Muscle Transposition: Does It Still Have a Role?

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ABSTRACT

Since the early 1900s, skeletal muscle transpositions have been employed for complicated cases of fecal incontinence to augment or replace the anal sphincter. Multiple techniques have evolved that vary with the type and configuration of muscle used in the reconstruction. Transposition of the gluteus maximus muscle was popular in the early stages of development but was replaced by techniques involving transposition of the gracilis muscle. Within the past 16 years, electrical stimulators have been applied to the transposed muscle flaps to create a dynamic reconstruction improving the efficacy of these neosphincters over their static counterparts. However, the stimulated versions are technically demanding with a high rate of morbidity secondary to complications of the multiple components and variations in technique. The stimulator used in this procedure has been removed from the US market, although it is still available in other countries. Currently in the United States, gracilis transposition is still employed in the absence of an electrical stimulator as an adjunct to the artificial bowel sphincter (Acticon Neosphincter^{TM}, American Medical Systems, Minnetonka, MN), such as in cases of severe muscle loss and congenital atresia. In European countries, the stimulated graciloplasty continues to evolve, leading to expansion of its use in total anorectal reconstruction for anal atresia and after abdominoperineal resection.

KEYWORDS: Fecal incontinence, muscle transposition, graciloplasty, gluteoplasty, neosphincter construction

Objectives: Upon completion of this article, the reader should be able to: (1) list current therapeutic options for failed overlapping sphincteroplasty; and (2) evaluate the results of each of these procedures.

Patients with severe fecal incontinence unresponsive to conservative measures can be divided into two broad categories of surgical approach. The first group includes those patients with an identifiable anatomic sphincter defect who can expect a 40 to 60% long-term surgical success rate with overlapping sphincteroplasty.¹ The absence of pudendal neuropathy yields

the best outcome in these patients.² The second group includes those patients with extensive sphincter damage, muscle loss, or pudendal neuropathy not amenable to direct sphincter repair. With the widespread prevalence of fecal incontinence and development of newer surgical techniques, the patient with severe fecal incontinence is seldom obligated to a permanent stoma. Neosphincter

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procedures involving transposition of autologous muscle grafts play an important role for these patients.

HISTORY OF MUSCLE TRANSPOSITION FOR FECAL INCONTINENCE

In the first half of the century, the gluteus maximus muscle was the most commonly used muscle in transpositions. Chetwood³ first described the operation in 1902 involving the gluteus maximus muscle and fascial slings to reinforce the sphincter muscles in children. In 1929, the procedure was revised such that the free ends of the fascia used to encircle the anus were anchored to the gluteus maximus muscle on each side. With this technique, the anal canal was enclosed in a fascial ring and the sphincter could be tightened by contracting the gluteus muscle.⁴ Since that time, multiple case reports have reinforced the gluteus maximus muscle as an effective replacement of the anal sphincter. However, enthusiasm for the gluteoplasty diminished after the introduction of the gracilis procedures.

Advantages of gracilis for transposition include its superficial location and ease of mobilization. As opposed to the fat and bulky muscle belly of the gluteus requiring bilateral transposition to encircle the anus, the gracilis is a long and flat muscle belly that allows unilateral mobilization to complete the wrap. In addition, use of the gracilis produces less of a functional movement deficit. Reports of gracilis muscle transposition were initiated by Pickrell and colleagues⁵ in 1952 to treat children with fecal incontinence due to neurologic and congenital anomalies. The technique involved wrapping the gracilis around the anus and attaching the free end to the contralateral ischial tuberosity. The basic concept was to create an anal encirclement repair similar to the Thiersch procedure using autologous tissue. Patients went through a period of training with exercises to learn to voluntarily contract and relax the muscle. The muscle contracted with abduction of the thigh and was made to relax by assuming the squatting position to avoid abduction of the leg. This technique met with only moderate success since these static, striated muscle flaps were prone to fatigue with chronic contraction. The transposed muscle did not have any involuntary tone at rest, and patients had to perform awkward movements to achieve imperfect continence. These problems are identical to those following the gluteus muscle transposition.

