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CASE REPORT - SPINE

Microsurgical reconstruction of the cauda equina after traumatic transecting injury

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Abstract
Introduction The microsurgical reconstruction of the cauda equina nerve roots (MRCER) after traumatic injury is a highly controversial procedure with very few reports in the literature.
Methods We report on four patients who had a penetrating traumatic injury in the lumbosacral area and underwent primary MRCER at our institution during the last decade.
Results All four patients presented complete distal sensory and motor palsy affecting the lower lumbosacral roots. Primary microsuture was feasible in three patients harboring stab wounds, whereas autologous nerve graft interposition was necessary in the patient who had a gunshot wound. At the 5-year follow-up, we observed a marked improvement in motor function in two patients, but no sensory recovery.

Keywords Lumbar spine trauma · Cauda equina lesion · Nerve regeneration · Microsurgery

Introduction

Cauda equina syndrome (CES) is a complex neurological disorder presenting a myriad of symptoms such as back pain, unilateral or bilateral leg pain, paresthesias and weakness, perineal or saddle anesthesia, sphincter incontinence, and other less common symptoms [7]. This clinical condition is most often caused by acute lumbosacral disk herniation. It may also be observed following traumatic injury to the lumbar spine, yet these cases present a less clearly defined clinical course and therapeutic approach [7]. Stab or gunshot injuries to the lumbar spine are uncommon causes of CES.

Penetrating lesions at the level of the thoracolumbar junction may manifest as conus medullaris syndrome, whereas those below this level usually manifest as lumbosacral radiculopathy (CES). Traumatic lesions of the cauda equina mostly cause sudden, acute neurological deterioration, unlike the gradual onset of lower motor neuron dysfunction observed in chronic CES. For this reason, traumatic lesions generally have a poorer prognosis [10].

At the initial emergency assessment, care must be taken to recognize sensorimotor deficits in the lower limbs. Targeted CT and MRI scans, as well as an electrophysiological assessment, allow for an accurate diagnosis even as early as the acute phase. Although it is possible to make a precise diagnosis of cauda equina lesions, outlining a proper treatment plan remains challenging.

There are very few experimental [7, 10] and clinical data [6, 13] regarding the direct reconstruction of the injured cauda equina. Although there is some preclinical evidence of regeneration in animal models, this approach has not yet been incorporated into the therapeutic armamentarium for human patients. We believe this report represents a valuable contribution to the field and may help foster the refinement of this elegant reconstructive strategy.

Methods

We report on four patients from the last 10 years who underwent primary microsurgical anastomosis of the cauda

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equina nerve roots following transecting injuries. These patients were treated at the emergency service of the Neurology Department of the University of São Paulo's Medical School. All four patients presented complete sensorimotor deficits in the legs, which were directly related to the trauma and had an acute onset immediately following it. We excluded patients with i) residual sensorimotor function, ii) a concomitant conus medullaris lesion, or iii) those who had been submitted to other surgical interventions, such as drainage of spinal hematomas, spinal canal decompression, debridement, or vertebral fusion.

All patients were submitted to a classic exploratory laminectomy at the injured spinal level, which was extended to two levels above and two levels below to allow for better visualization of the cauda equina. Using a microsurgical technique, the root stumps were identified, freed from scar tissue and debris secondary to the trauma, and primarily anastomosed using an 8-0 monofilament surgical suture for microsurgical repair (Fig. 1a).

Anatomical landmarks (mainly the foramina and root origin at the cord) were used to recognize the corresponding stumps. Because the spinal roots do not have an epineural sheath, they are less suitable for direct suturing than the nerve trunks. In one case, the proximal stumps were not satisfactorily accessible via the surgical approach. By compressing the jugular veins lightly and temporarily (Queckenstedt-Stookey maneuver), the roots migrated over two centimeters distally, allowing the suturing to be done with sural nerve graft interposition and without tension (Fig. 1b).

After surgery, patients remained hospitalized for 1 to 2 weeks. Standard medical and physiotherapy regimens were initiated. After discharge, motor and sensory functions were assessed in the outpatient clinic for up to 4 years.

