 6 weeks. Sensory examination revealed a Brown-Séquard syndrome pattern with loss of pinprick sensation and temperature below T4 on the right side which recovered on the left side. Post-operative spinal MRI at day 4 revealed high signal at the repair site at the T2/3 level (Figs. 8, 9). An MRI performed at 3 months (Figs. 10, 11) revealed sign of significant spinal cord injury in the and micro-haemorrhages in the cord above and below the level of injury with associated post-operative changes. His ASIA score improved to E from D.

At a 18 month follow-up his is mobilising independently with normal lower limb power and does not need any mobility aid. He is under the care of neuropsychologists for post-traumatic stress disorder (PTSD).

Discussion
Stab wounds of the spinal cord represent approximately 26% of all spinal cord injuries [1, 5] and remains the most common cause of traumatic Brown-Séquard syndrome [2, 4, 6–10]. In this case, the patient had a picture of post traumatic Brown-Séquard syndrome like picture with complete recovery of the motor functions in a 3 month period with persistent sensory on the right side. It is interesting to note that the patient had 0/5 power in his left lower limb and 4/5 power in his right lower limb likely due damage to ipsilateral and contralateral spinothalamic tracts involvement unlike what is noticed in a pure hemi section of the cord.

Middleton et al. describe in their study that approximately 42% of patients with traumatic SCI have complete dysfunction without any movement or sensation below the site of injury and this may not be applicable to penetrating trauma to spinal cord, nevertheless it gives us an account of the severity of the pathology and clinical implications [11]. They have also eluded to the fact that only 14.3% of all SCIs are believed to be anatomically complete injuries, while the remainder of SCIs are considered as an incomplete functional deficiency with a few spared connections that could be established under

**Fig. 5** The appearance of the thoracic cord with hemi section on the right side with contused dura. Arrow points to the severed cord. Contused dura is seen in the cranial and caudal portion of the cord.

**Fig. 6** Repair of the cord from medial to lateral with 7/0 prolene.
proper interventions [11]. In this case, the knife injury had resulted in a hemi section of the cord contributing to incomplete functional status. It is useful to note that the therapeutic options for traumatic SCI include surgical decompression, anti-inflammatory drugs, hyperbaric oxygen therapy, and rehabilitation interventions [12]. SCI is still associated with a high disability rate despite the intensive rehabilitation programs carried out in hospitals worldwide [3, 12, 13].

In the case described one may argue if microsurgical repair is superior to just removal of the knife without repair of the cord or instillation of fibrin glue to the severed margins. There is no evidence to prove the efficacy of a specific technique leading to good functional recovery. Administration of Dexamethasone in this case is following the observation of the severed cord and the rationale can be questioned. Dural reconstruction following cord repair is vital in preventing post-operative complications compromising recovery.
The clinical outcomes of SCI depend on the severity and location of the lesion and may include partial or complete loss of sensory and/or motor function below the level of injury. Literature describe that cervical level of the spinal cord (50%) with the single most common level affected being C5 and the thoracic level (35%) and lumbar region (11%) in case of Traumatic SCI [1, 11]. In case of penetrating cord injury the aetiology is varied and there is report of penetrating missile injury and management by Kumar et al. [14] where the emphasis on conservative management to surgical removal of the foreign body to avoid iatrogenic deficits. There are reports of accidental penetrating injury to cord secondary to Nail gun injury and wooden fragment penetration causing cauda equina syndrome where role of surgery is described [15–17].

With recent advancements in medical procedures and patient care, SCI patients often survive these traumatic injuries and live for decades after the initial injury [3]. Studies have shown that 40-year survival rate of these individuals was 47% and 62% for persons with tetraplegia and paraplegia, respectively [3, 7]. The life expectancy of SCI patients highly depends on the level of injury and preserved functions. Mary Joan Roach et al. in their recent study have concluded that the patients with penetrating SCI showed more complete injuries and lower surgery rates with worse functional outcome at 1 year [18]. In our case, these evidence gives us an understanding of long term implications in the management of SCI. Kevin Morrow et al. have concluded in their analysis pertaining to penetrating SCI that younger patients are affected and they utilise more health care resources. Surgery is undertaken to limiting progression of neurological deficits, stabilisation and to control infection [19].

In this case, the patient had signs and symptoms of Incomplete cord injury/ Brown-Sequard syndrome that was successfully managed with timely surgical intervention, intense post-operative care and physiotherapy. Neurophysiological monitoring is recommended as an imperative standard adjunct for intramedullary spinal surgery and in this case it was not used as the procedure was carried out of hours as an emergency. One may argue that this may not helpful as there was more than a hemi section in this case and it is likely that the SSEPs, MEPs and D waves would have been significantly compromised or absent.