In 1981, Salmons⁶ reported on the transformation of skeletal muscle from fast-twitch fatigue-prone (type II) muscle fibers to slow-twitch fatigue-resistant (type I) muscle fibers by application of low frequency electrical stimulation. Expanding on this idea in 1988, Baeten and associates⁷ connected a pulse generator to a patient with suboptimal function of the gracilis muscle transplant. The result was a neosphincter with involuntary resting tone. Widespread adoption of this technique improved

the success of gracilis transpositions. However, the procedure involves many components and requires technical expertise, predisposing it to an array of complications that proved to undermine its advantages. The increased morbidity and associated cost led to the abandonment by the manufacturer in 1999 in seeking FDA approval in the United States. Consequently, the focus shifted back to its static counterpart with modifications of the original technique to improve outcome. Graciloplasty continues to be performed in the United States to replace sphincter muscle loss and as an adjunct to the artificial bowel sphincter. However, in other parts of the world, advances in the technique of stimulated graciloplasty have led to its application to total anorectal reconstruction for anal atresia and following abdominoperineal resection (APR).

UNSTIMULATED GLUTEOPLASTY

Advantages of the gluteus maximus muscle include its large muscle bulk, single proximal innervation, and proximity to the anal canal. In addition, buttock contraction is a standard response to impending incontinence. In the prone-jackknife position, the lower 10% of both of the gluteus maximus muscles and fascia are mobilized from their origins on the ileum and sacrum and distally freed in two strips. The neurovascular bundle is preserved where it arises near the ischial tuberosity. The two strips on each side are tunneled beneath the skin and secured to their contralateral counterparts through lateral incisions on the contralateral sides of the anus (Fig. 1).

Though not as popular as the graciloplasty, this operation has been performed with variable results. Pearl and coworkers⁸ performed bilateral nonstimulated

Figure 1 (A) Unstimulated gluteoplasty. The lower 10% of both the gluteus maximus muscles and fascia are mobilized from their origins on the ileum and sacrum and distally freed in two strips. (B) The two strips on each side are tunneled beneath the skin and secured to their contralateral counterparts through (C) lateral incisions on the contralateral sides of the anus.

Table 1 Unstimulated Bilateral Gluteoplasty

Author	Country	Year	Patients	Results	
				Success	Failure
Pearl et al ⁸	USA	1991	7	6	1
Christiansen et al ⁹	Denmark	1995	7	3	4
Devesa et al ¹⁰	Spain	1997	17	10	7

gluteoplasty without diversion in seven patients with excellent results in six. In contrast, Christiansen and colleagues⁹ reported poor results as none of their seven patients were continent to liquid and only three were continent to solid. Most recently, Devesa and associates¹⁰ reported the largest clinical experience to date with only moderate results. Only 9 of the 17 patients who could be evaluated who underwent bilateral non-stimulated gluteoplasty achieved normal control. The morbidity of this procedure is exclusively related to wound infection of the perianal wounds.⁸⁻¹⁰ While unilateral gluteoplasty has been described,¹¹ better muscle bulk and more even distribution of tensile forces are created with bilateral gluteal muscle transpositions. Despite the wide variability in results, this technique continues to be preferred to colostomy in patients with severe fecal incontinence. The results of unstimulated gluteoplasty are shown in Table 1.

UNSTIMULATED GRACILOPLASTY

Two or three 5-cm longitudinal incisions along the length of the medial thigh allow identification and mobilization of the gracilis (Fig. 2). The neurovascular supply arises in the proximal portion of the muscle and allows division of the tendon at its attachment to the tibia without compromising viability. The muscle is then tunneled to either an anterior or posterior perianal incision. Using an additional contralateral anal incision,

Figure 2 Incisions for harvesting the gracilis. Two or three 5-cm longitudinal incisions along the length of the medial thigh allow identification and mobilization of the gracilis muscle.

the muscle is wrapped around the anus using one of three configurations: α , gamma, or epsilon (Fig. 3). The tendon is anchored to the contralateral ischial tuberosity with nonabsorbable suture. However, muscle—not tendon—is meant to encircle the anus as the operation aims to achieve a dynamic result as opposed to a Thiersch-type wrap of a fibrotic band of tendon. At completion, the wrap should allow the snug insertion of one finger. The patient relaxes the sphincter by assuming a squatting position and avoiding abduction of the leg, while the sphincter is made to contract by standing and abducting the leg.

