Nerve reconstruction in lumbosacral plexopathy

Case report and review of the literature

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Neurological injury to the lumbosacral plexus associated with pelvic and sacral fractures has traditionally been treated conservatively, despite significant and often debilitating functional deficits of the lower extremities. The authors report a case of reconstruction of the lumbosacral plexus, including nerve grafting to restore lower-extremity function caused by severe trauma to the pelvis. A 16-year-old boy sustained pelvic and sacral fractures in a motor vehicle accident. After stabilization of his orthopedic injuries, he suffered from paresis of his right gluteal and hamstring muscles and had no motor or sensory function below his knee. Two months later, he underwent reconstruction of his lumbosacral plexus performed using a nerve graft from his L-5 and S-1 nerve roots proximal to the inferior gluteal nerve and distal to a branch to the hamstring muscles. After another 2 months, his recovering saphenous nerve was transferred to the sensory component of the posterior tibial nerve by using cabled sural nerve grafts to restore sensation to the sole of his foot. After 2.5 years, he experienced reinnervation of his gluteal and hamstring muscles and could perceive vibration on the sole of his foot. With the assistance of a foot-drop splint, the patient ambulates well and is able to ski. Operative details and the relevant literature are reviewed.

KEY WORDS • lumbosacral plexopathy • pelvic/sacral fracture • nerve injury • nerve graft • pediatric neurosurgery

Lumbosacral plexus injuries following pelvic trauma have historically been left untreated because the condition is difficult to diagnose and very few treatment options exist. These factors are reflected in the literature. The true incidence of nerve injury associated with pelvic trauma is unknown. A review of the literature reveals an incidence of neurological injury of 30 to 46% in cases involving unstable pelvic fractures, and these cases often include severe and debilitating functional deficits. In a series of 13 sacral fractures, seven (54%) included a neurological deficit. Although cases of surgical management of lumbosacral plexus injuries have been reported, reconstructions remain uncommon. In this report we describe the nature of lumbosacral plexus injuries, methods for diagnosis, and the successful surgical treatment of a patient.

Anatomical Considerations

The lumbosacral plexus is a combination of the lumbar and sacral plexi (Fig. 1). The lumbar plexus consists of the first through fourth lumbar anterior rami. The sacral plexus consists of the L-4 contribution to the lumbosacral trunk, L-5, and the first three sacral anterior rami. The lumbosacral plexus originates from the cauda equina, which is formed by the ventral and dorsal roots of the five lumbar and five sacral spinal nerves. The nerve roots combine beyond the dorsal nerve root ganglion within the spine. This combined nerve exits the vertebral foramina and divides into the anterior and posterior rami. The posterior rami provide segmental motor and sensory innervation. The lumbar plexus (L1–4) leads to the sensory iliohypogastric, ilioinguinal, genitofemoral, and saphenous nerves. Its motor fibers form the femoral and obturator nerves, which supply the quadriceps and hip adductor muscles, respectively. The lumbosacral trunk (L4–5) and the sacral plexus (L5–S3) provide sensation to the posterior leg and foot, and lead to the superior and inferior gluteal nerves, which innervate the gluteal muscles, and the sciatic nerve, which innervates the hamstring and lower leg muscles via the tibial and peroneal nerves. Proximal to the fusion of anterior and posterior roots there are no common epineurial and perineurial sheaths making these roots vulnerable to injury. Because it traverses across the sacroiliac joint the lumbosacral trunk is also susceptible to more distal injury, particularly in cases of severe pelvic disruptions.

Abbreviations used in this paper: EMG = electromyography; MUP = motor unit potential.

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Case Report

This 16-year-old boy was hit by a train while driving a truck in August 1998. He sustained bilateral femur, pelvic, and sacral fractures for which he was treated at a community hospital (Fig. 2). His pelvic fracture was a combined fracture involving both the anterior and posterior pelvic segments. He suffered bilateral pubic rami fractures extending to the acetabular roof on the right and a vertical fracture of the right sacrum extending through the right sacral ala that included comminuted fracture fragments abutting the right sacroiliac joint. Although the sacroiliac joint was not clearly disrupted, the right ilium and attached sacral fragment were displaced superiorly compared with the left side; therefore, a vertical pelvic fracture with hemipelvic displacement was diagnosed. After his recovery the patient was referred to our institution because of persistent right sciatic nerve palsy. The physical examination revealed no hamstring or gluteal muscle function. Moreover, the patient demonstrated no motor or sensory function below the knee except along the saphenous nerve and no Tinel sign was present along the sciatic nerve. Nerve-conduction EMG studies revealed no continuity of the tibial and peroneal divisions of the sciatic nerve. There were 4+ fibrillations in the gluteus maximus and minimus, hamstring, and gastrocnemius muscles, and no voluntary MUPs were noted. Mild involvement of the femoral nerve was also apparent, including a mild loss of motor units and substantially fewer fibrillations. Computerized tomography myelography revealed cystic dilation of the right L-4, L-5, S-1, and S-2 nerve root sheaths, an indication of possible traumatic injury to the meninges.

