

Retroperitoneal femoral nerve reconstruction in the pediatric population

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BACKGROUND: Retroperitoneal femoral nerve lesions in children are rare. They can result in a complete femoral nerve palsy causing severe functional impairment of ambulation and standing and sensory impairment of the anterior and medial thigh extending down the medial aspect of the leg. While treatment can be challenging due to the complex anatomy of the region and the difficulty of achieving adequate surgical access, femoral nerve repair has led to the recovery of useful function in adult patients.

OBJECTIVE: The authors review their experience from the surgical treatment of three consecutive cases of this rare lesion in children while focusing on validated outcome measures.

METHODS: A retrospective chart review of all cases of retroperitoneal femoral nerve transection treated surgically was completed (n=3). Data collected included demographics, timing of repair, surgical approach, Medical Research Council muscle grading scores, The Hospital for Sick Children Active Movement Scale scores and follow-up period.

RESULTS: Follow-up ranged from two to 4.5 years. All three patients had excellent motor recovery and ambulated without assistance. Sensory function also improved, with a substantial resolution of preoperative dysesthesia in one case. There were no major complications.

CONCLUSIONS: Complete retroperitoneal femoral nerve transection in children is a rare but devastating injury. Appropriate surgical access to the retroperitoneal space is a prerequisite for lumbar plexus reconstruction and mandates a team approach. In the present series, all patients regained excellent function following reconstruction. The surgical treatment of these unusual lesions in childhood proved highly rewarding.

Key Words: Femoral nerve; Pediatric; Surgery

While lumbar plexus and retroperitoneal femoral nerve lesions in children are rare, when present, femoral nerve palsy can result in severe functional impairment of ambulation and standing. In addition, sensory impairment is observed over the anterior and medial thigh, extending down to the medial aspect of the leg to the arch of the foot. Treatment is challenging due to the complex anatomy of the region and the difficulty of achieving adequate surgical access. A conservative approach is often chosen given that the surgical risks are believed to outweigh potential benefits. Consensus that femoral nerve repair leads to recovery of useful function exists in the adult literature (1-7). To our knowledge, however, there are no publications in the literature that specifically address these lesions in children.

The femoral nerve, the largest branch of the lumbar plexus, is formed from the anterior divisions of the L2, L3 and L4 nerve roots, which converge within the psoas muscle. The nerve then travels obliquely to emerge laterally between the psoas and the iliacus at the pelvic brim and continues into the thigh deep to the inguinal ligament, distal to which it divides into its terminal branches. The femoral nerve innervates the psoas and iliacus muscles, which are the primary flexors of the hip, as well as the quadriceps femoris, which provides extension of the leg at the knee.

Due to the protection afforded by the pelvic girdle, injuries to the proximal femoral nerve or to its contributing nerve roots in adults are generally found in patients who have sustained high-energy trauma or, less commonly, secondary to an intrapelvic iatrogenic, neoplastic, infectious or inflammatory process (4-6,8,9). In the more common case of nerve injury due to pelvic trauma, the diagnosis is often delayed by the presence of concomitant soft tissue or bony injuries, which can mask the underlying neurological deficits and render physical examination difficult.

In the present article, the experience derived from the surgical treatment of three consecutive cases of this rare lesion in children is reported, focusing on results assessed using validated outcome measures.

METHODS

All cases of retroperitoneal femoral nerve transection treated surgically by the senior authors were included in the present series. Data were collected from the charts of the three patients who underwent retroperitoneal femoral nerve reconstruction. The patients were assessed both preoperatively and postoperatively using the Medical Research Council (MRC) muscle grading scores (10) and The Hospital for Sick Children Active Movement Scale (AMS) (11). The present study was approved by the Research Ethics Board of The Hospital for Sick Children, Toronto, Ontario.

Surgical strategy

All surgical procedures were performed in collaboration with the general surgery service, who provided the retroperitoneal dissection and exposure of the lumbar plexus. Beginning with the patient prone, sural nerve grafts are harvested from both lower extremities in an endoscopically assisted fashion (12). The patient was then moved to the decubitus position with the table 'broken' at the level of the contralateral kidney.

