Restoration of voluntary emptying of the bladder by transplantation of innervated free skeletal muscle

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Summary

Background On the basis of studies with animals and experience with functioning muscle transfer in plastic surgery, we have developed a surgical technique to restore detrusor function for patients with bladder acontractility in whom there is no treatment alternative.

Methods Three patients (aged 26 years, 28 years, and 68 years) with bladder acontractility as a result of spinal-cord injury (two patients) and chronic overdistension (one patient), who required catheterisation for bladder emptying for 5 years, 2 years, and 2 years, respectively, took part in our study. The patients were treated with microneurovascular free transfer of autologous latissimus dorsi muscle to the bladder to restore detrusor function. Follow-up included clinical and urodynamic evaluation, colour doppler sonography, intravenous urography, and flow-mode computerised tomography.

Findings The three patients voluntarily emptied their bladders at 16 weeks, 16 weeks, and 30 weeks after surgery, respectively. There was no need for further catheterisation throughout the follow-up period. On urodynamic assessment at 12 months after the operation bladder capacity was found to be 600 mL, 600 mL, and 650 mL, residual urinary volume 0 mL, 50 mL, 90 mL, and maximum flow rate 26 mL/s, 25 mL/s, and 18 mL/s, respectively. Activity at the transplanted latissimus dorsi was confirmed by ultrasonography and flow-mode computerised tomography.

Interpretation Microneurovascular free transfer of latissimus dorsi muscle to functionally restore a deficient detrusor muscle has proved to be successful for the three patients in our study. This technique may also be an option to restore the function of other smooth-muscle organs.

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Patient	Age (years)	Aetiology	Previous treatment	Duration of catherterisation (months)	Pretreatment bladder capacity (mL)
1	26	SCI T12/L1	CIC	60	700
2	28	SCI T12	CIC	24	750
3	68	Myogenic	Supra-pubic catheter	24	800

SCI=spinal-cord injury; CIC=clean intermittent catheterisation.

Table 1: **Pretreatment data of the three patients treated with LDDM**

Introduction

Free functioning muscle transfer has proved to be a valuable reconstructive procedure in patients with substantial functional deficits in the extremities, abdominal wall, or facial musculature.[1,2] The gracilis, latissimus dorsi, and gastrocnemius[3–5] are the muscles most frequently used for transplantation. In selected patients presenting with severe cardiopathy a pedicled latissimus-dorsi flap is used to support heart function.[6]

At present little can be gained from treating a bladder, which is flaccid as a result of lower motor neuropathy or impaired detrusor contractility, by electrical stimulation of the spinal cord, sacral roots, or the detrusor muscle itself.[7,8] Bladder myoplasty offers the only treatment alternative in these patients and is being investigated.

On the basis of results from studies with animals[9,10] we developed a surgical technique with neurovascular free latissimus dorsi transfer to restore voluntary emptying of the bladder in patients with long-standing bladder acontractility in whom there is no treatment alternative.

Patients and methods

We followed up three men who had had functioning latissimus dorsi detrusor myoplasty (LDDM) for at least 12 months. Two patients presented with an acontractile bladder secondary to traumatic injury to the spinal cord. In the third patient the chronically overdistended bladder had not recovered at 26 months after radical transurethral prostatectomy despite two repeat transurethral resections to remove any tissue that might have caused functional obstruction. In this patient suprapubic catheterisation had to be continued for 24 months because several attempts at removing the catheter had failed.

Ethical committee approval was obtained and written informed consent was obtained in all patients before surgery. The patients' pretreatment data are summarised in table 1.

During surgery the patient was placed in a supine position with the left shoulder elevated and the left arm placed over his head. An axillary incision was made to expose the anterior border of the latissimus dorsi muscle and the main branches of the thoracodorsal vessels and nerve. A flap of at least two thirds of the muscle (about 15 cm×25 cm) was removed. Resting muscle length was calculated by measuring the distances between a series of marking sutures placed in the muscle. Every effort was made to re-extend the muscle to its original length when fixing it in the pelvis.