In October 1998 the patient underwent T10–S1 laminectomies including exploration and dissection of proximal nerve roots through a standard longitudinal skin incision. The L-5 and S-1 nerve roots were identified and observed to be in good condition, indicating that the injury was distal to this level. The motor branch to the hamstring muscles and the inferior gluteal nerve were dissected through a separate longitudinal incision in the proximal posterior thigh and infragluteal region. Reconstruction was performed using a 45-cm reversed sural nerve graft, which was sutured in an end-to-end fashion to the L-5 and S-1 nerve roots proximally and to the inferior gluteal nerve and the branch to the hamstring muscles distally by using a 9-0 nylon suture (Figs. 3 and 4). The nerve graft was tunneled using a Medtronic (Minneapolis, MN) tunneling device in a subfascial plane to facilitate the back closure. The size match was considered quite satisfactory. No attempt was made to reinnervate muscles below the knee because the distance from the lumbosacral plexus prohibits reinnervation before degeneration of the neuromuscular junction. A fibrin glue and Gelfoam (Pharmacia & Upjohn, Kalamazoo, MI) “sandwich” was fashioned over the dural closure and a dural sleeve of bovine pericardium was constructed around the nerve root as it exited the dural closure. The pa-
The patient was discharged home on postoperative Day 7. He remained capable of only partial weight bearing for 2 weeks with the use of an ankle–foot orthosis and then progressed to full weight bearing. Physical therapy was prescribed to help the patient regain full range of motion and strengthen the innervated muscles.

The patient continued to experience numbness in the sole of his foot, and in December 1998 he underwent surgery for transfer of the saphenous nerve to the sensory component of the posterior tibial nerve in which two 20.5-cm cables of sural nerve graft were used. The saphenous nerve was identified in the thigh, and the tibial nerve was identified in the proximal calf. The nerve graft was taken from the proximal saphenous nerve to the tibial nerve distal to the motor branches. The knee was immobilized for 2 weeks postoperatively and then the patient was permitted full range of motion of the leg. Strengthening exercises were begun and progressed as tolerated by the patient. In a follow-up examination in July 1999 no reinnervation of the gluteal muscles was observed, and only a flicker of contraction was detected in his hamstring muscles. At this time, an advancing Tinel sign along the saphenous–tibial nerve graft was also noted. After 2 years, however, definite strong contraction in his gluteal and hamstring muscles was observed. At the 4-year follow-up examination, he demonstrated Medical Research Council Grade 4/5 strength of knee flexion (Fig. 5) and Grade 3/5 gluteal muscle function.

In October 2000 decreased sensation remained in the sole of the patient’s right foot and a Tinel sign had reached the tarsal tunnel. A tarsal tunnel release was performed to facilitate further regeneration from his saphenous–tibial nerve sensory transfer to the sole of his foot. By March 2001 the Tinel sign had advanced past the tarsal tunnel and in February 2002 he was sensing vibration from a 30-cycles per minute tuning fork applied to the sole of his foot. He has not reported any problems with skin breakdown. With the assistance of an ankle–foot orthosis, the patient ambulates well and is able to ski.

Discussion

In 1936, Lam13 reviewed the literature from the previous 20 years and was able to find only 14 cases of nerve injury among 1889 cases of pelvic fractures (0.75%). He concluded that neurological injury accompanying pelvic fractures was probably more common than reported, and in his own series of 100 pelvic fractures he found nine cases of nerve damage, an incidence of 9%.13,21 In 1975 Barnett and Connolly1 reviewed the literature of lumbosacral nerve root avulsions and found 13 cases reported in the literature and added one of their own. They also concluded that the condition was frequently overlooked. A more recent review of the literature in 1997 identified 35 cases of lumbosacral nerve root avulsion and noted an association with pelvic fractures.4

