CONFERENCE REPORT

Applied electrophysiology of transposed muscle stimulation: practical considerations and surgical experience on graciloplasty for faecal incontinence

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Abstract. Dynamic Graciloplasty has demonstrated to be a reliable option in the treatment of end-stage Faecal Incontinence with stable results after long-term evaluation studies. Continence restoration varies from 40 to 65% depending on incontinence etiology and surgical experience. In spite of that mechanisms of chronic electrostimulation, necessary to obtain muscular fiber conversion and increase contractile resistance to a prolonged stimulation still remains unfriendly to many colorectal surgeons. On the basis of pioneering experience on this field we examine the main critical aspects of electrostimulation, ranging from neurovascular bundle preparation to electrodes insertion and stimulation protocol application. The experience in the last 36 dynamic graciloplasties performed for Faecal Incontinence treatment is presented. A long-term success rate of 75% was achieved. Key features for a good postoperative contractile response were identified in a careful gracilis mobilization, in a meticolous identification of nervous pedicle and in the prudent early p.o. stimulation. Fibers conversion was obtained after a 10-11 weeks of training period with on/off stimulation in the majority of patients and battery life was significantly prolonged with a meticolous search of the lowest intraoperative stimulation thresholds. Early failures demostrated to be linked mainly to postoperative septic complications, while long-term results were significantly related to the efficacy of muscular recruitment and in preoperative phase, to a careful patients selection.

Key words: Faecal incontinence, graciloplasty, electrostimulated gracilis transposition

Introduction

In 1952, Kenneth Leroy Pickrell (1) first demonstrated the possibility of using the gracilis muscle for sphincteroplasty in the treatment of children with faecal incontinence due to a neurogenic cause (spina bifida).

In the original Pickrell technique, the muscle was detached from its distal insertion and transposed to the perineum to encircle the anus. To obtain continence the muscle had to be transposed making a tight loop around the anus.

Due to the impossibility of obtaining an active, long standing contraction, the muscle was fixed tightly to the contralateral ischiatic tuberosity. However the patient was able to increase the effect of graciloplasty with a voluntary adduction of both legs.

In spite of a preliminary wide scale adoption, long term results of Pickrell's technique were controversial; an overall review of long-term results showed that successful rates did not exceed 50% of cases. Infection, ischemia and a "passive tied sling effect" were the most observed causes of late failure (2-6).

In the '80s, significant technical improvements in supporting graciloplasty were obtained with electrostimulation and reducing the "Thiersch effect" by tendons fixation to the contralateral dermal layers instead of to fixed structures such as the periostium.

Cavina in 1987 (7) reported his first experience with short-term electrostimulation (ES) applied to a double-wrap graciloplasty after an Abdominoperineal Resection for lower rectal cancer.

In these experiences electrostimulation was applied daily by means of external stimulators connected to the muscles with transcutaneous electrodes. The original aim of electrostimulation was to avoid postoperative muscular atrophia but during the experience other secondary effects of stimulation appeared: a good reference for spontaneous voluntary biofeedback and some "tone" achieved by the stimulated muscles.

External devices did not allow a continuous stimulation of the transposed muscles and stimulation protocols were adopted empirically using a "burst cyclic stimulation" for some hours/day.

In 1988, Baeten (8) first applied chronic low-frequency stimulation to support graciloplasty for FI treatment *(dynamic graciloplasty)*.

Baeten's technique was similar to that of Cavina's as far as "loose tendons fixation" was concerned but differed from the latter in its aim which was to obtain a continuosly stimulated muscle contraction avoiding at the same time the fenomenon of "muscular fatigue" which is typical of any skeletal muscle like the gracilis.

Since 1988 "dynamic graciloplasty" has been adopted by many colorectal centers, mainly for the treatment of "end-stage" faecal incontinence. Long-term results of a prospective, multicenter trial were recently reported showing a significant improvement of the quality of life and a full continence restoration in 63 and 57 percent of non-stoma patients at 12 and 18 months respectively (9, 10).

