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ORIGINAL STUDY

Complications and outcomes of functional free gracilis transfer in brachial plexus palsy

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The purpose of this study was to evaluate the outcomes and complications following free functional gracilis transfer for restoration of elbow flexion and/or finger flexion in patients with acute or chronic brachial plexus injuries.

A review of 130 free functioning gracilis muscles transferred for brachial plexus injuries was undertaken to evaluate the failure rate as well as late complications.

The overall failure rate (defined as a non-function muscle or one that failed acutely) was 15.4%. The most common late complication was fracture of the clavicle (5.4%). A technical modification of the procedure resulted in a decrease in these complications from a early rate of 7.9% graft failures and 7.9% clavicle fractures to a 2.4% (n = 1) failure rate and zero clavicle fractures in the subsequent 41 consecutive cases.

Observations made in this series lead to a technique change, which has thus far resulted in no clavicle fractures, no bowstringing, improved graft viability and function, and a statistically significant decrease in overall complications ($p < 0.001$) associated with use of functioning free gracilis transfer in brachial plexus reconstruction.

Keywords : gracilis transfer ; brachial plexus injury ; brachial plexus ; free functioning muscle transfer ; free functional gracilis transfer.

INTRODUCTION

The use of functional free gracilis muscle transfer with extraplexal donor for re-innervation was first described by Ikuta *et al* to restore function in

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the setting of a chronic brachial plexus injury in a young boy (12). The advantage of this technique is especially attractive when nerve grafting or transfers are not an option, such as in the setting of preganglionic injuries, or when significant time has elapsed from injury to reconstruction (1,3,4,6-10,13,14). Further combinations of two free functioning gracilis transfers with additional nerve transfers have demonstrated the ability to obtain elbow flexion and extension in addition to prehension in the acute brachial plexus injury as described by Doi (3,6-10).

The overall functional success rate of the free functioning gracilis muscle transfer has been reported to be between 65 to 96% (3,5,7,11). Despite the encouraging success rates, few authors have commented on the complications rates other than catastrophic failure (ie : loss of muscle). Complications, such as clavicle fractures, the need for additional tenolysis, and the incidence of bowstringing of the gracilis tendon and non-functioning muscles have not been adequately addressed.

The purpose of this study is to describe the outcomes and complications associated with free functioning gracilis muscle transfer for restoration of upper extremity function in patients with brachial plexus injuries.

MATERIALS AND METHODS

After Institutional Review Board (IRB) approval was obtained, a retrospective review of the brachial plexus clinic database was undertaken to identify all patients with brachial plexus injury (adult and paediatric) who underwent free functional gracilis muscle transfer to restore elbow flexion or finger flexion in either the acute or chronic setting. As a major change in the surgical technique occurred in 2005, the patients were divided into two cohorts, those that underwent surgery between 1989 and 2004 and those who underwent surgery between 2005 and 2007. The overall survival rate of the gracilis muscle, complications which included post surgical clavicle fractures, nonfunctioning or inadequately functioning muscles (those with BMRC Grade II or less) and need for additional surgery related to the free functioning muscle were evaluated.

Surgical technique

Between 1989 and 2004, the technique utilized was modified from previous descriptions of the technique (3,6,7).

The gracilis was harvested together with its innervating branch of the obturator nerve and its vascular supply, a branch of the profunda femoris artery. A skin paddle was typically harvested as well to facilitate postoperative flap monitoring (2). Intercostal motor nerves, the spinal accessory nerve or the musculocutaneous nerve were used as donor nerves. The entire gracilis from pubic symphysis to the pes anserine insertion distally was taken, and positioned in the recipient site such that the nerve was as close as possible to the donor nerve. Prior to 2005, the proximal gracilis was placed beneath the clavicle which had been subperiosteally stripped, and was wrapped up around the clavicle over the superior and anterior surfaces of the bone. The proximal gracilis tendon was advanced proximally, wrapped underneath the clavicle, and secured to the clavicle via anteriorly placed drill holes or suture anchors (Statek Suture Anchors, 2.5 mm, Zimmer, Warsaw, IN, USA). This was done in the central portion of the clavicle (fig 1). The arterial and venous anastomosis was to the artery and venae comitantes of the thoracoacromial trunk, which lay slightly posterior and medial to the gracilis muscle. No vein grafts were employed. The distal gracilis tendon was woven into the biceps tendon by a Pulvertaft weave with tensioning at 30° of elbow flexion, or to the extensor carpi radialis brevis tendon after being prolonged with a free tendon graft, typically the tendon of the flexor carpi radialis.