A generous flank incision starting at the ipsilateral paraspinous muscles (just inferior to the 12th rib), extending to a point superior to the anterior superior iliac spine and continuing medially to the

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TABLE 1
Summary of patient age, nature of lesion, nerve gap and timing of surgery

Patient, age (years), sex at surgery	Nature of retroperitoneal nerve lesion	Repaired nerve and nerve gap	Timing of sural nerve grafting
A 15, male	Severe crush injury with open book pelvic fracture	Right femoral nerve 11–14 cm	Six months post-trauma
B 16, male	Radical resection of malignant schwannoma at L3 root level	Left femoral nerve 12 cm	Two months postablation
C 1, female	Cyclic neutropenia with cecal perforation and necrotizing fasciitis	Right femoral nerve 10 cm	Four months postexcision

TABLE 2
Summary of surgical details

Patient	Fibrin glue	Duration, h	Sural nerves	Major complication
A	Yes	16	Both	None
B	Yes	19	Both	None
C	Yes	16	Both	None

midline at the level of the symphysis pubis was used to gain optimal exposure. The dissection was then continued through skin, subcutaneous tissue, fascia and abdominal musculature to the level of the peritoneum. The retroperitoneal space was entered by reflecting the intraperitoneal structures anteromedially, this enabled identification of the ipsilateral iliacus and psoas muscles, the ureter and the gonadal vessels. The lumbar spine was exposed at multiple levels as required. In all cases, very dense, thick scar tissue resulting from the previous trauma or surgery was encountered. All of the relevant structures were identified and the injured neural structures were released from the thick scar that encased them. The nerve segments both proximal and distal to the lesion were subsequently identified. Intraoperative nerve stimulation was performed to document any residual nerve function. The damaged segment of nerve or nerves was resected, and a complete cross-section of the stumps at both ends of the resection were sent to pathology for frozen section analysis using toluidine, blue dye as described previously in obstetrical brachial plexus palsy (13). This enabled evaluation of whether the nerve stumps were suitable for use in the reconstruction. Once adequate stumps were identified and the nerve gap was measured, sural nerve grafts were used to reconstruct the defect in a tension-free manner. The neurorrhaphies were completed with fibrin glue under the operating microscope.

Table 1 provides a summary of the age, nature of injury, nerve gap and timing of reconstruction for all three patients. The major features of the three operations are summarized in Table 2.

CASE PRESENTATIONS

Case A

A 15-year-old male who sustained a severe crush injury to the pelvis and lower extremities when a concrete block wall he was helping to construct collapsed on him. His injuries included an open-book pelvic fracture with a wide diastasis of the right sacroiliac joint, left pubic ramus fractures and a urethral disruption. Neurological examination of the lower extremities showed diffuse weakness at all lumbosacral nerve roots levels, worse on the right than on the left. Five months postinjury, the patient exhibited complete recovery of motor function on the left side and significant improvement in the function of all muscle groups on the right side, except for knee extension, which remained rated at 0 on the MRC Scale, and weak hip flexion. Electromyography and magnetic resonance imaging (MRI) studies were performed to evaluate the status of the right femoral nerve. While the MRI did not demonstrate definite evidence of a nerve root avulsion, stimulation of the right femoral nerve provoked no response and needle testing of the vastus lateralis showed denervation without signs of reinnervation. Sensory testing revealed profound hyperesthesia of the right foot and anesthesia of the anterior and lateral aspects of the right thigh. The patient was bedridden as a result of the pain and sensitivity in his right leg and foot.

Femoral nerve reconstruction was undertaken six months following the original trauma (Table 2). A stretch injury of the retroperitoneal femoral nerve was identified and resected. The femoral nerve was reconstructed with one sural nerve graft from the L2 root and four grafts from the fused L3–L4 stump (Figure 1). Neurolysis of the lumbosacral trunk was a component of the operative dissection.

Case B

A 16-year-old male presented with a mass in the retroperitoneal space, which was determined to be a malignant peripheral nerve sheath tumour. The lesion, centred on the L3 nerve root, was irradiated and, two months later, widely resected by the neurosurgery service including sacrifice of the L2 and L4 nerve root contributions to the lumbar plexus. Immediate nerve reconstruction was considered intraoperatively, but was not undertaken because the adequacy of the resection could not be confirmed definitely at the time.

Clear margins were ultimately confirmed on final pathology. Following this resection, the patient exhibited an obvious neurological deficit consistent with loss of femoral nerve function. Knee extension was 0 on the MRC scale (0 on AMS) while hip flexion was 1 on the MRC scale (2 on AMS). Decreased sensation over the left anterior thigh and medial lower leg was also evident.

