Reconstructed bladder innervation above the level of spinal cord injury to produce urination by abdomen-to-bladder reflex contractions

Case report

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Neurogenic bladder dysfunction following spinal cord injury is a major medical and social problem for which there is no ideal treatment strategy. This paper describes the authors’ attempts to establish bladder reinnervation, by establishing an abdomen-to-bladder reflex pathway, in a patient with an injury to the conus medullaris.

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Key Words • spinal cord injury • bladder • reinnervation

Case Report

Examination. This 38-year-old woman was referred for the evaluation and treatment of an atonic bladder caused by a conus medullaris injury in June 2000. She had fallen from an elevated height, sustaining an L-1 compression fracture and suffering complete paraplegia. She complained of urinary retention and anuria, and an indwelling urinary catheter was placed. A serious urinary tract infection developed, for which antibiotic therapy was instituted. The results of a urodynamic study revealed the following: maximal urine flow rate, 2.2 ml/second; residual urine volume, 570 ml; vesical pressure, 30.2 cm H2O; abdominal pressure, 29 cm H2O; and detrusor pressure 1.3 cm H2O (Fig. 1).

Operation. Eight months after the injury, we elected to perform abdomen-to-bladder pathway reconstruction. Informed consent was obtained from the patient prior to enrollment in this study. The procedure was performed after induction of general endotracheal anesthesia. A 3-channel Foley catheter was introduced into the bladder with 1 channel connected to a drainage bag and another connected to a pressure transducer leading to a urody-
namic unit. A standard L5–S3 laminectomy was performed with the patient lying prone. The dura mater was opened through a paramedian incision, exposing the DR and VR of the S-3 nerve. The right S-3 VR was identified and separated from the DR by microdissection. After the location was confirmed, the S-3 VR was transected. An additional standard T9–11 laminectomy was then performed. We identified the T-10 spinal segment by the entrance of the T-10 roots. After the right VR of T-10 was identified with an operating microscope and found to be functional, it was transected. A sural cutaneous nerve approximately 30 cm in length was used as the nerve graft. Using a 10-0 absorbable suture, one end of the nerve graft was anastomosed to the proximal stump of the T-10 VR; the other end of the nerve graft was put into a plastic tube and secured with a stitch. The plastic tube was then pulled through the cutaneous tunnel to thread the nerve graft into the other incision. The distal end of the nerve graft was then released from the plastic tube and sutured to the S-3 VR (Fig. 2). The wound was closed in 3 layers of sutures with an external drain.

Postoperative Course and Follow-Up. After surgery, broad-spectrum antibiotics were given for 3 days. The patient was moved to rehabilitation clinics 2 weeks after surgery. There were no changes to her neurological deficits at that time, which confirmed that transection of the T-10 VR had not caused any detectable damage to the sensory or motor systems. Follow-up visits were scheduled once every 3 months postoperatively. At these visits, urodynamic studies, including maximum detrusor pressure, maximum flow rate, and residual urine volume, were performed.

After the reconstructive procedure, the indwelling urinary catheter remained in place for 1.5 years, during which the patient contracted multiple urinary tract infections, presumably as a result of the catheter. Two years postoperatively, the patient experienced recovery of both bladder storage and voiding functions. She could void by abdomen-to-bladder reflex contractions, which she initiated by scratching her T-10 dermatome, and the urethral catheter was removed. No further urinary infections were observed.

To date, the patient has been followed up for 10 years. She remains paraplegic. Her impaired renal function fully resolved. The results of a urodynamic study 10 years after surgery revealed that the intravesical pressure increases rapidly, whereas the abdominal pressure does not change significantly: the maximal urine flow rate was 60 ml/second, residual urine volume was 35 ml, vesical pressure was 144 cm H2O, abdominal pressure was 39 cm H2O, and detrusor pressure was 105 cm H2O (Fig. 3).

Discussion

In the US alone, more than half a million patients suffer from neurogenic bladder after SCI, and an additional 50,000 people sustain an SCI each year. Despite the fact...
that the treatment of neuropathic bladder in patients with SCI has been a persistent challenge for clinicians and reconstructive surgeons, there are still no effective treatments. Most treatments for the neuropathic bladder have focused on improving micturition. In recent decades, various efforts have been made to treat bladder dysfunction by magnetic stimulation, reconstruction of the detrusor with neuromuscular flaps, and selective excision of the sacral nerve root, but satisfactory outcomes are uncommon. Sacral nerve root electrostimulation, developed by Brindley, is currently the only effective clinical treatment, but it yields inconsistent results and is unsuitable for injuries to the conus medullaris, which regulates micturition.