Results

All patients were male and ranged in age from 22 to 33 years. Please see Table 1 for epidemiological and clinical follow-up data.

A stab wound of the lumbar spine was the cause of injury in three patients, whereas one patient was the victim of a gunshot injury. Two patients had trauma at level L4 and the other two patients at level L5. Motor and sensory deficits at presentation are summarized in Table 1.

Surgical repair was performed 3 days after trauma (in the acute phase) in two cases, 15 days after trauma (sub-acute phase) in one case, and 3 years following trauma (chronic phase) in the fourth patient. All the transected nerve stumps visible in the surgical field were primarily sutured guided by anatomical landmarks. Unfortunately, they could not be identified through electrophysiological monitoring, since all patients were operated on in an emergency setting. Sural nerve grafts were necessary for reconstruction in the patient with the gunshot injury, who was treated in the acute phase.

Improvement in motor function of the perineal and bladder detrusor muscles was observed in the two patients who were treated acutely: 4 months after surgery in the patient with the stab wound (which was likely due to spontaneous recovery), and 4 years after nerve graft suture in the patient with the gunshot injury. The latter patient presented long-term improvement in distal lower limb motricity, and despite the

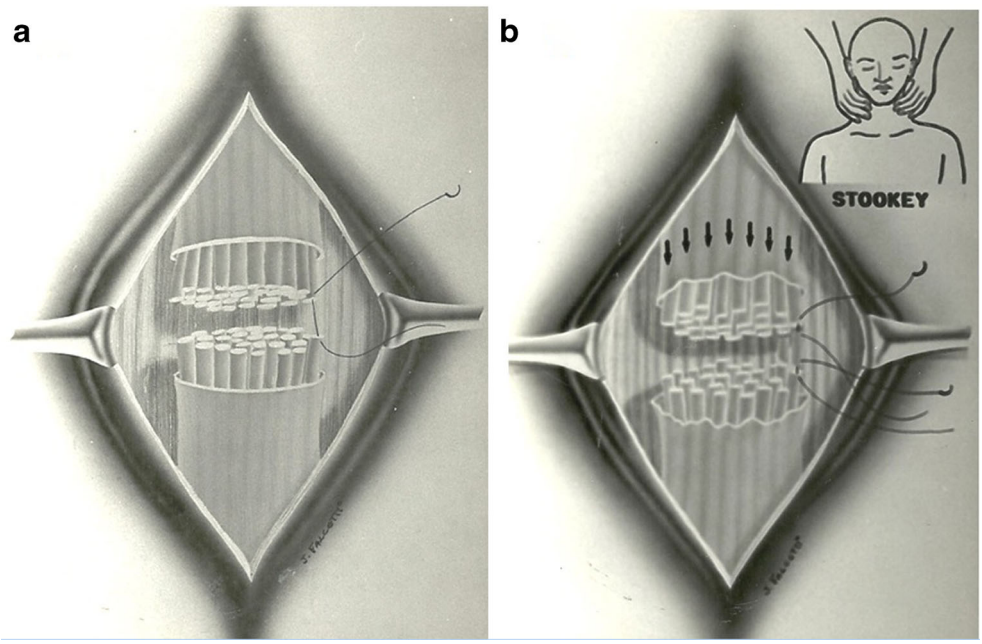

Fig. 1 Primary microsurgical repair of the cauda equina. **a** Surgical repair of the epineural sheath using an 8-0 monofilament suture. **b** When the root stumps were not visible in the surgical field, we used the Queckenstedt-Stookey maneuver to render the roots visible again, thus allowing the suture to be applied without tension. This was done with sural nerve graft interposition

Table 1 Epidemiological data and clinical outcome of the patients submitted to cauda equina repair