Nerve reconstruction was undertaken two months later (Table 2). A healthy proximal stump of the L2 nerve root was identified. The L3 root had been excised within the intervertebral foramen precluding reconstruction at that level. The L4 root had been divided very proximally and, while the root was identified, its histological appearance was poor, making it unsuitable as a graft site. Six sural nerve segments were grafted between the proximal L2 stump and the distal femoral nerve.

Case C

A 12-month-old female with cyclic neutropenia presented with severe Gram-negative sepsis and hemodynamic instability resulting from a perforated cecum. She rapidly developed necrotizing fasciitis over the right lower abdominal wall necessitating radical excision and debridement of her right lower quadrant viscera and abdominal wall. Included in the resection, of necessity, was a segment of her right psoas muscle and right retroperitoneal femoral nerve. The patient recovered from her sepsis and neutropenia and progressed to undergo abdominal reconstruction and skin grafting. Four months postoperatively, she demonstrated the expected absence of right knee extension, graded at 0 on the MRC scale (0 on AMS). She had just been learning to walk before her illness but had become nonambulatory postoperatively.

Four months later, the segmental defect of the femoral nerve was reconstructed using three sural nerve grafts between the retroperitoneal femoral nerve and the three main branches of the femoral nerve identified distal to the inguinal ligament (Table 2).

RESULTS

The patients were followed regularly by plastic surgery, physiotherapy and occupational therapy to document their progress. Clinical follow-up continued for 4.5 years, three years and two years after surgery for patients A, B and C, respectively. Table 3 outlines the preoperative and postoperative knee extension. All patients showed excellent results postoperatively both in motor and sensory functions. There were no major complications in any of the patients. Sensory function improved in all patients with substantial resolution of preoperative dysesthesia in one patient.

TABLE 3
Preoperative and long-term postoperative motor assessment

Patient	Age at follow-up, years	Duration of follow-up, years	Knee extension			
			Preoperative		Postoperative	
			MRC	AMS	MRC	AMS
A	20	4.5	0/5	0/7	5/5	7/7
B	20	3	0/5	0/7	2+/5	6/7
C	3	2	0/5	0/7	4/5	7/7

AMS Active Movement Scale; MRC Medical Research Council

Case A



The severe dysesthetic pain that this patient had experienced preoperatively was markedly improved on the first postoperative day. This finding was attributed to the neurolysis of the lumbosacral trunk that had been performed. At eight months postoperatively, he was able to extend his knee with gravity eliminated. By 11 months, he could walk without crutches and extend his knee against gravity at. At two years postreconstruction, he was able to walk without aids, ascend stairs one at a time, swim and participate in sports. The hyperesthesia and pain both resolved completely by the third postoperative week and protective sensation returned within six months (Video 1).

Case B



Quadriceps contraction was felt three months postoperatively. Extension against gravity was present but weak at five months and was strong 18 months. He was walking freely without aids at five months postreconstruction and walked without a limp at 18 months. At the three-year follow up, he was able to jog and participate in sports with occasional difficulty ascending stairs. There was some sensory improvement in the anterior thigh and lower leg with residual hypoesthesia in the anterior thigh (Video 2).

Case C



Knee extension with gravity eliminated was noted at three months postoperatively, by 11 months she was able to extend against gravity with resistance. She was walking with support at four months postreconstruction and walking without support but with a slight limp at 11 months. She was able to run and undertake reciprocal stair climbing without a limp at two years postreconstruction. Assessment of sensory changes was limited given then young age of the patient (Video 3).

DISCUSSION

Lesions involving the lumbar plexus or the retroperitoneal femoral nerve may result in significant motor and sensory impairment, limiting the individual's ability to stand and ambulate in addition to an area of sensory deficit involving and area extending from the medial thigh down to the medial leg and arch of the foot. These lesions are well reported and documented in the adult population; and consensus exists that surgical exploration and repair of these lesions can lead to recovery of useful function in this group (1-7). These types of lesions, however, are rarely reported in the pediatric population. To our knowledge, there are no published series focusing on this type of lesion in the pediatric population, although several case series reports do include some pediatric patients in their results (5,7,14,15). In 2005, Tung et al (4) reported on a single case involving a 14-year-old patient involved in a motor vehicle accident with sciatic nerve palsy with loss of hamstring and gluteal muscle function. After reconstruction of the motor branches to the hamstring and inferior gluteal nerve with sural nerve grafts to the L5 and S1 nerve roots, the patient obtained 4/5 MRC knee flexion and 3/5 gluteal muscle function. In a series involving 10 patients with lumbosacral plexus injuries treated surgically reported by Lang et al (1) in 2004, two were children. The first was a three-year-old who sustained an injury at the L5, S1-2 level with loss of sciatic nerve function. This