In 1972 a postmortem study by Huittinen8 was motivated by a case review of 407 patients with pelvic fractures in which a 27% incidence of sacroiliac injuries was reported. Follow-up examination of these patients revealed that 46% of patients with unstable pelvic fractures had suffered persistent neural damage. Neurological deficits were limited to the L-5 through S-5 roots, with the predominance of injury concentrated in L-5 and S-1. The study comprised 42 patients with pelvic fractures, including 40 lumbosacral nerve injuries recorded in 20 patients. Thirty-eight of the 42 patients sustained unstable pelvic fractures. Traction injuries involving the lumbosacral, superior gluteal, and obturator nerves were identified in 21 patients. Ruptures were noted in 15 patients; the locations included the cauda equina, superior gluteal, obturator, and anterior rami of L5–S3. In most cases of rupture, simultaneous ruptures were noted. In all cases, both the ventral and dorsal roots ruptured between the dorsal root ganglia and spinal cord. No avulsion of the roots from the spinal cord was found. Ruptures were associated with a fracture–dislocation of the posterior pelvic ring, not with fractures of the foramina. In Huittinen’s series all six cases of spinal root avulsion occurred proximal to the spinal ganglia and distal to the lumbar enlargement of the spinal cord. Also, the distal stumps were observed to have been pulled through the intervertebral foramina and were not visible at the time.
of laminectomy. The author concluded that the force of action in lumbosacral root avulsion is coaxial with the spinal cord rather than perpendicular, as in the case of cervical root avulsion in brachial plexus injuries, and that this explained the existence of a significant postganglionic ventral root following avulsion.

A specific nerve injury may be associated with a particular type and pattern of pelvic fracture. Traction injury to the lumbosacral trunk and superior gluteal nerve is the most prevalent nerve injury because both structures cross the sacroiliac joint. This lesion is most likely caused by disruption at this site, resulting from a sacroiliac joint dislocation, juxtaarticular fracture, or vertical pelvic fractures, particularly "double vertical" fractures that involve the anterior and posterior pelvic rims and cause hemipelvic displacement, as in the case reported here. Injury to the obturator nerve is also frequently observed with fractures involving the posterior pelvic rim. Fractures through the sacral foramina are likely to cause compression of the anterior primary rami of the sacral nerves, which contribute to the innervation of most of the hip, thigh, leg, and foot muscles. Rupture of the roots of the cauda equina, which is much less frequent, is observed in cases involving gross hemipelvic dislocation and transverse sacral fractures.8

The neurological features of lumbosacral plexus injury are less well described in the literature than those of brachial plexus injuries. The severity of these injuries ranges from minor disturbances to complete paralysis and loss of sensation. The involvement of the superior gluteal nerve can cause weakness of hip abduction and internal rotation. An L-5 root injury manifests as sensory disturbances in the dorsum of the foot and the lateral lower leg and as weakness in the anterior tibial compartment musculature. The S-1 and S-2 roots are represented mostly in the posterior leg and are responsible for hip extension, knee, and plantar flexion. They provide sensation to the posterior leg, the lateral side and sole of the foot, and the genitalia (S-2).23 Recovery after injury if forthcoming is slow, and permanent impairment of gait and lower-extremity function may occur.3 Involvement of the S2–5 roots, which may be overlooked because of the lack of obvious changes in lower-extremity function, can affect urinary and anal continence, and sexual function.23

Electrodiagnostic and radiographic studies can both be used to confirm the diagnosis. Patients may demonstrate loss of nerve action potentials and electromyographic evidence of muscle denervation. If a normal action potential is obtained in a patient with suspected root rupture, then somatosensory evoked potential monitoring should be performed. In root ruptures proximal to the dorsal root ganglia, the peripheral nerve cell body is viable and normal peripheral studies may be obtained; however, evoked potentials will not be recorded proximally. The absence of action potentials does not rule out the possibility of root rupture because injuries can occur at multiple levels. The denervated muscle that is typical in cases of lower motor neuron lesions such as lumbosacral plexus injury will demonstrate fibrillations on EMG studies, but these studies do not provide information regarding the anatomical level of injury. If muscle recovery occurs, the number of fibrillation potentials will decrease and voluntary MUPs will appear and increase.15,20 The demonstration of MUPs indi-
cates muscle reinnervation and a favorable prognosis for functional recovery.