Between 8/27/2005-12/1/2007, the surgical technique of placement of the gracilis on the clavicle was modified. The gracilis was no longer wrapped around the clavicle, but placed on the anterior surface of the acromion and distal clavicle and shifted laterally compared to the previous technique (fig 2A,B). A #2 nonabsorbable suture was placed through the acromion and three suture anchors or bony tunnels were placed in the distal clavicle approximately 1 cm apart. The proximal gracilis tendon was then sewn to the acromion and lateral clavicle such that the vascular pedicle could easily reach the thoracoacromial vessels. As the gracilis was attached to the lateral acromion and clavicle, the vessels were medial to the gracilis. Care was taken to avoid circumferential subperiosteal stripping of the clavicle.

Medical records were reviewed for outcome of the free functioning muscle with respect to BMRC grading. Failure was defined as BMRC grade of II or less, or an

Fig. 1. — The technique for the recipient site used between 1989 and 2004, involved placement of the gracilis beneath the clavicle which had been subperiosteally stripped. The gracilis was then wrapped up around the clavicle over the superior and anterior surfaces of the bone and secured to the clavicle via anteriorly placed drill holes or suture anchors (Statek Suture Anchors, 2.5 millimeters, Zimmer, Warsaw, IN, USA) in the central portion of the clavicle. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved).

early catastrophic failure. Complications and subsequent surgeries related to the free functioning gracilis transfer were also noted.

Statistical analysis

The effect of the alteration in technique was evaluated using the Fisher's Exact Tests. Means are reported with 95% confidence intervals. Statistical tests with p values less than 0.05 were considered statistically significant. All analysis was conducted using SAS version 8.2 (SAS Institute Inc, Cary, NC, USA).

RESULTS

During the study period (1989 to 2007), a total of 130 patients underwent a free functioning gracilis transfer for brachial plexus reconstruction. Of the 130, 15 underwent the Doi procedure for restoration of elbow flexion/extension and prehension using bilateral gracilis muscles. Sixty-five underwent transfer of the gracilis for elbow flexion alone, while 50 underwent a one-stage procedure to obtain elbow flexion/extension and prehension.

Two separate cohorts were identified : patients who underwent the procedure prior to the technique change (prior to August 27, 2005), and patients who underwent the procedure after the technique change (August 27, 2005-December 1, 2007).

Prior to August 27, 2005, when the change in technique was made, 89 patients underwent transfer of the gracilis muscles. Of the 89 patients, 15 underwent the Doi procedure for restoration of elbow flexion/extension and prehension using bilateral gracilis muscles, 47 underwent transfer of the gracilis for elbow flexion alone, while 27 underwent a one stage procedure to obtain elbow flexion/extension and prehension. Of these patients, 7 (of 89) (7.9%, CI = 3 to 16%) had postoperative clavicle fractures in the operative site. Fractures occurred at an average of 56.6 weeks postoperatively (range : 12-156 weeks) after gracilis transfer. Although local pain was problematic, loss of elbow flexion did not occur. Three patients were treated nonoperatively ; 4 were treated operatively using plate and screw constructs. Mechanism of injury was as follows : fall from ground level height [3], pathological fracture while rolling over in bed [1], during activities of daily living [1], while playing with friends [1] in a young boy, and unknown in one. Initial nonoperative treatment was employed in six patients. The fracture went on to radiographic but clinically asymptomatic nonunion in one, healing in one patient, it healed in one after use of a bone stimulator, and three patients required open reduction and internal fixation for nonunion after failed nonoperative therapy.

