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Gracilis urethromyoplasty – an autologous urinary sphincter for neurologically impaired patients with stress incontinence

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Purpose: To investigate the effect of a neurovascularly intact gracilis muscle urethral wrap, to be used to restore urinary continence as a transposed urinary sphincter graft, in patients with neurogenic lower urinary tract dysfunction. *Methods*: Five neurologically impaired men with a denervated and damaged urinary sphincter mechanisms were treated. The etiology of sphincteric insufficiency included sphincter denervation in three patients, external sphincterotomy in one, and urethral trauma due to a chronic indwelling catheter in one. All patients underwent gracilis urethromyoplasty sphincter reconstruction. Two patients also underwent concomitant ileocystoplasty and one patient ileocystostomy because of poor bladder compliance and a bladder capacity of <200 ml. *Results*: The gracilis urethromyoplasty functioned as a new autologous sphincter with follow-ups ranging from 6–35 months. The surgery was successful in four patients. Three of the four patients were managed with intermittent catheterization, and one managed by ileocystostomy. The fifth patient continued to require an indwelling urethral catheter. *Conclusion*: Gracilis urethromyoplasty achieves compression of the urethra using a neurovascularly intact muscle graft. The functional urethral closure, obtained from the gracilis muscle wrap, assures dryness, and permits intermittent self-catheterization. It also avoids the risks of infection, erosion, or malfunction associated with the artificical urinary sphincter. The potential exists for electrical stimulation of this muscle graft to allow volitional control of the neo-sphincter mechanism, and voluntary voiding.

Keywords: urinary incontinence; tissue transplantation; muscles; electric stimulation; urodynamic; spinal cord injury

Introduction

Urinary incontinence caused by intrinsic sphincteric deficiency is a devastating medical and social condition. Except for periurethral collagen injection and the artificial urinary sphincter, many patients are relegated to indwelling urethral catheters or to urinary diversions. Recently, the use of a neurovascular intact skeletal muscle as an autologous sphincter has been reported for fecal and urinary incontinence.[1–5] Various muscles including the gracilis, sartorius and gluteus maximus muscles have been utilized.

Anal sphincter myoplasty, where the gracilis muscle is used to reinforce anal sphincter function, has been promising in the treatment of fecal incontinence.[6–9] This technique utilizes a neurovascularly intact gracilis muscle as a circumferential perianal wrap. Anatomical accessibility of the gracilis muscle as well as its long neurovascular pedicle make it an ideal choice in providing a neo-sphincter for the urethra. In this preliminary study, five neurologically impaired patients who had failed conservative medical management for urinary incontinence underwent a gracilis urethromyoplasty.

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Methods

Since February 1994, five neurologically impaired men with severe stress urinary incontinence, due to external sphincter control failure, underwent gracilis urethromyoplasty. All of the patients had been managed with indwelling urethral catheters preoperatively. Preoperatively, a history and a physical examination were also performed. Urodynamic tests investigated detrusor stability, bladder capacity and Valsalva leak point pressure. In addition, a cystoscopic evaluation of the urethra, sphincter, and bladder was also performed.

The etiology of sphincteric insufficiency included sphincter denervation in three patients, external sphincterotomy in one patient, and urethral trauma due to a chronically indwelling catheter in one patient

(Table 1). All patients underwent gracilis urethromyoplasty sphincter reconstruction. Three patients underwent concomitant ileocystoplasty because of poor bladder compliance and a bladder capacity <200 ml.

A urodynamic evaluation was performed preoperatively and at 3, 6 and 12 months postoperatively. The urodynamic testing was done in accordance with guidlines of the International Continence Society. The infusion rate was 50 ml/min, and the cystometrogram and Valsalva leak point pressure were done under fluoroscopic visualization using a Laborie Aquarius multichannel system.

Surgical technique
Prophylactic intravenous antibiotics, ampicillin and gentamycin, are administered preoperatively in all patients. The patient is placed in the dorsal lithotomy position, which does not compromise the incision and exposure necessary for intestinal bladder augmentation. The abdomen, perineum, medial thighs and knee of one leg are prepared and draped. A medial thigh incision is made parallel to the long axis of the gracilis muscle. The muscle is mobilized and the tendinous portion is incised immediately cranial to the knee joint. This allows adequate length for mobilization and the urethral wrap. We have found it necessary to make a second incision caudal to the knee to completely release the gracilis muscle's tendinous insertion on the tibial bone.

Great care is take to avoid manipulation or damage to the gracilis muscle's neurovascular pedicle located along the proximal medial one-third of the muscle belly. Intraoperative electrical stimulation during dissection confirms the location of the neurovascular pedicle, and assures the viability of the muscle flap.