There is evidence to support that Neuroplasticity plays an important in SCI recovery and physiologically based approach for the rehabilitation of walking has developed, translating evidence for activity-dependent neuroplasticity and the neurobiological control of walking [20, 21]. Neuroplasticity occurs at multiple levels following SCI: Cortical, subcortical, brainstem and spinal cord both short-term and long-term, supporting the need for long term rehabilitation in these cases [21].
There is a paucity of reports eluding to repair of the spinal cord secondary to stab injury and particularly to the thoracic spine. Spinal cord repair is technically feasible however several factors should be considered, particularly the nature of injury, type of the foreign body, age of patient, time to repair from trauma and neurological status of the patient along clear understanding of treatment options. This case demonstrates that with multidisciplinary input, a combination of prompt surgical intervention and rehabilitation has helped an adult patient with penetrating stab injury to the spinal cord.

Spinal rehabilitation post repair of the cord

Intensive rehabilitation remains the key in recovery of traumatic SCI patients. This is provided a tertiary care centre by a team of dedicated Physicians, Physiotherapists, Occupational therapists, Orthotists, Neuropsychologists and Neuropyschologists. In this case, after the initial period of Intensive post operative care, patient was transferred to the National Spinal Injuries Unit where the majority of recovery took place (https://www.spinalunit.scot.nhs.uk/, https://www.gla.ac.uk/research/az/scisci/). This involved an Intensive inter-disciplinary comprehensive care and patient tailored rehabilitation programme to facilitate the patients' return to their own community. Once the patient was discharged from the inpatient care, out-patient clinics provided general review, urology, fertility, orthopaedics, neurosurgery, skin, and antispasm measures for patients with spasticity. This demonstrates the need for both short and long term rehabilitation input that is essential and it has to be delivered by an experienced multidisciplinary team.

There is recent emerging evidence to prove that non-invasive brain stimulation, as well as spinal cord stimulation, are promising techniques for the rehabilitation of patients with spinal cord injury due to their novelty, effectiveness and minimal side effects [22–24]. In this case, there was no necessity for any stimulation of brain or spine as he showed a remarkable improvement with combination of therapies. He does have spasticity after a 18 month period that is affecting the left limb function to some extent that is currently being managed with low dose of oral diazepam.

Conclusion

This is the first documented case of hemi-section of the thoracic cord secondary to penetrating knife injury that was successfully repaired and the patient has made a successful functional recovery. The aim of the treatment is to safely remove the foreign body followed by a meticulous and prompt microsurgical repair with water tight duroplasty. The clinical outcome depends on multiple factors including the nature of injury, appropriate preoperative imaging to determine the type of spinal cord injury, clinical judgement and expertise with a suitable post-operative multi-disciplinary treatment facility providing an intensive care and rehabilitation support. The role of spinal neuroplasticity following repair plays a significant role in spinal cord healing and this is supported by provision of high quality intensive medical care. This concurs with recent evidence that in penetrating SCI, surgery is undertaken to limit progression of neurological deficits, stabilisation or infection control. Long term follow-up by the neurorehabilitation team including neuropsychological support is recommended.

Acknowledgements

I profoundly thank the patient for consenting to the preparation of this technical report. I thank the Intensive care team and Anaesthetists of the Royal Infirmary of Edinburgh, Scotland, NHS Lothian for the excellent post operative care. Spinal rehabilitation was provided by the Queen Elizabeth National Spinal Injuries Unit, Glasgow, NHS Greater Glasgow and Clyde, Scotland and my sincere gratitude to the entire team of Physicians, Nursing team, Physiotherapists, Occupational therapist, Management and Neuropsychology team involved in the patient's care. We are very grateful to the neuro-intensive care physicians, Nursing staff in the Intensive care unit in the Royal Infirmary of Edinburgh, UK and the Rehabilitation team in the Queen Elizabeth Spinal injuries unit, Glasgow, UK.

Author's contributions

The author is the primary Consultant who treated this patient and was responsible for the write up of this technical case report. The author(s) read and approved the final manuscript.

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Funding

No funding was received for the preparation of this article.

Availability of data and materials

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Declarations

Ethics approval

Not applicable.

Consent for publication

Written consent is obtained from the patient for purpose of publication.

Competing interests

The authors declare that they have no competing interests.

References

1. Park SD, Kim SW, Jeon I. Brown-Sequard syndrome after an accidential stab injury of cervical spine: a case report. Korean J Neurotrauma. 2015;11(2):180–2. https://doi.org/10.13004/kjnt.2015.11.2.180 Epub 2015 Oct 31. PMID: 27169090; PMCID: PMC4847515.

2. Ahuja CS, Nori S, Tetreault L, Wilson J, Kwon B, Harrop J, et al. Traumatic spinal cord injury-repair and regeneration. Neurosurgery. 2017;80:S9–S22.
3. Wilson JR, Cadotte DW, Fehlings MG. Clinical predictors of neurological outcome, functional status, and survival after traumatic spinal cord injury: a systematic review. J Neurosurg Spine. 2012;17(1Suppl):11–26. https://doi.org/10.3171/2012.4.JOSSPI1245.