A midline abdominal incision was made and the lowermost segmental motor nerve supplying the rectus abdominis as well as the ipsilateral inferior epigastric artery and vein were dissected and marked. The bladder was freed from surrounding tissue down to the trigone, leaving the main vasculature intact. The

Figure 1: **Final intraoperative view of transplanted latissimus dorsi muscle (LDM) completely covering the acontractile bladder**

The microvascular anastomoses between the donor thoracodorsal vessels (T) and the recipient inferior epigastric vessels (E) are seen on the right. The coapted nerve (N) is also marked.

pedicle of the dissected latissimus dorsi, containing the thoracodorsal vessels and nerve was divided. Microvascular end-to-end anastomosis to the inferior epigastric vessels and nerve coaptation to the dissected intercostal branch were done with 9-0 and 10-0 monofilament non-absorbable sutures, respectively (figure 1). The transferred latissimus dorsi muscle was wrapped around the bladder with longitudinal tension and a slightly spiral configuration of the muscle fibres to restore the original resting tension with the help of the marking sutures. In this way about 75% of the bladder, which had been dissected free, was covered by latissimus dorsi leaving only the area of the trigone and the lateral vesical pedicles uncovered.

During the first postoperative week, perfusion of the transferred muscle was monitored with a permanent intramuscular probe to measure the pO_2 (Lycox, GSM, Kiel, Germany).[11]

The postoperative bladder drainage for all three patients was maintained by an indwelling catheter and subsequent intermittent self-catheterisation for 12 weeks. 3 months after surgery the patients were admitted for follow-up examination including uroflow, assessment of voided volume and residual urine, intravenous urography, and doppler sonography of the bladder. The patients were instructed to empty their bladders by actively contracting the lower abdominal musculature. The catheterisation intervals were gradually lengthened depending on the residual urinary volumes. In addition, urodynamic evaluation and flow-mode computerised tomography were done at 6 months and 12 months after the operation.

Results

As of August, 1997, the patients had been followed up for 20 months, 16 months, and 12 months, respectively. The only postoperative complication observed was a dislocation of the pO_2-probe which had to be repositioned in patient 1 on the first day after the operation. Wound healing at both the donor and recipient sites was uncomplicated in all patients. The postoperative pO_2 concentrations ranged between 10 mm Hg and 60 mm Hg in all three patients. In the first 8 months after the operation patient 1 had several episodes of urinary-tract infection caused by *Escherichia coli* although there was no residual urine; the urinary-tract infections have not recurred since.

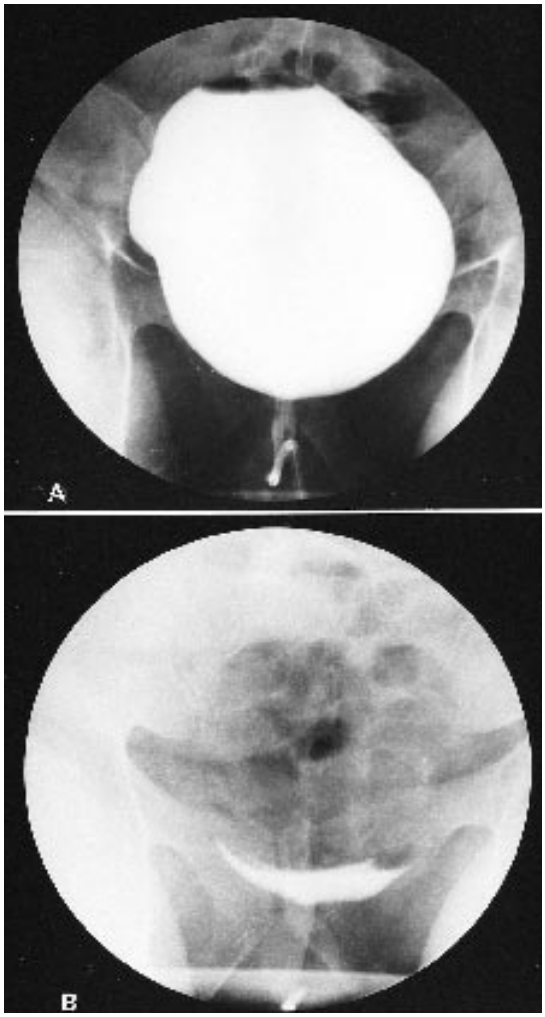

Figure 2: **Cystourethrography before (A) and after (B) bladder emptying**

The urodynamic data are given in table 2. The time interval between surgery and cessation of catheterisation was 16 weeks in the two younger patients, and 30 weeks in patient 3.

