RESEARCH ARTICLE

Reoperation Rate and Indication for Reoperation after Free Functional Muscle Transfers in Traumatic Brachial Plexus Injury

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Abstract

Background: Free functional gracilis muscle transfers (FFGT) are an option for reconstruction after traumatic brachial plexus injury. Few studies report the rate of revision surgeries following free functional muscle transfers. We examined the reoperation rate and indication for reoperation after primary reconstruction of upper extremity function with a free gracilis transfer after brachial plexus injury.

Methods: From 2003-2016, we identified 25 patients who underwent a free functional gracilis muscle transfer for restoration of upper extremity function. We reviewed their medical charts to record patient, injury, and treatment characteristics. Indication for reoperation and reoperative procedure were also identified.

Results: Fourteen out of 25 patients (56%) had a reoperation after FFGT. Four flaps were re-explored for vascular compromise, but there were no flap failures. The majority of reoperations involved adjustment of tendon excursion (8/14) which demonstrated that tenolysis was the main procedure.

Conclusion: Despite promising results of free functional gracilis transfers, reoperation is relatively common and should be discussed with the patient as a preoperative strategy. Early exploration of vascular compromise may decrease the flap failure. Poor tendon excursion is a common unpredicted consequence after FFMT and is the main indication for reoperation.

Level of evidence: IV

Keywords: Brachial plexus injury, Free functional muscle transfers, Indication, Reoperation rate

Introduction

Free functional muscle transfer using the gracilis muscle is a tool that can restore upper extremity function in patients with traumatic brachial plexus injuries – especially for patients with a delayed presentation, who are ineligible for nerve grafts or transfers, or have undergone prior surgery with unsatisfactory outcomes (1-3). The success rate of achieving active movement against gravity or better (Medical Research Council grade 3 strength or higher) through elbow flexion after a free functional gracilis transfer (FFGT) for traumatic brachial plexus injury (BPI) varies from 53% to 96% (1-7). Despite these promising results regarding restoration of elbow function after FFGT for BPI, preceding published data indicates that

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complications that require surgical treatment may occur in a number of patients (1, 3, 5, 7-13). Five to 17% of these procedures may undergo reoperation specifically for flap survival. In five to 23% of these procedures, functional limitations are the main indication for reoperation (1, 5, 8-13).

In this context, we studied the rate of unplanned reoperation of primary reconstruction of upper extremity function with a FFGT after BPI and described the indications for these reoperations.

Materials and Methods

Study design

After approval by our institutional review board, we queried a research database of two tertiary level hospitals in a single metropolitan area of the United States of America comprising the years 2002 to 2016. We retrospectively included all patients aged 18 or older with traumatic brachial plexus injury, as defined by International Classification of Disease 9 (ICD-9) codes for injury of the brachial plexus (953.4). This resulted in an initial cohort of 550 patients. After excluding patients who did not have a free functional gracilis transfer (FFGT) for restoration of upper extremity function, our final cohort comprised 25 patients. We manually recorded patient characteristics (age, sex, BMI, smoking status), injury characteristics (mechanism of injury, associated trauma, injury pattern, pre- or postganglionic) and treatment characteristics (prior brachial plexus surgery, time from injury to muscle transfer, origin of muscle transfer, insertion of muscle transfer) from the medical records. We also recorded characteristics of the FFGT surgeries (inflow vessel, outflow vessel, type of anastomosis, postoperative anticoagulation, nerve supply, additional nerve graft, first or second-staged procedure) and the characteristics of the reoperations (stage for reoperation, indication, procedure performed, number of reoperations).

We defined a reoperation as an unplanned operation that was performed after a first or second stage FFGT. Arthrodesis and tenodesis comprising the wrist were excluded from this definition, as these usually are planned operations that are performed to improve hand function (14, 15).

Our cohort consisted of 21 men (84%) and the mean patient age was 36 ± 13 years [Table 1]. All brachial plexus

