



## Brief Correspondence

# Challenges for Restoration of Lower Urinary Tract Innervation in Patients with Spinal Cord Injury: A European Single-center Retrospective Study with Long-term Follow-up

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### Abstract

Xiao and colleagues in China reported successful restoration of bladder control in patients with spinal cord injury (SCI) by establishing a somatic-autonomic reflex pathway through lumbar-to-sacral ventral root nerve rerouting. We evaluated long-term results in eight patients who underwent this procedure at a German university clinic between 2005 and 2007. The primary outcome was the occurrence of voiding upon stimulation of the skin, with normalization of bladder pressure when filling, as assessed with videourodynamics at each visit. Videourodynamic variables, urinary tract infections, and bladder/stool events recorded in a patient diary were stored in a prospective database and reviewed retrospectively. Intraoperative testing indicated successful nerve rerouting in all eight patients. Duration of follow-up was 71 mo (range: 56–86). No patient reached the primary goal of voluntary voiding with normalization of detrusor pressure at any point during follow-up. No improvements in videourodynamic or diary variables regarding bladder function were observed. In view of the lack of short (12–18 mo) and long-term (71 mo) success in our patients and others, the risks of any surgical procedure using general anesthesia, and potential for unmet expectations to wreak havoc on patient emotional well-being, we cannot recommend this procedure for patients with SCI.

**Patient summary:** Although the hope was to improve long-term outcomes of spinal cord injury patients, intraspinal nerve rerouting did not improve or normalize bladder function. In view of the lack of success, we cannot recommend this procedure until proven in clinical studies.

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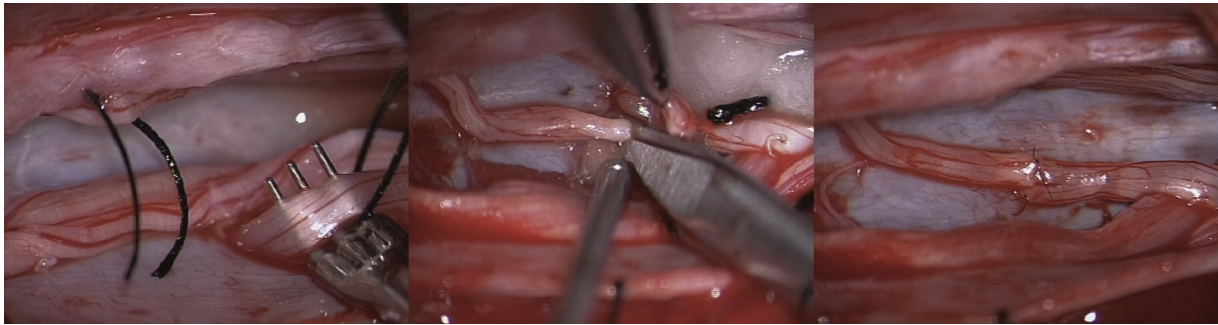
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In patients with spinal cord injury (SCI), upper motor neuron damage above the level of S1–S2 (vertebral level T12–L1) typically leads to detrusor overactivity that when combined with a hypercontractile external sphincter

results in detrusor sphincter dyssynergia. To restore voluntary bladder control in patients with SCI, Xiao et al [1,2] developed a method of rerouting the ventral motor root of a lumbar nerve by anastomosis to the ventral root of



**Fig. 1 – Steps of the surgical procedure. (Left) Identification of the L5 efferent and S3 efferent root by electrical stimulation (hook electrode) and detrusor pressure increase (not shown). (Center) Root transection. (Right) Nerve root anastomosis with fixation to the dura mater.**

an autonomic nerve that controls the bladder. The goal was to create a new reflex arc from the L5 dermatome through the sensory part of L5 to the spinal cord and through the anastomosis via S2 or S3 to the bladder and bowel. According to the model, scratching the skin of the leg would stimulate the L5 dermatome and trigger urination. Motor axons of the somatic reflex arc would regenerate into autonomic preganglionic nerves, reinnervate the bladder's parasympathetic ganglion cells, and transfer somatic reflex activity to the detrusor muscle.

Xiao et al reported success with this technique in numerous patients in China, even when it was performed long after the injury [3,4]. Based on these reports and encouraging preliminary results in two patients enrolled in a US clinical trial [5], we treated eight eligible SCI patients with this procedure at a German university clinic between 2005 and 2007 [6]. The aim of the current study was to evaluate long-term results in our patients.

We selected patients based on criteria set by Xiao and colleagues [3]. Patients were eligible if they had upper motor neuron damage (C6–T11), an A classification according to American Spinal Injury Association criteria, and urodynamically verified detrusor overactivity or detrusor sphincter dyssynergia. After hemilaminectomy and identification of dedicated ventral roots by intraoperative videourodynamics and electromyography, an intradural nerve anastomosis of

L5 to the S2 ventral root (Fig. 1) was performed in accordance with instructions provided by Dr. C.G. Xiao, and he attended the first two operations himself. Patients were taught to stimulate the corresponding dermatome by scratching or by using an electrical stimulator to activate the newly established reflex pathway.

Patients returned for follow-up after 1, 3, 6, 12, and 18 mo and annually thereafter. The primary outcome was the occurrence of voiding upon stimulation of the skin, with normalization of bladder pressure when filling, as assessed with videourodynamics at each visit. Patients also reported in a questionnaire whether they could elicit voiding by scratching or electrostimulation of the skin. Videourodynamic variables, urinary tract infections, and bladder/stool events recorded in a patient diary were stored in a prospective database and reviewed retrospectively. Supplement 1 describes the full study methods and patient characteristics.

Of our eight patients, four had detrusor sphincter dyssynergia and four had detrusor overactivity (Supplementary Fig. 4). Intraoperative videourodynamics showed that electrical stimulation of the ventral roots elicited the end organ response (urinary bladder pressure, urethral/anal sphincter pressure, and ipsilateral muscle response on electromyography). The mean follow-up was 71 mo (range: 56–86). Table 1 presents the results of videourodynamic

**Table 1 – Videourodynamic evaluation: preoperative and last postoperative visits**

Patient no.	Results of stimulation, yes/no		Bladder capacity, ml		Maximum DP, cm H <sub>2</sub> O		Bladder compliance, ml/cm H <sub>2</sub> O		
	DP ↑	Voiding	Pre	Post	Pre	Post	Pre	Post	Post
1	No	No <sup>a</sup>	353	500	104	5	100		108
2 <sup>b</sup>	No	No	499	NA	75	NA	30		NA
3	No	No	361	356	53	40	148		100
4	No	No	224	200	38	20	46		10
5	No	No	213	310	99	72	100		4
6	No	No	603	565	15	29	60		38
7	No	No	264	220	69	40	56		NA
8	No	No	250	92	35	52	NA		12

DP = detrusor pressure; NA = not available; ↑ = increased.

<sup>a</sup> This patient demonstrated onetime voiding that was not reproducible and was retrospectively interpreted as detrusor overactivity with involuntary leakage.

<sup>b</sup> Patient lives abroad and was unable to return for follow-up, but the patient, local urologist, and affiliated spinal cord injury unit responded to mailed questionnaires.

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