Gender	Age (y)	Penetrating lesion	Injury level	Motor deficit	Sensory deficit	Vegetative deficits	Time of surgery	1 year follow up
Male	22	Stab wound	L5	Right foot drop	Right L5, perineal anesthesia	Urinary retention	3rd day	complete bladder function recovery after 4 months
Male	23	Gunshot	L4	Abolished leg extension, feet flexion and extension bilaterally	Both L5, perineal anesthesia	Urinary retention	1st and 3rd day	no recovery for 9 months; after 4 years ambulatory with cane, improvement of the vesical function
Male	22	Stab wound	L4	Feet flexion quadriceps paresis	Both L5 and S1	Urinary retention	3 years	No improvement
Male	33	Stab wound	L5	Feet flexion	Both S1	Urinary retention	15 year	Mild sensory recovery

presence of sensory ataxia, he was able to walk without help. In two patients, no objective improvement was observed at the 1-year follow-up, and one reported subjective improvement of sensibility in the legs, which cannot be attributed to the surgery. These two patients were treated in the sub-acute and chronic phases, respectively.

The patients' recovery was relatively uneventful and all underwent a standard physiotherapy regimen and a program for bladder and bowel reeducation. At the time of the long-term follow-up, an improvement in perineal motor function was observed in two of the patients, while improvement of bladder detrusor activity and lower limb function was observed in one patient. In two patients, no improvement was observed at the 1-year follow-up; however, one patient referred to improvement of bladder sensation and emptying, which could not be documented.

Discussion

Opting for surgery in the treatment of penetrating spinal injury is a controversial issue [12, 13]. In general, it is widely acceptable to indicate surgery in cases of injury to the cauda equina with nerve root compression, neurologic deterioration, the presence of foreign bodies within the vertebral spinal canal, the presence of spinal epidural hematoma, and persistent CSF leak.

On the other hand, some authors maintain that penetrating lesions to the cauda equina associated with neurological impairment should always be treated with surgical decompression, aimed at separating the roots from the granulation tissue and trauma debris [11, 13]. According to these authors, this approach favors functional recovery. However, there is a lack of scientific evidence confirming this view.

LeBlanc et al. [11] described a marked improvement in motor function in human victims of spinal stab injuries following microsurgical reconstruction of the cauda equina. These authors concluded that surgical treatment with primary suture of the cauda equina should always be considered, even in complete lesions. Their result is in agreement with our observation that acute repair favors good motor outcome and that waiting for epineural thickening affords no advantage in cauda equina lesions, as this only leads to the formation of more scar tissue [11]. In fact, the scar tissue formed during the waiting period may result in additional stretching of the nerve root (during reanastomosis of the severed ends), and could additionally result in the need for nerve graft interposition, which is considered to be less effective than primary reanastomosis [11].

The regeneration of transected motor roots after primary suturing has been shown to occur in animal models [8, 9]; sensory roots, on the other hand, do not regenerate. The regeneration potential of the cauda equina nerve roots is theoretically the same as that of other peripheral nervous system (PNS) constituents, and, therefore, the sprouting fibers originating in the cauda equina do not have the negative influence of myelin-derived substances that act as axonal blockers in the CNS [e.g., Nogo, myelin-associated microprotein(MAG), oligodendrocyte myelin glycoprotein (OMG), among many others] [5].

Differences in cellular regeneration capabilities between the PNS and the CNS also apply to structural tissues. The neurilemmal tube seems to guide sprouting axons within the peripheral nerves. Unfortunately, the neurilemmal tube is absent in the CNS. When a nerve root is sectioned and sutured directly to the cord, the regenerating fibers end up at the spinal cord, without functional reinnervation, although some authors have demonstrated some degree of reinnervation when reinserting avulsed roots [2, 3, 14].

Experimental studies have also shown that the surgical replantation of avulsed roots after brachial plexus and cauda equina injuries can restore not only motor, but also autonomic pathways, thus facilitating the recovery of neurological function [2, 3, 14].

In addition, experimental assays in mammals have shown motor recovery months to years after end-to-end anastomosis of radicular stumps. However, the degree of recovery was shown to be less prominent when interposing nerve grafts [4].