4. WHO WHO. Spinal Cord Injury WHO fact sheet N 384 (2013). Available online at: https://www.who.int/news-room/fact-sheets/detail/spinal-cord-injury.

5. Peacock WJ, Shroobree RD, Key AG. A review of 450 stab wounds of the spinal cord. S Afr Med J. 1977;51(26):961–4.

6. Johnson S, Jones M, Zumsteg J. Brown-Séquard syndrome without vascular injury associated with Horner’s syndrome after a stab injury to the neck. J Spinal Cord Med. 2016;39(1):111–4. https://doi.org/10.1179/2045772314Y.00000000297.

7. Shavelle RW, Paculdo DR, Tran LM, Strauss DJ, Brooks JC, De Vivo MJ. Mobility, confinement, and life expectancy in persons with Asia impairment scale grade D spinal cord injuries. Am J Phys Med Rehabil. 2015;94:180–91. https://doi.org/10.1097/PHM.0000000000000140. Spinal Cord Med. 2016;39(1):111–4. doi: 10.1179/2045772314Y.00000000297. Epub 2015 Feb 9.

8. Pouw MH, van de Meent H, van Middendorp JJ, Hirshfeld S, Thietje R, van Kampen A, et al. Relation of the diagnosis traumatic cervical Brown-Squard-plus syndrome: an analysis based on the neurological and functional recovery in a prospective cohort of 148 patients. Spinal Cord. 2010;48(8):614–8.

9. Kakulas BA. Neuropathology: the foundation for new treatments in spinal cord injury. Spinal Cord. 2004;42:549–63.

10. Ramadan WS, Abdel-Hamid GA, Al-Karim S, Zakar N, Elassouli MZ. Neuroectodermal stem cells: a remyelinating potential in acute compressed spinal cord injury in rat model. J Biosci. 2018;43:897–909.

11. Middleman JW, Dayton A, Walsh J, Rutkowski SB, Leong G, Duong S, et al. Life expectancy after spinal cord injury: a 50-year study. Spinal Cord. 2012;50:803–11. https://doi.org/10.1038/sc.2012.55.

12. Zheng Y, Mao Y-R, Yuan T-F, Xu D-S, Cheng L-M. Multimodal treatment for spinal cord injury: a sword of neuroregeneration upon neuromodulation. Neural Regen Res. 2020;15(8):1437–50. Published online 2020 Jan 28. https://doi.org/10.4103/1673-5374.274332.

13. Alizadeh A, Dyck SM, Karimi-Abdolrezae S. Traumatic spinal cord injury: an overview of pathophysiology, models and acute injury mechanisms. Front Neurol. 2019;10:282. Published online 2019 Mar 22. https://doi.org/10.3389/fneur.2019.00282.

14. Kumar A, Pandey PN, Chhani A, Jaiswal G. Penetrating spinal injuries and their management. J Craniovertebral Junct Spine. 2011;2(2):57–61. https://doi.org/10.4103/0974-8237.100052.

15. Goyal RS, Goyal NK, Salunke P. Non-missile penetrating injuries. Indian J Neurotrauma (IJNT). 2009;6:81–4.

16. Pal D, Timothy J, Marks P. Penetrating spinal injury with wooden fragments causing cauda equina syndrome: case report and literature review. Eur Spine J. 2006;15:5574–7.

17. Lunawat SK, Taneja DK. A foreign body in the spinal canal: a case report. J Bone Joint Surg Br. 2000;82:267–8.

18. Roach MJ, Chien Y, Kelly ML. Comparing blunt and penetrating trauma in spinal cord injury: analysis of long-term functional and neurological outcomes. Topics Spinal Cord Inj Rehabil. 2018;24(1):121–32. https://doi.org/10.1310/sccio2402-121.

19. Morrow KD, Podet AG, Spinelli CP, Lasseigne LM, Crutchler CL, Wilson JD, et al. A case series of penetrating spinal trauma: comparisons to blunt trauma, surgical indications, and outcomes. Neurosurg Focus FOC. 2019;46(3):E4 Retrieved Aug 14, 2021, from https://thejns.org/focus/view/journals/neurosurg-focus/46/3/article-pE4.xml.

20. Oyinbo CA. Secondary injury mechanisms in traumatic spinal cord injury: a nugget of this multiply cascade. Acta Neurol Log. 2011;71:281–99.

21. Amendola L, Corghi A, Cappuccio M, De lure F. Two cases of Brown-Squard syndrome in penetrating spinal cord injuries. Eur Rev Med Pharmacol Sci. 2014;18(1):2–7.

22. de Araujo AVL, Barbosa VRN, Galdino GS, Fregni F, Massetti T, Fontes SL, de Oliveira SD, da Silva TD, Monteiro CBM, Tonks J, Valgála et al. Effects of high-frequency transcranial magnetic stimulation on functional performance in individuals with incomplete spinal cord injury: study protocol for a randomized controlled trial. Trials. 2017;18(1):522. https://doi.org/10.1186/s13063-017-2280-1.