The use of suprasacral nerve transfer to bypass a spinal cord lesion has been reported in animal studies. In our preclinical experiments, we established a novel artificial abdomen-to-bladder reflex arc in which the stimulation of the intercostal nerve sends motor impulses through the modified efferent branch into the bladder to elicit autonomous contraction. The results of electrophysiological studies and the measurement of intravesical pressure confirm that this new reflex pathway is effective and safe. Based on the results of our preclinical experiments, we attempted bladder reinnervation, by establishing an abdomen-to-bladder reflex pathway, in a patient who had sustained a conus medullaris injury.

The patient was paralyzed after sustaining an SCI and had lost sensation and motor function below the knees. The results of the preoperative urodynamic study demonstrated a lack of detrusor reflex and the external sphincter was denervated, which suggested that the sacral cord center that controls the bladder reflex was completely damaged. Twenty-four months after the reflex pathway reconstruction surgery, the patient regained urinary function. The results of the postoperative urodynamic study revealed that intravesical pressure increased rapidly, whereas abdominal pressure did not change significantly. Therefore, it appears that the reacquisition of urinary function is primarily due to detrusor contraction rather than contraction of the bladder by the abdominal muscles. This outcome would suggest that the improvement was due to the activity in the newly reconstructed bladder pathway. Stimulation of the T-10 dermatome generates an impulse that is transmitted to the bladder through the regenerated nerve axons, thereby stimulating the contraction of the detrusor muscle.

We agree that 8 months after injury there is still the potential for spontaneous neurological recovery, but our patient remained paraplegic after 10 years of follow-up. None of the functions of her low limbs were recovered. Only her bladder function was improved. Furthermore, we found that when stimulating dermatomes other than the T-10 dermatome, the patient could not void. Thus, we think it is more likely that the clinical results are attributed to this procedure.

Bladder function is mainly controlled by the S-3 spinal nerves in Asian people. We established a new pathway with the use of intradural microanastomosis of the right T-10 VR to the S-3 VR, performing autogenous nerve grafting. Technically, the most important requirement for establishing an abdomen-to-bladder reflex pathway is an undamaged somatic reflex arc above the SCI lesion. Our procedure, therefore, should be suitable for spinal cord lesions located at the conus medullaris, as long as the target organ is not damaged. The procedure involves only the transection of 2 VRs to establish the abdomen-to-bladder reflex pathway. It does not involve the placement of electrodes around the nerves or the insertion of other equipment inside the body, as is required in nerve stimulation therapies. It may restore controllable voiding without sacrificing any important function otherwise. However, special attention should be given to certain details for optimal results. The microanastomosis should be tension free and clearly end to end to avoid neuroma or nonfunctional connection. To minimize blood loss, the hemilaminectomy should not expand too far laterally. The DR, usually the T-10 DR, is used as the afferent branch of the abdomen-to-bladder reflex arc and serves as the starter of micturition. It should remain intact.

It is difficult to determine the proper timing for surgical intervention with suprasacral nerve transfer to bypass a spinal cord lesion. As a general rule in nerve reconstruction, early nerve repair usually leads to a better functional outcome. Our procedure uses only one sacral nerve, sparing the other sacral nerves. It maintains sufficient anatomical structures to allow spontaneous recovery. Because the gain outweighs the loss, we think the operation can be done as early as possible.

Our results indicate that intradural nerve grafting and sacral VR anastomosis can be performed to establish an artificial bladder reflex arc and ensure voluntary micturition in patients with a lumbosacral injury. This technique utilizes an intact abdominal reflex above the conus medullaris and works in the initial phase of reinnervation.
level of paraplegia. This may represent a new method for treating the SCI patients with an atonic bladder caused by thoracolumbar fracture.

**Disclosure**

The authors report no conflict of interest concerning the materials or methods used in this study or the findings described in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Hou. Acquisition of data: Lin. Analysis and interpretation of data: Chen. Drafting the article: Lin. Reviewed final version of the manuscript and approved it for submission: all authors.

**References**


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