Best results were achieved in patients affected by post-traumatic incontinence due to wide disruption or laceration of the sphincteric apparatus.

At present "dynamic graciloplasty" still remains a very selective procedure which is adopted by few specialized centers. This "selective adoption" is undoubtedly due to the specific indications ("end-stage incontinence, refractory to other medical and surgical procedures") but this is true only in part.

Our experience in the last few years with Colorectal Colleagues, as well as General Surgeons, has shown that the Surgeon is generally "refractory" to deal with aspects which are not *strictly* surgical. And electrostimulation is one of these.

This could explain the better mental acceptance to some procedures, like the "artificial sphincter", which are simpler but are, without doubt, less effective than a graciloplasty, at least to date.

Briefly, we will examine the core aspects of electrostimulation and summarize our experience in faecal incontinence treatment.

Aims of chronic electrostimulation

Skeletal muscles are characterized by a fast and strong contraction but by a short resistance to prolonged fatigue.

The external anal sphincter and gracilis are both skeletal muscles but their function is significantly different: leg adduction for the gracilis muscle and continence maintenance in basal and urge conditions for the external anal sphincter. A continuous leg adduction is impossible to maintain, due to muscular fatigue and a consequent tetanic contraction while anal continence is maintained without any muscular consequence.

This apparent contradiction is explained by the evidence that in the gracilis muscle there is a predominance of type II (or fast-twitch) fibers, while the external anal sphincter shows a strong predominance (80%) of type I (or slow-twitch) fibers. In fact, the distinction between red and white (or skeletal and smooth) muscles is an historic artifact.

In the '60s, Buller (11) demonstrated that it is the motor neuron that determines the physiological histochemical and biochemical characteristics of the innervated fibers.

In fact, when a fatigue *prone* muscle (in which fast-twitch-type II fibers are predominant) was stimulated by a nerve originally assigned to a fatigue *resistant* muscle (in which slow-twitch - type I fibers are predominant) the new stimulation regimen lead to a transformation of the fiber pattern.

The fast-contracting muscle was then converted into a slow-contracting one.

The phenomenon of structural adaptation to the motor neuron characteristics was then called fiber conversion. It was demonstrated that changes are not only functional but also structural and are reversible if the "new" stimulation regimen is stopped.

Table 1. Standard electrostimulation protocol

Week	On	Off	Off/on ratio
I-II	0.1	1.2	1:12
III-IV	0.2	1.2	1:6
V-VI	0.4	0.7	1:75
VII-VIII	1	0.5	2:1

Fiber conversion was first adopted in 1985 by Carpentier and Chachques to obtain cardiac assistance by stimulation of latissimus dorsi transposition, the so called cardiomioplasty.

In Dynamic Graciloplasty muscular conversion gives the opportunity of a continuous stimulation of the transposed muscle without any tetanic exhaustion.

In order to obtain conversion, the gracilis is submitted to a protocol "mimicking" a motor neuron stimulation of a "slow-contracting " muscle (table 1). The time needed for conversion usually ranges from 8-11 weeks and a stable fatigue resistant contraction is easily shown by the absence of fibrillation during continuous simulation at a frequency of 15-20 Hz.

Technical aspects

In order to obtain the best results by the gracilis stimulation, two technical aspects must be enphasized: a correct surgical technique during the muscle mobilization and a correct implant of electrodes which connect the stimulator with the muscle.

Gracilis mobilization should be performed gently, avoiding any muscle damage in particular during the access to the proximal insertion which contains nerves and the main artery. Usually the main vascular pedicle, which arises from profunda femoris artery, is able to maintain a good vascularization once the muscle has been detached from tibial insertion and completely freed from surrounding tissues. Any vascular damage leads to fiber damage and a weaker or inefficient contraction.

In addition, it is important to make sure that the tunnel around the anus is sufficiently wide in order to avoid an excessive compression over the muscle with a consequent ischemia.