The original description by Pickrell and coworkers⁵ demonstrated 100% continence with his pediatric patients. Subsequently, Corman¹² reported on 14 patients followed for at least 5 years, 11 of whom had excellent or fair results. He attributes his success to appropriate patient selection including only relatively young, motivated patients without functional colonic dysmotility and with disabling incontinence secondary to trauma or congenital anomaly. Christiansen et al¹³ were also successful with 13 patients of whom all but 3 improved. Sielezneff and associates¹⁴ were successful with 8 patients, all of whom improved using the original procedure described by Pickrell combined with post-operative biofeedback. In contrast, Yoshioka and Keighley¹⁵ reported poor results in 6 patients who underwent graciloplasty, all of whom required a colostomy and 5 of whom had a septic complication. Eccersley et al¹⁶ reported that two thirds of patients had improvement in continence with half of the patients experiencing good function. They concluded that these results were comparable to the results of their stimulated counterparts. In this study, better results were obtained in younger patients and in individuals without pudendal neuropathy, suggesting that in such patients nonstimulated graciloplasty alone may be effective.

In an attempt to improve outcome, the procedure was modified by Kumar and colleagues¹⁷ to include bilateral gracilis transpositions. They performed this procedure in 10 patients with a colostomy for diversion. All of the 9 who underwent colostomy reversal were fully continent at 2 years. Though more investigation is needed, the improved results compared with unilateral graciloplasty suggests that the bilateral wrap may be a better alternative to the stimulated graciloplasty. Results of the nonstimulated graciloplasty are shown in Table 2.

DYNAMIC GRACILOPLASTY

The technique of stimulated graciloplasty generally involves two or three phases with the number of required operations dependent on the use of an optional stoma. Phase 1 consists of transposition of the gracilis muscle from the thigh to form a skeletal muscular ring around the anus. The distal severed portion is anchored to the

Figure 3 (A) Wrapping the gracilis around the anus. (B) The muscle is wrapped around the anus using one of three configurations: α , gamma, or epsilon.

contralateral ischial tuberosity. The stimulator (Fig. 4) is implanted in the abdominal wall while the leads are placed either on the main trunk or into the intramuscular portion of the gracilis near the nerve. Phase 2 involves 8 weeks of muscle conditioning with increasing levels of low-frequency neuromuscular stimulation. During this conditioning, the muscle fibers gradually convert from rapid-twitch, easily fatiguable fibers to tonic, slow-contracting fibers. The use of diverting stoma requires additional operative intervention for creation and closure. Upon completion of phase 2, the patient is able to control continence with the use of an external magnet (Fig. 5). The patient can turn the neurostimulator on, causing the muscle to contract, and off, causing the muscle to relax.

Stimulated graciloplasty is currently the most studied and employed transposition procedure for fecal incontinence with most recent reports of success between 57% and 93% (see Table 3). The Dynamic Graciloplasty Therapy Study Group has provided the most prospective multicenter data with regard to outcome of this procedure. The initial report on the efficacy revealed improvement in continence and quality of life in the majority (60%) of patients.¹⁸ Long-term efficacy reported in a separate study revealed a 62% success rate and improve-

ments in functional and quality-of-life variables that persisted during a 2-year duration.¹⁹

While many studies have proven the efficacy of the stimulated graciloplasty, concern arose about the high rates of complications and need for reoperation. In the original study by the Dynamic Graciloplasty Therapy Study Group,¹⁸ the complication and reoperative rates were 74% and 40%, respectively. Other studies also revealed high rates of infection, hardware failure, and postoperative evacuatory dysfunction. In a single institution study performed at Cleveland Clinic Florida, complications included lead fibrosis, seroma of the thigh incision, excoriation of the skin above the stimulator, fecal impaction, anal fissure, parastomal hernia, rotation of the stimulator, premature battery discharge, fracture of the lead, perineal skin irritation, perineal sepsis,

Figure 4 The stimulator. The stimulator is implanted in the abdominal wall while the leads are placed either on the main trunk or into the intramuscular portion of the gracilis near the nerve.