The gracilis muscle is tunneled subcutaneously without tension to the perineum. A perineal inverted 'U' incision exposes the periurethral region allowing mobilization of the bulbous urethra and encircling of the muscle. The dissection is identical to that used to place an artificial urinary sphincter. The gracilis is threaded around the urethra creating a 360 degree wrap closely approximating the gracilis and the urethra. Prior to suture fixation, the bulbous urethral wrap is stabilized by delivering the tendinous portion of the distal gracilis through the center of the muscle belly. The muscle is then fixed at the contralateral pubic bone with non-absorbable sutures (Figure 1).

In those patients who had dynamic urethral myoplasty, two intramuscular electrodes are sutured into the muscle belly near the nerve insertion site. The electrodes are secured where maximal contraction is observed during intraoperative testing. Insulation sheaths are secured and the electrodes are tunneled to the lower abdomen where they are connected to a subcutaneously positioned pulse stimulator (Itrel III^{TM}, Medtronic, Minneapolis, MN).

After implantation, a stimulation program is initiated that will transform the gracilis from type II fast-twitch, fatigued fibers to type I slow-twitch, fatigue resisitant fibers. Intermittent stimulation is started with a cycle of 0.125 s 'on' and 2 s 'off', with a burst frequency of 25 Hz. The voltage is adjusted at

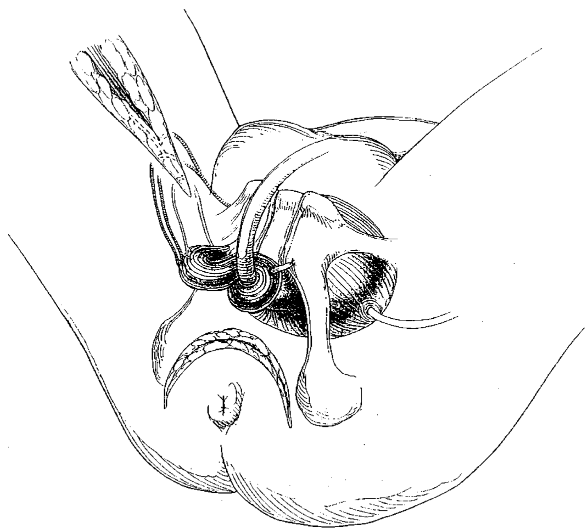

Figure 1 Illustration of the gracilis muscle wrap around the bulbous urethra

Table 1 Patient characteristics

Pt	*Age*	*Cause of incontinence*	*Duration of spinal injury*	*Bladder management*	*Concurrent surgery*	*Further treatment*
1	25	GSW T11 para.	6 years	Urethral catheter	Ileocystoplasty augmentation	Collagen injection × 2
2	32	GSW T12 para	12 years	Urethral catheter	None	None
3	38	T4 para., external sphincterotomy	5 years	Urethral catheter	None	Indwelling urethral cathter
4	25	Traumatic T10 para.	15 years	Urethral catheter	Ileocystoplasty augmentation	Pulse generator implantation for muscle stimulation
5	32	Traumatic T10 para. Chronic indwelling catheter	7 years	Urethral catheter	Ileocystostomy	None

GSW: Gun shot wound. Para: Paraplegia

the level of contraction perception (1–4 volts). The stimulation cycle is increased every 2 weeks with an external programmer. By 8–12 weeks the cycle is 100% 'on' with the frequency being decreased to 15 Hz. The dynamic urethral myoplasty is set in the 'on' stimulation setting except during micturition. The pulse generator is turned 'off' by the patient with a patient programmer for micturition.

Results

Preoperative urodynamic studies and cystourethroscopy results revealed a Valsalva leak point pressure <40 cmH_2O and a denervated and damaged urinary sphincter mechanism in all five patients. Follow-up ranged from 6 to 35 months (mean = 16 months). All patients during follow-up demonstrated low-pressure urinary storage. There were no postoperative arterial and/or venous complications in the leg following the gracilis muscle operation. In addition, there were no apparent leg motor deficiencies, nor deleterious effects on erectile function.

The Valsalva leak point pressure before gracilis urethromyoplasty was 24.2 ± 9.2 cmH_2O. At the longest follow-up evaluation the Valsalva leak point pressure was 57.5 ± 21.0 cmH_2O. Bladder volumes at Valsalva leak point pressure, before and after urethromyoplasty, were 120.5 ± 70.2 ml and 342.0 ± 121.4 ml, respectively (Figure 2). The increase in bladder capacity was due to both the bladder augmentation and the increased outlet resistance of gracilis urethromyoplasty. Enterocystoplasty were done for diminished bladder capacity and poor bladder compliance in two patients and was successful in both.