A correct placement of electrodes is also crucial. Muscular contraction results from the sum of the full contraction of each single fiber and this contraction is best obtained when the stimulus can easily reach all the muscular fibers (fibers recruitment) at the lowest voltage.

Consequently, the electrodes should be placed in such a way to allow the maximum contact with muscular fibers and nerves. The placement of electrodes which is ortogonal to the main muscular axis gives a reasonable guarantee of a homogeneous diffusion of electrical stimulation.

After the implant, intraoperative e.s. parameters are recorded (minimal and full contraction thresholds, circuit impedance) and the stimulator (Implantable Pulse Generator - Medtronic) is programmed using a telemetrical console (Console Programmer Model 7432- Medtronic – Kerkrade, The Netherlands).

Stimulation is started during the first two postoperative weeks using the following parameters: pulse width of 210 msec, frequency of 25 pps, cyclic on/off mode (0.1/1.2 sec) and an amplitude necessary to obtain continence (mean: 1.5 and 0.95 volts for intramuscular and "over-the-nerve" implants respectively).

To allow type II fiber conversion, electrostimulation follows the already decribed protocol based on a first training period of cyclic stimulation (8 weeks) and a further regimen of a continuous, low-frequency (15 pps.) stimulation.

Our experience

From February 1986 to May 2003, 36 patients (27 females, 9 males) underwent electrostimulated graciloplasty (Table 2) for Faecal Incontinence treatment. Mean age was 43.57 years (range: 14-75 yrs).

The overall preoperative length of incontinence varied from a minimum of one month (traumatic FI) to the maximum of forty years. The indication for graciloplasty was based on clinical and instrumental findings showing full incontinence, refractory to multiple therapy (IV-V on the Williams scale).

Etiology distribution showed 5 (14%) congenital incontinence, and 31 (86%) acquired incontinence.

Preoperative assessment consisted in clinical examination, review of continence questionnaires and a

Table 2. Summary of patient history in 36 patients treated with electrostimulated graciloplasty since 1991