Table 2 Unstimulated Graciloplasty

Author	Country	Year	Patients	Success
Pickrell et al ⁵	USA	1952	34	34
Corman et al ¹²	USA	1985	14	11
Christiansen et al ¹³	Denmark	1990	13	10
Sielezneff et al ¹⁴	France	1996	8	8
Yoshioka and Keighley ¹⁵	UK	1988	6	0
Kumar ^{17*}	UK	1995	9	9
Eccersley ^{16**}	UK	1999	8	8

*Bilateral graciloplasty as opposed to unilateral graciloplasty.

**Combined with postoperative biofeedback.

Figure 5 The magnet. The patient is able to control continence with the use of an external magnet that turns the stimulator on and off.

rupture of the tendon, tendon erosion, muscle fatigue during programming sessions, electrode displacement from the nerve, and fibrosis around the nerve.²⁰ Complications reported in other studies included hardware infections, muscle detachment, device malfunction and migration, pulmonary embolism, and severe unresolved pain that resulted in hospitalization and reoperation in numerous cases. Some of these complications led to stoma creation or death. Consequently, the Dynamic Graciloplasty Therapy Study Group investigated the etiology and impact of these complications.²¹ In this

report, 211 complications occurred in 93 cases of dynamic graciloplasty. Forty-two percent had severe complications, though recovery was achieved in 92%. Fortunately, only major infections adversely affected outcome, leading the authors to conclude that although the complication rate was high, most of the complications could be treated and did not adversely affect outcome.

Modifications of certain aspects of the procedure have decreased some of the morbidity. Placing the leads along the intramuscular portion of the nerve rather than directly on the exposed portion of the nerve trunk has virtually eliminated problems with nerve fibrosis, lead displacement, and high impedance.^{22,23} Improved infection control measures have decreased the rate of infectious complications.²⁴ Aside from the critical influence of the method of stimulation (intramuscular versus directly on the nerve trunk), no other parameters have been identified to be predictive of successful outcome.²² However, outcome strongly correlates with surgical experience.²⁵

Several studies have found evacuatory dysfunction to be a common problem in up to 25% of patients after stimulated graciloplasty, particularly in patients with altered preoperative rectal sensitivity and compliance.^{21,22,24} It is suggested that severe urgency secondary to rectal hypersensitivity and low rectal compliance predisposes to poor outcome. Williams and associates²⁶ reported a procedure involving rectal augmentation with a segment of distal ileum in combination with the dynamic graciloplasty. Urgency was abolished and continence restored in all three individuals in whom this procedure was employed. However, long-term follow-up of patients with stimulated graciloplasty revealed that the postoperative evacuatory dysfunction resolves spontaneously with time in most cases, making the augmentation procedure unnecessary.^{24,27,28}

Despite the positive effects of cost, quality of life, and durability, Medtronic Inc. (Minneapolis, MN)

Table 3 Stimulated Graciloplasty

Author	Country	Year (n)	Patients (months)	Follow-up	Morb (%)	Comp# (%)	Reoperation (%)	Success
Mavrantonis et al ²²	USA	1999	21IM	21				93
			6DS	13				10
Mander et al ¹⁸	Multicenter	1999	64	10		38		56
Madoff et al ^{25*}	Multicenter	1999	128	26	41	138		66
Baeten et al ²⁷	Multicenter	2000	123	12	74		40	60
Konsten et al ²³	Netherlands	2001	200IM				3	74
			81DS				26	57
Wexner et al ¹⁹	Multicenter	2002	129	24				62
Bresler et al ²⁸	France	2002	24		42		46	79
Rongen et al ²⁴	Netherlands	2003	200	72		138		72

*Study involves both stimulated graciloplasty and gluteoplasty. IM, intramuscular; DS, direct nerve stimulation.

Table 4 Total Anorectal Reconstruction

Author	Year	Country	Patients	Follow-up	Success	Morb
Cavina et al ³⁰	1998	Italy	98	55	85 (87%)	37%
Violi et al ³³	1999	Italy	8	6	7 (88%)	
Rouanet et al ³¹	1999	France	7	32	5 (71%)	57%
Rullier et al ³²	2000	France	12	28	7 (58%)	73%
Saunders ³⁴	2004*	UK	14	53	8 (57%)	71%

*Includes the continent colonic conduit or antegrade continent enema as an adjunct to the procedure.

discontinued seeking FDA approval in the United States of the neurostimulator in 1999. Currently, this operation remains a viable option throughout the rest of the world.