Table 1. Patient Characteristics after Receiving Free Functional Muscle Transfer

Variable	All patients (n=25)	Had reoperation		*P-value*
		No (n=11)	Yes (n=14)	
Age, mean (SD), years	36 (13)	38 (16)	34 (11)	0.43[1]
Male sex, n (%)	21 (84)	10 (91)	11 (79)	0.60[2]
BMI, mean (SD), kg/m2	29 (5.3)	30 (4.9)	28 (5.7)	0.41[1]
Smoker, n (%)	11 (44)	5 (46)	6 (43)	>0.99[2]
Motor vehicle accident related mechanism of injury, n (%)	22 (88)	10 (91)	12 (86)	>0.99[2]
Had brachial plexus associated trauma, n (%)	20 (80)	9 (82)	11 (79)	>0.99[2]
Injury pattern, n (%)				
Panplexus	21 (84)	8 (73)	13 (93)	0.29[2]
Upper type	4 (16)	3 (27)	1 (7.1)	
Pre- or postganglion, n (%)*				
Pre-ganglion	19 (83)	7 (70)	12 (92)	0.28[2]
Post-ganglion	4 (17)	3 (30)	1 (7.7)	
Had prior brachial plexus surgery, n (%)	10 (40)	5 (45)	5 (36)	0.70[2]
Time from injury to muscle transfer, mean (SD), years	2.8 (3.9)	3.0 (4.6)	2.7 (3.4)	0.88[1]
Origin of first muscle transfer procedure, n (%)				
Clavicle	23 (92)	9 (82)	14 (100)	0.18[2]
Other than clavicle	2 (8.0)	2 (18)	0 (0.0)	
Insertion of first muscle transfer procedure, n (%)				
Distal biceps tendon	5 (20)	4 (36)	1 (7.1)	0.084[2]
EDC	17 (68)	5 (45)	12 (86)	
Other	3 (12)	2 (18)	1 (7.1)	
Received post-op anticoagulation, n (%)	20 (80)	9 (82)	11 (79)	>0.99[2]

1Independent t-test; 2Fisher's exact test
* in 2 cases, this data was not extractable from the charts

injuries in our cohort were closed traction injuries. There were no patients with a sharp transection. The mean follow-up duration was 42 ± 38 months.

Statistical Analysis

We described categorical variables with frequencies and percentages. Continuous variables were described with the means and standard deviations. The association between re-operation and continuous variables (age, BMI, time to surgery) were analyzed with the independent t-test for normally distributed variables and the Wilcoxon rank-sum test for non-normally distributed variables. Associations of re-operation with dichotomous and categorical variables were analyzed using the Fisher exact test. Our initially planned multivariable analysis was infeasible due to the low number of FFGT's.

Results

Fourteen out of 25 patients (56%) had at least one reoperation after their FFGT. There was no association between patient, injury or treatment characteristics and the occurrence of reoperation [Table1].

All of the muscle flaps survived and only in one case (4%) was there a need for revision of the vascular anastomosis. More than half of the patients (52%) had a second-staged FFGT and fourteen patients (56%) had a reoperation after a FFGT [Tables 1; 2].

Most reoperations (57%) were due to poor tendon excursion. The first-stage procedures had a higher reoperation rate (57%) than the reoperations resulting from second stage procedures [43%; Table 3]. All four reoperations due to perfusion problems occurred within one day after the index procedure. There were no flap failures. The two reoperations due to wound complications both were performed two days after the index procedure. The remaining eight reoperations due to poor tendon excursion had a median time from the FFGT to the (first) reoperation of 25 months (IQR 20 – 36 months). Of those who had a reoperation, four patients (29%) had more than one reoperation [Table 3]. The indications for these were skin deformity (n=1; 25%), wound complications (n=1, 25%) and poor muscle function (n=2; 50%). In accordance, the performed procedures were skin revision, incision and drainage, scar contracture release, and retensioning the tendon insertion, respectively. Two patients needed a third reoperation for scar contracture release.

Table 2. Characteristics of FFMT surgery

Characteristic	n / reported number
Inflow vessel	
Thoracoacromial artery	17 / 17
Outflow vessel	
Cephalic vein	8 / 21
Thoracodorsal vein	1 / 21
Thoracoacromial vein	8 / 21
> one vein	4 / 21
Type of anastomosis	
End to end	18 / 24
End to side	5 / 24
Both	1 / 24
Nerve supply for FFMT	
Branch of the Flexor carpi ulnaris	1 / 24
Two Intercostal nerves	2 / 24
Phrenic nerve	1 / 24
Medial pectoral nerve	2 / 24
Spinal accessory nerve	18 / 24
Nerve-graft	4 / 20
Had a second-staged procedure	13 / 25

Table 3. Characteristics of reoperations (n = 14)

Characteristic, n (%)	
Stage for reoperation indication	
First stage	8 (57)
Second stage	6 (43)
Indication for reoperation	
Compromised perfusion	4 (29)
Poor tendon excursion	8 (57)
Wound complications	2 (14)
Reoperation procedure	
Incision and drainage	2 (14)
Additional muscle transfer	1 (7.1)
Amputation	1 (7.1)
Nerve anastomosis exploration	1 (7.1)
Pulley creation	1 (7.1)
Tenolysis	3 (21)
Tendon reattachment	1 (7.1)
Vascular revision	4 (29)
More than 1 reoperation	4 (29)

Discussion

Published data indicates that there is a variation in both the incidence of secondary surgery and the indications for reoperation after FFGT to the upper extremity. We found that more than half of the patients who received a FFGT underwent unplanned reoperation and the majority of reoperations were for tendon adhesions or length-tension mismatch.