Prior to the procedure change, seven patients had failure of their gracilis graft (7.9%, CI : 3.2-15.5). Of these, failure mechanism was as follows :

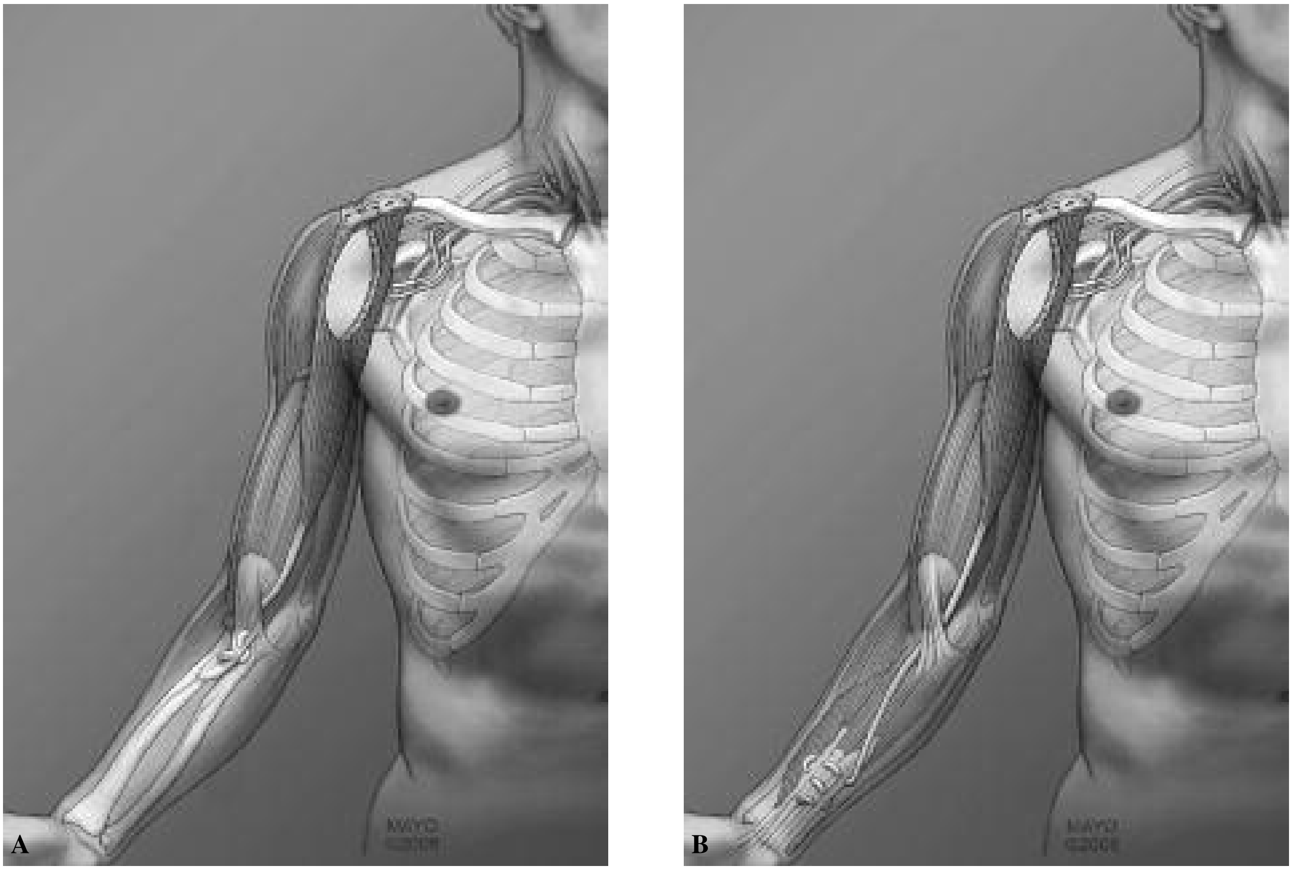

Fig. 2. — A, B) In the second cohort of patients, the placement of the gracilis on the clavicle was modified. The gracilis was no longer wrapped around the clavicle, but placed on the anterior surface of the acromion and distal clavicle and shifted laterally compared to the previous technique. A #2 nonabsorbable suture was placed through the acromion and three suture anchors or bony tunnels were placed in the distal clavicle approximately 1 cm apart. The proximal gracilis tendon was then sewn to the acromion and lateral clavicle such that the vascular pedicle could easily reach the thoracoacromial vessels. As the gracilis was attached to the lateral acromion and clavicle, the vessels were medial to the gracilis. Care was taken to avoid circumferential subperiosteal stripping of the clavicle. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved).