TOTAL ANORECTAL RECONSTRUCTION

In 1976, Simonsen and coworkers²⁹ were the first authors to use the gracilis muscle to restore continence in a perineal colostomy after APR. In the mid 1980s, the procedure was performed worldwide and included transposition of both gracilis muscles to replace the sphincter and puborectalis mechanism followed by placement of an external neurostimulator. The results of recent studies are shown in Table 4. Cavina et al³⁰ reported on the largest series of 98 patients with the longest follow-up of 55 months with an 87% success rate and 37% morbidity. Rouanet and colleagues³¹ reported good results with success in 5 of 7 patients who could be evaluated. In a study by Rullier and colleagues,³² in 12 of 15 patients with a 28-month follow-up, 7 were continent and 12 complications occurred. In this study, neosphincter stenosis was common and resulted in poor functional results, leading the authors to suggest using a single gracilis. Violi et al³³ described a different approach in which the procedure was followed by biofeedback training and only delayed, selective use of implantable pulse generators to minimize complications and conserve resources. Seven of the 8 patients who had their colostomy reversed had full or partial continence. Though these studies suggest satisfactory continence and avoidance of a colostomy in up to 50% with this procedure, the rate of morbidity from complications is high. The most dramatic complication is significant tissue necrosis of the anus or neoanus that occurs more frequently when this procedure is performed after APR than for incontinence alone. Consequently, careful analysis of the risk-benefit ratio should be taken into consideration and discussed with the patient before embarking on this procedure.

Because of severe evacuatory dysfunction, patients undergoing anorectal reconstruction with electronically stimulated gracilis neoanal sphincter for atresia or after APR do not fare as well as patients with incontinence alone.³⁴ Consequently, those individuals with severe evacuatory problems unresponsive to conservative treatment showed significant improvement and avoidance of

a colostomy in 50% when a continent colonic conduit or antegrade colonic enema procedure was performed subsequent to the total anorectal reconstruction.³⁴

MYOPLASTY FOR CONGENITAL ATRESIA

In 1952, Pickrell and coworkers⁵ used the gracilis in the management of children with fecal incontinence secondary to congenital malformation (spina bifida, meningocele). In 1988, Baeten et al⁷ implanted the first neurostimulator in a patient with anal atresia who had been treated with conventional graciloplasty 10 years earlier, resulting in complete continence. In 1995, Baeten et al³⁵ published their expanded experience in a series of 9 patients with anal atresia, achieving continence in 55%. Recent results from a multicenter prospective trial revealed a 50% success rate for congenital fecal incontinence, though these results were not as good as the 71% success reported for acquired fecal incontinence and 66% success noted after APR for rectal cancer.²⁵ In a recent study comparing the Acticon Neosphincter^{TM} and stimulated graciloplasty for congenital atresia, the overall improvement of continence was 60% for Acticon Neosphincter^{TM}, American Medical Systems, Minnetonka, MN, and 50% for stimulated graciloplasty, with a 50% morbidity rate for both procedures.³⁶ The stimulated gracilis neosphincter is an efficient method of treating patients with congenital fecal incontinence.

Alternatively, augmented unilateral gluteoplasty with fascia lata graft was used to treat 11 young patients between 5 and 19 years of age with fecal incontinence due to congenital or neurologic disorders.³⁷ The use of the fascia lata tendon yielded a lower incidence of morbidity related to the tension on either the muscle flap or its neurovascular bundle. Most (72%) of the patients were clinically improved as demonstrated by incontinence scores and anorectal physiologic studies. This procedure may be a new option for patients with congenital atresia.

SUMMARY

Myoplasties have acquired an important role in anal sphincter repair for those patients with end-stage fecal incontinence who wish to avoid a colostomy. The

stimulated graciloplasty is currently the most popular and widely performed myoplasty procedure and is an effective alternative in restoring continence. A recent systematic review concluded that stimulated graciloplasty was clearly superior and highly effective with 42 to 85% success in comparison to colostomy whereby colostomy is, by design, incapable of restoring continence.³⁸ In addition, the stimulated graciloplasty is cost-effective. In a prospective longitudinal clinical trial involving patients with intractable fecal incontinence, cost was compared between stimulated graciloplasty, conventional treatment, and stoma.³⁹ The cost of treatment for a lifelong dynamic graciloplasty (\$31,733) was more expensive than lifelong conventional therapy (\$12,180) but resulted in better quality of life. Stoma treatment was the most expensive (life-long stoma care \$71,576) and by nature does not attempt to restore continence. In another study of 200 patients with the longest follow-up to date, the durability of good results over a 5-year period led the authors to conclude that the dynamic graciloplasty was a cost-effective treatment for fecal incontinence.²⁴