Cystourethrography revealed a slightly irregular shape of the bladder, no reflux on emptying, and bladder evacuation almost to completion (figure 2). The well-vascularised transplanted latissimus dorsi and its contractions during bladder emptying were shown by doppler sonography and flow-mode computerised tomography.

Discussion

The lack of a promising treatment for bladder acontractility secondary to either lower motor neuropathy or detrusor myopathy has prompted researchers to undertake laboratory[12] and clinical studies[13–15] on the

Patient	Postoperative catheterisation (weeks)	Bladder capacity (mL) at urodynamic assessment (6 months/12 months)	Volume of residual urine (mL) at 6 months/12 months	Maximum flow rate (mL/s) at 6 months/12 months	Maximum detrusor pressure (cm H_2O) during bladder emptying at 6 months/12 months	Bladder compliance at 6 months/12 months (mL/cm H_2O)
1	16	550/600	40/0	28/26	64/82	69/75
2	16	620/600	95/50	22/25	20/23	87/102
3	30	700/650	200/90	10/18	16/21	104/115

Table 2: **Urodynamic results**

feasibility of bladder myoplasty. Successful restoration of voluntary emptying of the bladder with either upper thigh[13] or abdominal skeletal muscle[14,15] has been reported in patients with congenital malformations of the spine and lower urinary tract, or with post-traumatic lower motor neuropathy. However, we decided to use the latissimus dorsi muscle because of its size, strength, viable bulk, and suitable fibre length for the required range of contraction, reliable vascular supply, solitary motor nerve, and minimal donor-site morbidity, particularly when harvested from the non-dominant side.

Functional synergism of the reinnervated transplanted muscle with its donor nerve has been observed in reconstructive surgery on the limbs and the abdominal wall.[2,4] Substitution of a defective smooth muscle lining an internal organ by means of neurovascular free striated muscle transfer, however, is a fairly new technique,[9,10] which may prove useful in several conditions.

Selection of the most suitable donor motor nerve is a crucial aspect in bladder myoplasty. The advantages of using the lowermost motor branch of the rectus abdominis muscle are that tension-free coaptation between recipient and donor nerve can be achieved, and that the rectus muscle is involved in the bladder emptying process when the Valsalva manoeuvre is applied. Our patients were able to initiate bladder emptying without extensive training simply by abdominal straining. In contrast to the Valsalva manoeuvre, which only leads to a rise in intra-abdominal pressure, there is an additional net increase in true detrusor pressure (table 2) ranging from 21 cm H_2O to 82 cm H_2O. High detrusor pressures that could cause renal damage may be prevented by surgically reducing the resting muscle tension at the recipient site (eg, with a larger muscle transplant). Furthermore, high intraluminal pressures in patients who have had myoplasty might be decreased by either pharmacologically or surgically reducing outflow resistance.

Synchronous contraction of the transplanted latissimus dorsi and the rectus abdominis as shown by both ultrasound and flow-mode computed-tomography scanning provides further evidence that the transferred muscle actively contracts. Of note is the considerably longer time required by patient 3 to resume spontaneous emptying of his bladder; we assume that on account of the patient's advanced age reinnervation of the transplanted muscle took longer than in younger patients thus resulting in more pronounced atrophy.

To achieve optimal micturition pressures and volumes, the transfer of the latissimus dorsi muscle, in combination with partial cystectomy, should be considered in patients with oversized bladders. However, in patients presenting with reduced bladder capacity LDDM might need to be combined with bladder augmentation. Another intriguing option would be to combine transfer of latissimus dorsi muscle with bladder autoaugmentation—ie, partial detrusorectomy.

Potential shortcomings of the technique are the need for a second incision at the donor site and the microneurovascular anastomoses. In experienced hands, however, the rate of microsurgical complications as well as donor-site morbidity are low.[3,16] None of our patients have reported any problems either at the donor or the recipient site.

Contributors

Arnulf Stenzl and Milomir Ninkovic designed the study and wrote the manuscript. Arnulf Stenzl, Milomir Ninkovic, Georg Bartsch, and Hans Anderl were involved in the surgery. Dieter Kölle did the preoperative and postoperative examinations. Rudolf Knapp supervised all imaging procedures.

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