2 arterial thromboses, 1 patient with arterial and venous thromboses, 1 venous thrombosis, 1 haematoma, 1 infection, 1 vascular insufficiency with apparently patent vessels at exploration. All patients were male, with average age 33.4 years (range 17-65 years). Exploration and removal of the muscle occurred at an average of 6.8 days post index procedure (range 1 day-34 days). Eleven patients (12.4%, CI 6.3-21.0) who had their procedure prior to the technique change had nonfunctioning muscles (grade III or less) at final follow-up. Twelve patients in this cohort also experienced bowstringing as a complication (n = 12, 13.5%, CI 7.2-22.4).

The second cohort included those patients who underwent the modified procedure after August 27, 2005.

After 8/27/05, when modifications to the technique were made, 41 patients underwent the procedure, with no clavicle fractures to date (0%, CI = 0-8.6%). One graft failure (2.4%, CI = 0 to 12.9%) occurred after the technique change. A 26-year-old female developed an infection in the 12 days after surgery. Her transferred gracilis was explored, was initially viable, but succumbed to infection and with vessel thrombosis. The muscle was subsequently removed 15 days postoperatively.

At final follow-up, 1 (2.4%, CI 0-12.9) of the transfers was nonfunctional (the patient with the failed muscle secondary to infection). No patients in this cohort experienced bowstringing (n = 0, 0%, CI 0 to 8.6).

Differences between failure rates, clavicle fracture rates, and non-functioning muscles and before and after the procedure change were not statistically significant (p = 0.434, 0.097, 0.102). However, the difference in bowstringing and overall complication rate before and after the technique change was statistically significant (p = 0.018, < 0.001).

DISCUSSION

In this series, complications were observed, and are believed to be related to surgical technique. A modification in technique led to a decrease in complications. No clavicle fractures were observed after the change in technique, and fewer failures and nonfunctioning muscles were observed. Although differences between failure rates, clavicle fracture rates, and non-functioning muscles and before and after the procedure change were not statistically significant (p = 0.434, 0.097, 0.102), differences in bowstringing and in overall complication rate before and after the technique change were statistically significant (p = 0.018, < 0.001).

The modification resulted in less soft tissue dissection and stripping, which was believed to lead to clavicle fracture in the early technique. In addition, devascularization may have promoted failures of the graft itself, with a 7.9% failure rate prior to technique change and a 2.4% failure rate after procedure change.

In this series, patients who had clavicle fracture were likely to have experienced minimal or trivial trauma. The disuse osteopenia together with the "old" way of attaching the free muscle to the clavicle is hypothesized to have lead to the fracture. Furthermore, most patients developed a nonunion with nonoperative therapy despite the presence of a minimally displaced fracture.

Based upon these experiences, we make the following recommendations and observations following functional free muscle transfer to restore elbow flexion.

Firstly, the clavicle on the ipsilateral side may be susceptible to insufficiency type fractures with trivial trauma. Use of a less invasive approach which preserves the periosteum and soft tissues with the free muscle draped over the anterior superior aspect of the clavicle rather than wrapped from posteriorly then over anterior and superiorly may decrease risk of this complication. In addition, this seems to result in better function of the vascular pedicle, as indicated by a 5.5% decrease in failure rate, a 10% decrease in nonfunctional muscles and a 13.5% decrease in bowstringing.

When clavicle fractures do occur, the functional status of elbow flexion is usually not compromised.

Many of these insufficiency fractures will require operative fixation for nonunion. The disuse osteopenia from the injury may predispose to nonunion. In our series, a clinically asymptomatic nonunion occurred in one patient, 1 fracture healed, 1 required use of a bone stimulator for delayed union, and 3 patients required open reduction and internal fixation after a prolonged nonoperative course. Later in the series, primary operative therapy was recommended when a clavicle fracture was identified.

The osteopenia and lack of use is thought to contribute to delayed or nonunion in these cases. The poor host bone makes use of the dual plating technique ideal to secure fixation and promote healing in these cases.

In conclusion, observations made in this series lead to a technique change, which has thus far resulted in no clavicle fractures to date, and improved graft viability and function.

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