With improved techniques and increasing experience, the adynamic versions of myoplasties are playing an increasing role in the initial approach to sphincter reconstruction. In some centers, elective use of the stimulators serves to conserve resources and minimize morbidity and need for reoperation resources while maintaining the same efficacy and outcome as their stimulated counterparts. In addition, the adynamic myoplasty remains an effective option in health-care settings where the stimulator is not available. Anecdotal experience at our institution with adynamic graciloplasty includes use for sphincter augmentation in cases of severe traumatic muscle loss prior to the placement of an artificial bowel sphincter (Acticon Neosphincter^{TM}, American Medical Systems, Minnetonka, MN).

Stimulated myoplasty procedures are particularly complex procedures prone to complications during the steep learning curve. Consequently, any type of stimulated muscle transposition necessitates careful patient selection, preoperative planning, and greater experience with the specific technique to minimize patient morbidity and justify this approach economically. Currently, an accurate predictor of successful outcome does not exist. No preoperative investigation has provided a clear perspective on outcome. Patients must have the psychological strength, emotional commitment, and financial resources that may be necessary for multiple revisional surgeries or ultimate device failure. Consequently, these procedures are more likely to benefit the young healthy patient with intractable fecal incontinence than the elderly frail patient with minimally symptomatic fecal soilage. In addition, increased experience is a critical factor in avoiding complications and improving successful outcome and therefore these procedures should be

performed at institutions with the necessary volume of patients to maintain expertise.

Because of the widespread prevalence of fecal incontinence and the recent development of new surgical techniques, other options exist for patients with fecal incontinence. The Acticon Neosphincter^{TM} received FDA approval in 1999. A recent multicenter, nonrandomized trial revealed the device to have significant rate of clinical success (85%), enhancement in quality of life, and a high degree of safety.⁴⁰ However, like the stimulated graciloplasty, limitations in use of this technique are related to the high rate of complications (most of which are related to infections of the foreign material with subsequent need for surgical revision) and an explant rate of 36%.⁴⁰ According to this study, the success rate, cost involved, and the morbidity from this and the stimulated graciloplasty are approximately the same. In a recent prospective comparison of 8 cases of dynamic graciloplasty and 8 implantations of the artificial bowel sphincter (ABS) followed over 3 years, there was no difference in complications, wound healing problems, or explantation rates. Though the ABS was found to be more effective in improving continence scores.⁴¹ However, larger long-term studies are needed.

Sacral nerve stimulation is a promising new therapy for fecal incontinence. However, large sphincter defects or patients with rectoanal atresia are not likely to benefit from this treatment and will continue to depend on the creation of sphincters. In addition, those patients who do not respond to this neuromodulation will be selected out for a neosphincter procedure. This group might be better candidates for success with a graciloplasty procedure.

The ideal muscle transposition has not yet been elucidated. Considerable controversy exists as to the best type of muscle (gracilis versus gluteus), the best configuration (α , gamma, or epsilon and whether unilateral is better than bilateral), whether postoperative biofeedback improves outcome, and whether the advantages of external stimulation outweigh the risk and cost. Important fundamental research must be performed to improve the outcome for myoplasties and their application for fecal incontinence and anorectal reconstruction. No individual center has gleaned enough experience with the various techniques; therefore, significant shortcomings exist because of this nonrandomized approach. Consensus and standardization are needed with respect to data collection, scoring systems, and quality of life assessment. There is a desperate need for properly controlled and adequately powered randomized studies to address issues. Longitudinal studies are needed to assess long-term results. Centers of expertise need to develop additional novel surgical techniques. Future efforts should be directed toward optimizing patient selection, surgeon training, and surgical techniques to minimize morbidity and maximize satisfactory outcomes. As the technology

and the techniques evolve and cost-containment is realized, the role of myoplasty will become more universal and include a broader spectrum of indications.

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