The surgery was considered to be successful in four patients. Three managed with intermittent catheterization, and one managed via ileocystostomy (Table 1). Of the three patients who managed with intermittent self catheterization, two had persistent partial stress incontinence. One subject required two periurethral collagen injections. The second patient subsequently

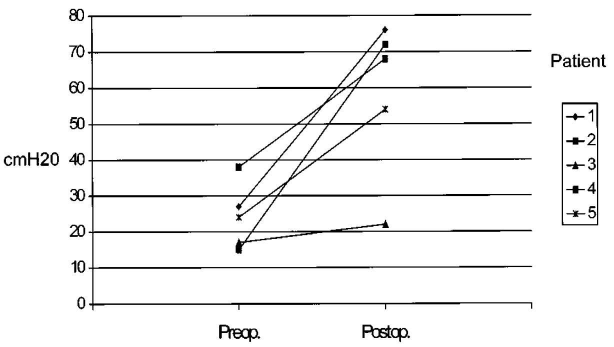

Figure 2 Comparison of Valsalva leak point pressure before and after gracilis urethromyoplasty

underwent a pulse generator implantation to electrically stimulate the wrapped gracilis muscle. Both patients became dry after the ancillary procedures. The fifth patient, who had a previous external sphincterotomy, did not improve after gracilis urethromyoplasty and continued to require an indwelling urethral catheter. Complications have included one wound infection (patient 3), and a bulbous urethral stricture distal to the gracilis urethromyoplasty (patient 1). The infection was resolved with local wound care and the stricture was successfully treated with a single visual internal urethrotomy. No long-term complications occurred in this series.

Discussion

We describe a new surgical procedure - moving a leg muscle from the patient's thigh to his or her urethra - that offers hope to those with severe urinary incontinence. The gracilis muscle normally helps to rotate the thigh inward, but when transferred and wrapped around the urethra, it can function as a replacement urinary sphincter.

In gracilis urethromyoplasty, the surgeon opens the inner thigh to expose the gracilis muscle, a slender strand extending from the pelvis to the knee. The muscle is removed carefully at the knee attachment. While preserving its nerve and blood vessel connections, the gracilis muscle is 'rotated' upwards to an incision made between the genitals and the anus. The muscle is then tunneled into this incision, wrapped around the urethra like a scarf around a neck, and sutured to the contralateral pubic bone.

Removing the gracilis muscle from the leg does not cause any mobility problems. The gracilis muscle is the smallest muscle in the thigh, and there are several other leg muscles that assist in the same functional movements. Transference of the gracilis to repair other genital and pelvic problems, including using it to create anal sphincters, has been previously performed.

The gracilis muscle is innervated by the obturator nerve emanating from the nerve roots at L2–4. Its blood supply, consisting of a main trunk and several branches originating from the profunda femoris artery,[10,11] enters near the upper third of the muscle. Because the blood vessels enter the muscle at a high level in the neurovascular bundle, transplantation is facilitated without the risk of functional compromise. The gracilis muscle serves to adduct, flex and rotate the thigh inward. Studies indicate that when the gracilis is used for anal sphincter reconstruction, flexion and extension of the thigh do not affect the tonicity of the reconstructed anal outlet. Abduction of the leg, however, increases tension of the anal opening while adduction of the thigh and acute flexion of the trunk, releases the orifice and perineal floor.[4]

The gracilis muscle as a neo-sphincter showed encouraging results for fecal incontinence. In one study, 73% of the patients had fecal continence restored.[6] The advantage in this technique of gracilis urethromyoplasty is the use of well-vascularized autologous tissue. This should reduce the risk of infection, urethral erosion and mechanical failure associated with artificial urinary sphincters.[12–14]

Gracilis urethromyoplasty, in neurologically impaired patients, is a promising treatment alternative to surgical bladder neck closure, and the artificial urinary sphincter for several important reasons. The first, and probably most important reason, is that no irreversible surgery is necessary as it is with bladder neck closure. The second advantage of gracilis urethromyoplasty is the avoidance of foreign bodies, device erosion, and infection that is frequently seen with the artificial urinary sphincter. When an artificial urinary sphincter becomes eroded or infected, it must be completely removed. This is not the case with the gracilis urethromyoplasty procedure. There was one wound infection with the gracilis muscle acting as an autologous sphincter, yet no surgical intervention was necessary. After local wound care, the incision closed up and the gracilis muscle sphincter continued to maintain adequate sphincter function.

In women, when the sphincter is damaged from long-term indwelling urethral catheters, we prefer the pubovaginal sling as the surgical method because of its simplicity. However, gracilis urethromyoplasty has been successfully applied in women with complex stress urinary incontinence who have failed other treatment modalities.