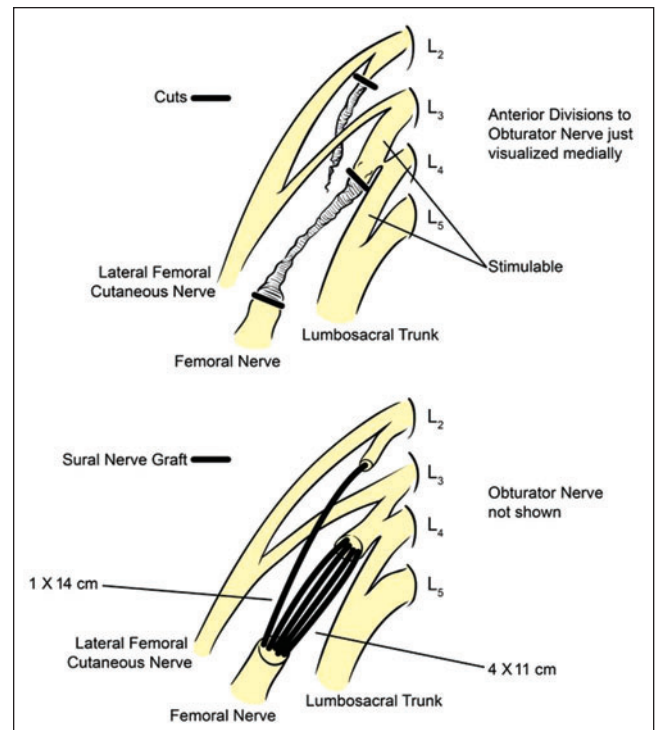


Figure 1) Operative drawing of Case A showing the location of the lesion of the femoral nerve that was resected after stimulation with no response (top panel), and reconstruction with a single sural nerve cable graft from L2 and four cable grafts from L3-L4 (bottom panel)

patient recovered hamstring and calf muscle function after nerve grafts from L5, S1 and S2 to the sciatic nerve but experienced persistent pain. The second patient was a five-year-old girl who also had lost function of her sciatic nerve and was able to regain 3/5 quadriceps and gluteal function after reconstruction with nerve transfers.

Treatment of these lesions in children is often challenging due to the complex anatomy of the region and the difficulty of achieving adequate surgical access. To date, there are no publications in the literature focusing on the surgical treatment and long-term follow-up of these lesions in the pediatric population.

In our series, all three patients had very good to excellent motor and sensory recovery, and were ambulating freely without aids at the long term follow-up visits. There are several factors that may have contributed to the results in our patient group. Two of these factors apply to nerve regeneration in general. The first of these two factors is that nerve regeneration occurs more rapidly at younger ages. This has been well documented in the literature (16-21). The concept of better regeneration following nerve repairs in younger patients has been understood for some time. In a review of repairs of nerves and tendons in the hand published in 1928, Bunnell (16) reported advanced age as a factor in reducing nerve regeneration. In 1983, Howell and Huber (17) reported a favourable prognosis in primary nerve repair in the younger population. These observations have been supported in more recent years with physiological and histological studies of nerve regeneration. The reasons appear to be multifactorial. Aging is associated with reduction in the rate of axonal transport of various materials resulting in failure of maintenance of the skeletal framework (22). Loss of myelinated nerve fibres and the decrease in size and myelin of the remaining myelinated fibres in older patients is believed to be partially responsible (23). Other factors include the proximity of these lesions to the central nervous system because it is believed that regeneration occurs more rapidly closer to the spinal cord in and the shorter regeneration distance to the motor end plates in children. Both of these advantages were

obtained in our patients. Finally, our young patients were very highly motivated and eager to get up and walk and return to their previously active lives, which played a very important role in the rehabilitation process.

CONCLUSIONS

Retroperitoneal femoral nerve transections injuries in children, although rare, may be amenable to surgical exploration and reconstruction. This is best achieved through a team approach with proper

planning to ensure appropriate surgical access to the retroperitoneal space. The surgical treatment of these devastating lesions in childhood proved highly rewarding.

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