Neurovegetative deficits may also be treated with primary repair of sectioned ventral roots. Following primary suture of sacral roots, Freemann et al. [4] observed penile erection in baboons, and Carlsson and Sudin et al. [1] described recovery of the micturition reflex in cats. These reports demonstrate that sacral ventral roots in mammals are able to regenerate anatomically and functionally after primary repair.

In the current report, we describe our experience with four patients who underwent primary repair of the transected cauda equina. Interestingly, we observed a marked improvement in vegetative function (bladder control) in both cases treated during the acute phase. It is noteworthy that neurogenic bladder is a significant cause of repetitive urinary infection and renal failure, and is also associated with high morbidity rates. One of the two patients treated acutely also demonstrated a marked improvement in motor function. Although less prone to recover, sensory function also improved in two of the patients. We do not attribute this finding to the surgery, however, since there is currently no clinical or experimental evidence in the literature supporting sensory recovery after PNS reconstruction.

It is interesting to note that none of the patients treated either in the sub-acute phase (15 days after trauma), or in the chronic phase (years after injury) presented any clinical improvement. Although this is a small sample series, this observation suggests that the ideal time-window for surgical repair may lie within a few days following trauma. Further reports with other patients are necessary to confirm this assumption.

Conclusion

We suggest that among the usual indications for the surgical treatment of lumbar spine traumas, professionals should also include exploratory laminectomy and, if necessary, microsurgical suture of the transected cauda equina roots.

Conflict of interest The authors declare no conflict of interest

References

1. Carlsson CA, Sundin T (1968) Reconstruction of severed ventral roots innervating the urinary bladder. Scand J Urol 2:199–210
2. Carlstedt T (2009) Nerve root replantation. Neurosurg Clin N Am 20(1):39–50
3. Carlstedt T, Havton L (2012) The longitudinal spinal cord injury: lessons from intraspinal plexus, cauda equina and medullary conus lesions. Handb Clin Neurol 109:337–354
4. Freemann LW (1952) Observations on spinal nerve root transplantation in the male Guinea baboon. Ann Surg 136:206–210
5. GrandPré T, Nakamura F, Vartanian T, Strittmatter SM (2000) Identification of the Nogo inhibitor of axon regeneration as a Reticulon protein. Nature 403(6768):439–444
6. Hadley MN, Walters BL, Grabb PA (2002) Pharmacological therapy after acute cervical spinal cord injury. Neurosurgery 50:S63–S71
7. Harrop JS, Hunt GE Jr, Vaccaro AR (2004) Conus medullaris and cauda equina syndrome as a result of traumatic injuries: management principles. Neurosurg Focus 16(6):e4
8. Havton LA (2012) A lumbosacral ventral root avulsion injury and repair model for studies of neuropathic pain in rats. Methods Mol Biol 851:185–193
9. Havton LA, Carlstedt T (2009) Repair and rehabilitation of plexus and root avulsions in animal models and patients. Curr Opin Neurol 22(6):570–574
10. Kostuik JP, Harrington I, Alexander D (1986) Cauda equina syndrome and lumbar disk herniation. J Bone Joint Surg 68:386–391
11. LeBlanc HJ, Gray LW, Kline DG (1969) Stab wounds of the cauda equine. J Neurosurg 31:683–685
12. Lee KH, Lin JS, Pallatroni HF, Ball PA (2007) An unusual case of penetrating injury to the spine resulting in cauda equina syndrome: case presentation and a review of the literature. Spine (Phila Pa 1976) 32(9):E290–E293
13. Mikami Y, Tasaki A, Morita W, Kuroda E, Hoshikawa Y (2012) Penetrating injury to the cauda equina: a case report and review of the literature. J Spinal Disord Tech 25(1):64–67
14. Sköld MK, Svensson M, Tsao J, Hultgren T, Landegren T, Carlstedt T, Cullheim S (2011) Karolinska institutet 200-year anniversary. Symposium on traumatic injuries in the nervous system: injuries to the spinal cord and peripheral nervous system - injuries and repair, pain problems, lesions to brachial plexus. Front Neurol 2:29