An important adjunct to gracilis myoplasty is the use of electrical stimulation to train the muscle, also referred to as dynamic graciloplasty. This procedure converts the gracilis from a predominantly fast-twitch fiber muscle to a slow-twitch fiber muscle by implanting, and subsequently stimulating the intramuscular electrodes via a pulse generator.[15] We have subsequently implanted a pulse generator with intramuscular electrodes in one patient (patient 4). After an 8 week stimulation training period, the patient noted subjective improvement and was able to stop using absorbent products needed for leakage (Chancellor, personal communication). From our experience in spinal cord injured patients, due to muscle atrophy or denervation, some patients cannot be stimulated, and therefore dynamic gracilis urethromyoplasty is futile. The patient whose gracilis muscle did not contract with intraoperative electrical stimulation had persistent mild stress incontinence. He did, however, respond well to a periurethral collagen injection (patient 1). We are presently studying gracilis urethromyoplasty with and without electrical stimulation for men with severe stress urinary incontinence post prostatectomy. We are also investigating another promising 'wrap' application entitled dynamic bladder myoplasty for patients diagnosed with detrusor areflexia.[16,17] Dynamic bladder myoplasty involves wrapping a neurovascular intact rectus muscle around the bladder, and electrically stimulating it to contract and empty.

Conclusions

Gracilis urethromyoplasty achieves urethral compression by using a neurovascularly intact muscle graft. The functional urethral closure assures dryness and permits intermittent self-catheterization in neurologically impaired patients. The potential exists for chronic electrical stimulation of this muscle graft to allow volitional control of the neo-sphincter mechanism. We need to await long-term results before fully determining the utility of this procedure.

References

1 Janknegt RA, Heesakkers JPFA, Weil EHJ, Baeten CGMI. Electrically stimulated gracilis sphincter (dynamic graciloplasty) for treatment of intrinsic sphincter deficiency: a pilot study on feasibility and side effects. *J Urol* 1995; **154:** 1830–1833.
2 Grandjean P *et al.* Dynamic myoplasty: surgical transfer and stimulation of skeletal muscle for functional substitution enhancement. *J Rehab Res Dev* 1995; **33:** 133–144.
3 Chancellor MB, Rivas DA, Janknegt RA. Gracilis urethromyoplasty: a novel autologous urinary sphincter. *Curr Surg Tech Urol* 1996; **9:** 1–8.
4 Williams NS *et al.* Electrically stimulated gracilis sphincter for bladder incontinence. *Lancet* 1993; **341:** 115–116.
5 Janknegt RA, Baeten CGMI, Weil EHJ, Spaans F. Electrically stimulated gracilis sphincter for treatment of bladder sphincter incontinence. *Lancet* 1992; **340:** 1129–1130.
6 Baeten CGMI *et al.* Anal dynamic graciloplasty in the treatment of intractable fecal incontinence. *N Engl J Med* 1995; **332:** 1600–1605.
7 Kennedy HL. Stimulated gracilis neo-sphincter clinical trial. *West J Med* 1994; **160:** 77–80.
8 Konsten J, Baeten CGMI, Havenith MG, Soeters PB. Morphology of dynamic graciloplasty compared with the anal sphincter. *Dis Colon Rectum* 1993; **36:** 559–563.
9 Devesa JM *et al.* Total fecal incontinence - a new method of gluteus maximum transposition: preliminary results and report of previous experience with similar procedures. *Dis Colon Rectum* 1992; **35:** 339–349.
10 Pickrell KL, Broadbent TR, Masters FR, Metzger JT. Construction of a rectal sphincter and restoration of anal continence by transplanting the gracilis muscle. *Ann Surg* 1952; **135:** 853–862.
11 Watanabe T *et al.* Gracilis muscle dynamic urethral sphincter myoplasty: rat model experience. *J Urol* 1996; **156:** 1507–1510.
12 Martins FE, Boyd SD. Post-operative risk factors associated with artificial urinary sphincter infection-erosion. *Br J Urol* 1995; **75:** 354–358.
13 Marks JL, Light JK. Management of urinary incontinence after prostatectomy with the artificial urinary sphincter. *J Urol* 1989; **142:** 302–304.
14 Light JK, Pietro T. Alteration in detrusor behavior and the effect on renal funcion following insertion of the artificial urinary sphincter. *J Urol* 1986; **136:** 632–635.
15 Hallan RI *et al.* Electrically stimulated sartorius neo-sphincter: canine model of activation and skeletal muscle transformation. *Br J Surg* 1990; **77:** 208–213.
16 Chancellor MB, Rivas DA, Salzman SK. Detrusor-myoplasty to restore micturition. *Lancet* 1994; **343:** 669.
17 Chancellor MB *et al.* Detrusor-myoplasty, in nervated rectus muscle transposition study, and functional effect on the spinal cord injury rat model. *Neurourol & Urodynam* 1994; **13:** 547–557.