This study should be interpreted in light of its strengths and limitations. This study comprises of data from two tertiary hospitals in a single metropolitan area. This limits the generalizability of these findings. In addition, the ability to identify cases in our institutional database relies on accurate coding by the surgeon. However, based on prior research, it is unlikely that miscoding would have a noteworthy influence on this study (16). Third, we did not have enough patients who had a FFMT in order to restore upper extremity function to perform a

meaningful statistical analysis. Strengths of this study include that we manually reviewed the identified medical charts, providing a level of detail equivalent to other retrospective studies. Specially, we focused on all complications and unsatisfactory outcomes which required the reoperations which few studies have addressed.

We found that 14 out of the 25 patients in this study (56%) underwent reoperation after primary reconstruction of upper extremity function with a FFGT. The estimated reoperation rates from previous publications varied from nine to 46% in patients receiving a free functional muscle transfer for restoration of upper extremity function after BPI (1, 3, 5, 8, 11, 12). That number might be underestimated compared to our cohort since it was indirectly counted from the outcomes, complications and secondary procedures from their publications.

From the literature reviews, the major causes of free tissue transfer reoperations in early phase were vascular thrombosis (17-19) and partial flap loss (20). We had a higher percentage of patients who had compromised vascular perfusion (four in 25 patients; 16%) compared to other series (1, 5, 8, 11, 12) and all of them underwent reoperation. However, no flap loss was found. The reported survival rates of free functional gracilis transfers varied from 83.3% to 97.3% (3, 5, 8, 11, 12). Of the four patients who underwent re-explorations within 24 hours, three had compromised venous outflows due to hematoma collections and one patient had skin flap monitoring failure but a well-vascularized muscle flap. In our cohort, all vascular explorations were performed within 24 hours after recognition of flap compromise.

Poor tendon excursion was the main indication for reoperation (eight out of 14 reoperations; 57%) in our study. Three patients had a tenolysis procedure and the remaining five patients received unplanned procedures consisting of tendon reattachment, pulley creation, nerve anastomosis exploration, an additional latissimus dorsi muscle transfer and in one case amputation (Table 3). According to the previous studies, tenolysis was reported as one of the common secondary procedure following FFGT (1, 5). Early mobilization programs to treat poor tendon excursion may reduce the need for tenolysis (12, 21). However, all patients in our cohort started their postoperative rehabilitation program six to eight weeks after surgery. Late mobilization may be beneficial to allow maturation of the nerve coaptation and vascular anastomosis, but comes at the cost of tendon adhesions (21).

Tendon reattachment was reported as additional surgery in order to re-tension the gracilis tendon (11). One patient in our study had underwent distal gracilis tendon reattachment to the biceps for elbow flexion with tightening.

Nerve anastomosis exploration was performed in one patient who had poor motor recovery. Another patient had an additional latissimus dorsi muscle transfer for restoration of elbow flexion. The literature reviews also supported the result of latissimus dorsi muscle transfer as a promising procedure for elbow reanimation in patients with traumatic brachial plexus injury (22, 23).

Elective amputation might be requested in some situations. A recent publication proposed the conditions that the patient requested this procedure: Pan-plexus injury; non-recovery after all other surgical options were obtained; and at least one chronic complication for example chronic infection, nonunion fractures, full-thickness burns, chronic neck pain with arm weight (24). Our one patient had performed transhumeral amputation because of non-recovery after FFGT.

Bowstringing has also been reported as the common complication in other studies (8, 13). In our cohort, one patient who had the poor tendon excursion caused from bowstringing problem. In our practice, we used the mobile wad as a pulley and loosening of the mobile wad may have been a consequence of muscle atrophy over time. In the revision procedure, we created a new pulley by utilizing a tensor fascia lata graft. To reduce this complication, previous publication suggested to use the flexor carpi ulnaris as an additional pulley to prevent the bowstringing (25).

Our findings are complementary to prior published studies emphasize that half of patients who underwent free functional muscle transfers in traumatic brachial plexus injury may need reoperation which is relatively common. Reoperation rate should be discussed with the patient as a preoperative strategy. Rapid identification and intervention for vascular compromise of the flap may decrease flap failure. Poor tendon excursion is common unpredicted consequence after FFMT and is the main indication for reoperation.

Disclosure statement: This study was approved by Institutional Review Board in Partners Human Research. All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Informed consent was obtained from all individual participants included in the study. None of the authors has a financial interest in any of the products, devices, or drugs mentioned in this article.

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