Patient	Sex	Age	Etiology of incontinence	Type/ present Williams score	Previous treatment	Duration of FI
080-DME	F	71	Idiopathic	ACQ/n.e.	None	5 years
081-VE	F	19	Myelomeningocele	CON/2	None	19 years
083-RM	F	38	Iatrogenic (rectal prolapse + hemorrhoids)	ACQ/1	Rectopexy	2 months
086-PD	M	16	Traumatic: traumatic hemipelvectomy	ACQ/2	Left colostomy	3 months
088-BN	F	73	Idiopathic	ACQ/3	Biofeedback	5 years
089-MG	M	23	Traumatic: pelvic crushing	ACQ/1	Left colostomy	8 months
091-CG	F	25	Anal atresia	CON/5	Pull-through	25 years
093-MW	F	55	Post-partum + constipation	ACQ/1	Left hemicolectomy, rectopexy	2 years
094-AG	F	19	Traumatic: gunshot wound (hunting rifle)	ACQ/1	Left colostomy Cannulation of anal canal with Petzer probe	2 years
095-CM	F	46	Post-partum	ACQ/4	Sphincteroplasty	10 years
097-CD	F	38	High congenital rectovaginal fistula	CON/1	None	38 years
098-IG	F	63	Iatrogenic, post-fistulectomy	ACQ/2	Biofeedback	18 months
102-FN	M	23	Anal atresia	CON/1	Pull-through, fistulectomy, fistulectomy + sphincteroplasty	6 years
111-LE	F	38	Iatrogenic, post-fistulectomy	ACQ/5	Multiple fistulectomies and sphincteroplasties	4 years
119-MM	F	61	Post-partum	ACQ/1	None	1 year
120-SA	F	72	Iatrogenic + rectocele	ACQ/2	Postanal repair, anterior vaginoplasty	2 years
121-TP	F	37	Post-partum	ACQ/n.e.	None	17 months
124-BC	M	50	Verneuil's disease	ACQ/n.e.	Colostomy	1 year
125-PM	F	52	Iatrogenic	ACQ/2	Biofeedback	3 years
127-SL	F	50	Iatrogenic post-fistulectomy e rectopexy	ACQ/5	None	20 years
128-SL	M	39	Iatrogenic post-fistulectomy	ACQ/1	Sphincteroplasty + colostomy	7 years
129-SL	F	58	Post-partum	ACQ/3	None	21 years
130-GP	M	24	Neurogenic	ACQ/2	Biofeedback	8 years
133-VC	F	75	Iatrogenic + descending perineum sysdrome	ACQ/2	Biofeedback	9 years
134-MMP	F	56	Idiopathic	ACQ/2	None	9 years
135-CM	F	27	Anal atresia	CON/2	Pull-through, anoplasty, Pickrell procedure	27 years
138-SM	F	46	Traumatic: following sexual abuse	ACQ/2	Hartmann procedure	2 years
139-FD	M	29	Traumatic: pelvic crushing e penetrating lesione of the rectum	ACQ/4	Left colostomy	2 years
144-FM	M	44	Rectal prolapse in spina bifida	ACQ/2	None	2 years
145-CR	F	60	Rectal prolapse	ACQ/n.e.	None	1 year
146-PL	F	70	Rectal prolapse	ACQ/n.e.	None	2 years
151-BE	F	65	Post-partum	ACQ/1	None	30 years
152-RM	F	60	Idiopathic	ACQ/2	Biofeedback	1 year
159-LGL	M	14	Traumatic: pelvic crushing with anorectal disinsertion + demolition of the sphincteral apparatus and pelvic floor (crushing trauma)	ACQ/2	Left colostomy	1 year
160-DMS	F	22	Traumatic: pelvic crushing (car accident) with penetrating lesion of the rectum + demolition of the sphincteral apparatus and of the perineum	ACQ/2	Left colostomy	5 years
161-BM	F	61	Post-partum	ACQ/3	Biofeedback	40 years

n.e.=not evaluable

complete physiological assessment: anorectal manometry, electromyography, endoscopy, defecography, ultrasound and barium enema studies.

All patients were submitted to regular clinical and physiological examination: continence scores, as well as EMM values, were recorded at 2, 4, 6, 12, 18, 24 months after ESGP and later at 6 month intervals.

Mean follow-up length was 49.78 months (average: 55.7, range: 6-140, S.D.: 39.4 months).

To bypass logistic difficulties (70% of patients live over 300 kms away from our Unit), a ready-on-call line and facilitation for periodic audits were adopted .

The failure rate was 25% (9 out of 36 pts).

At present, 31 patients are clinically evaluable (withdrawn: 2 pts with colostomy, 2 died, 1 lost to the f-up) and 23 of them (74%) are continent to liquid and solid stools (I-II levels of N.S. Williams' Scale).

Preoperative and postoperative (6 months) mean EMM values rose from 34 to 59 mmHg (Resting Pressure) and from 53 to 112 mmHg (Maximum Voluntary Pressure).

In all patients mean defecation frequency passed from 4.1 times/day (max: 12/day) to 1.4 times/day (max: 4/day) with a significant decrease in diaper use (from 4.4/day to 1.3/day).

Conclusions

Continence restoration is well known to be a difficult and often discouraging challenge for the Surgeon, in particular when incontinence results from multiple and often unpredictable factors.

Dynamic graciloplasty demostrated to be a reliable option, with stable results, in particular in acquired incontinence.

In post-traumatic incontinence, secondary to wide disruption of the sphincteric apparatus (pelvic traumas, penetrating injuries, impalement) it is the most effective procedure. Failures were mainly due to postoperative complications and, among these, perineal sepsis was the most threatening for muscular function.

In spite of its apparent complexity, the application of electrostimulation protocols is a fairly simple procedure and we believe that after specific training it can be easily adopted by any surgical team.

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