Radiographic evaluation should include plain films, which are required to diagnose pelvic and additional orthopedic injuries. If the patient demonstrates physical signs consistent with a lumbosacral plexus injury (especially if associated with an unstable pelvic fracture), additional spinal studies should be performed. Traditionally, lumbar myelography has been used to diagnose nerve root avulsion. The diagnosis is made by the detection of pseudomeningoceles, which appear as wide, contrast-filled outpouchings of the dural sac that lack any nerve roots. Computerized tomography with intrathecal contrast enhancement may demonstrate similar findings and more detail. More recently, magnetic resonance imaging has been shown to be useful and has been considered the imaging modality of choice. The advantages of magnetic resonance imaging are that it is noninvasive and does not require repositioning of the patient, which may be difficult for the patient with multiple-system trauma. The diagnosis of nerve root avulsion can be confirmed, however, only if two conditions again are met: 1) presence of a pseudomeningocele; and 2) absence of nerve roots within the pseudomeningocele. The most frequently damaged roots are (in order) L-5, S-1, and L-4.

Recovery of neurological function after these injuries is variable and will depend on the severity of the injury. In less severe cases, the prognosis is good, although residual sequelae such as mild leg weakness and muscle atrophy may occur. In more severe cases, there is greater weakness and wasting or paresis, with significant gait alteration and disability. As in nerve injuries associated with more common musculoskeletal trauma, the nerve damage will vary from neurapraxia to neurotmesis and the outcomes will vary accordingly. Some reports have noted some improvement in neurological function, despite evidence of residual low-grade nerve damage, whereas others have noted no significant neurological improvement in the long term.

Since the early 1980s surgical reconstruction of lumbosacral plexus injuries has been reported; both nerve repair and grafting techniques have been used primarily for traumatic injuries and have resulted in some recovery of proximal leg muscles. These injuries include both crush injuries involving pelvic fractures and sacroiliac dislocation as well as penetrating injuries, such as gunshot wounds and lacerations. Surgical management consists of primary repair when appropriate and the use of nerve grafts of up to 9 to 10 cm in length for more extensive injuries. In several of these cases successful functional restoration, including recovery of hip and gluteal muscles, knee flexors and extensors, and even musculature as far distal as the plantar flexors, has been reported. Recovery of some trophic sensation to the foot following reconstruction has also been described.

Electrodiagnostic and radiographic evaluation help to determine the severity of nerve injury and predict functional outcome. In brachial plexus injuries, nerve reconstruction is undertaken if no clinical or electrodiagnostic evidence of motor recovery is seen by 3 months postinjury, or sooner if clear evidence of root avulsion exists. A similar timeframe can be used to guide the surgical management of patients with lumbosacral plexopathy. Surgical reconstruction may result in the restoration of motor function after severe injury and root avulsion. Only proximal muscle groups such as those involved in brachial plexus injuries can regain function as a result of nerve grafting because the
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Fig. 5. Postoperative photograph demonstrating restoration of Medical Research Council Grade 4/5 knee flexion at 4-year follow-up examination.

long distance to more distal muscles prohibits reinnervation before degeneration of the motor endplate. Medications that have been shown to accelerate nerve regeneration, such as FK-506 (tacrolimus), may prove to be useful in the management of proximal peripheral nerve injuries by facilitating the more timely reinnervation of distal muscle groups.7,14

Conclusions

Lumbosacral nerve injuries and root avulsions occur as a result of unstable pelvic fractures. Because of the anatomy of the pelvis and cauda equina, a nerve root avulsion does not occur at its junction with the spinal cord; instead, it occurs distal to the cord and proximal to the dorsal root spinal ganglia. The anterior nerve root is a postganglionic motor nerve that is, like any peripheral nerve, capable of nerve regeneration; therefore, nerve grafting and other reconstructive techniques may be warranted in certain cases. With appropriate patient selection and surgical goals, satisfactory recovery of proximal motor function can be achieved. Patients suffering from high-risk injuries should be evaluated thoroughly to determine if they are candidates for reconstruction. Reinnervation of the hip, gluteal, and thigh muscles is possible if surgery is performed in a timely fashion, and some sensation to the foot can be restored.

References


Manuscript received September 22, 2003. Accepted in final form June 2, 2004. Address reprint requests to: Susan E. Mackinnon, M.D., Division of Plastic Surgery, Washington University School of Medicine, Suite 17424, East Pavilion, 1 Barnes-Jewish Plaza, St. Louis, Missouri 63110. email: mackinnons@msnotes.wustl.edu.

J. Neurosurg. (Pediatrics 1) / Volume 102 / January, 2005

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