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Single Versus Double Tendon Transfer to Improve Shoulder External Rotation During the Treatment of Brachial Plexus Birth Palsy

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Abstract

Background: Tendon transfers are commonly performed in patients with brachial plexus birth palsy (BPBP) to improve function. Transferring 2 tendons in patients with C5-7 injury has the potential complication of loss of midline function. The purpose of this study was to investigate whether a single tendon transfer (1TT) as opposed to the traditional double tendon transfer (2TT) resulted in any differences in functional outcomes in patients with C5-7 BPBP. **Methods:** A retrospective review of all patients with C5-7 BPBP who underwent tendon transfers to improve shoulder external rotation over a 5-year period was performed at 2 institutions. Outcomes were assessed using the modified Mallet (MM) classification scores. **Results:** Twenty-two C5-7 patients had complete records of preoperative and postoperative MM scores, including 11 sex-matched patients in both the 1TT and 2TT groups. When comparing preoperative and postoperative MM categories, there were significant improvements in both the 1TT and 2TT groups for global abduction ($P < .05$ and $P < .01$, respectively) and external rotation ($P < .00001$ for both). Modified Mallet (MM) hand to neck scores were significantly improved in the 2TT group ($P < .05$) but not in the 1TT group ($P = .053$). Internal rotation scores significantly decreased in both groups ($P < .001$). Both groups demonstrated significant increases in total scores from the preoperative MM scores ($P < .01$). **Conclusion**: The 1TT and 2TT procedures result in substantial gains in upper extremity functions for patients with C5-7 BPBP as measured by the MM score, specifically within the global abduction and external rotation subcategories. However, a significant loss occurs in internal rotation for both groups.

Keywords: brachial plexus, nerve, diagnosis, tendon transfer, surgery, specialty, range of motion, shoulder, anatomy, retrospective study, birth injuries, nerve injury, brachial plexus birth palsy, Erb palsy

Introduction

Brachial plexus birth palsy (BPBP) continues to be a substantial issue affecting 1 to 3 per 1000 live births.[1,2] While up to 80% to 90% of BPBP injuries may resolve with minimal long-term functional deficits, 1 center noted that 27%[3] of its referrals had contractures requiring operative intervention to help regain some form of function.[2,4]

Brachial plexus injuries can involve the C5-6 roots (upper trunk/Erb palsy), the C5-7 roots (extended Erb palsy), or all the roots (C5-T1/global). The second most common injury pattern is the extended Erb palsy.[4,5] As shoulder internal rotation contractures are the most common problem requiring treatment in children with incomplete nerve recovery, the primary goal of most surgeries performed on the shoulder for BPBP is to restore its external rotation and abduction.[4]

However, it is important to note that the C5-7 injury pattern presents an especially challenging scenario due to increased involvement of muscles that perform internal rotation (ie, subscapularis, latissimus dorsi, pectoralis major, teres major), whereas a C5-6 injury pattern does not affect these muscles in the same manner. Operative intervention to restore external rotation has traditionally used the transfer of both latissimus dorsi and teres major tendons to the rotator cuff footprint (double tendon transfer [2TT]) to rebalance

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the shoulder and obtain improvements in external rotation and abduction.[6,7] However, this may result in loss of midline function in patients with C5-7 injuries due to an imbalance of excessive external rotation without sufficient internal rotation.[8] Therefore, a modification of the procedure has been proposed where a single tendon transfer (1TT) in C5-7 patients was performed to achieve a more balanced shoulder (external rotation strength = internal rotation strength).

The purpose of this study was to determine whether there were any clinically significant differences between patients undergoing 1TT versus 2TT.

Methods

Study Design

After institutional review board approval was obtained at both institutions in this study, a retrospective review of all patients with BPBP was performed over a 5-year period (2009-2014). One hundred three patients were identified who had been diagnosed with a brachial plexus injury that underwent a tendon transfer about the shoulder with joint reduction. Twenty-five of these patients had an injury involving the C5-7 nerve roots, with 22 of these patients having complete preoperative and postoperative documentation for range of motion (ROM) and modified Mallet (MM) scores. Of the 22 patients who underwent tendon transfers, there were 11 sex-matched patients in each of the 1TT and 2TT groups. Three surgeons were involved in the care of these patients, and all performed the procedure using a very similar technique.[7] Collected information included patient demographics, injury pattern, type of operation, age at operation, complications, and concomitant procedures. Specific outcomes included preoperative and postoperative shoulder abduction ROM and MM scores, which are part of all the attending surgeons' routine examination of patients with BPBP in the outpatient setting. The preoperative data were obtained from the outpatient visit that was in close proximity to the surgical date.

Statistical Analysis

Statistical analysis was performed using Microsoft Excel (2010) and included basic ROM and MM score averages and standard deviations. The Student *t* test was used to assess significance in differences between the 1TT and 2TT groups regarding MM and shoulder abduction ROM values. The significance level was set at $P < .05$.

Results

Demographics

Twenty-two patients were included in the study, with 11 patients in each tendon transfer group. Of the 11 patients in each tendon transfer group, there were 6 men and 5 women.

Preoperative Characteristics

The average age at the time of tendon transfer procedure was 3.6 years (range: 1-5.4 years) in the 1TT and 4.1 years (range: 2.1-12.7) in the 2TT group ($P = .6$). All but 1 patient had a teres major tendon as the single tendon of transfer in the 1TT group.

The average amount of time from the initial documentation of the preoperative to the follow-up postoperative documentation of the MM and shoulder ROM was 22.6 weeks (range: 7.5-38.5 weeks) in the 1TT group and 22.46 weeks (range: 1.2-47.7 weeks) in the 2TT group ($P = .98$).

1TT Versus 2TT Preoperative Assessment

Between the 1TT and 2TT groups, there was no statistically significant difference in the preoperative MM categories of shoulder abduction (+0.09, $P = .63$), external rotation (+0.09, $P = .56$), internal rotation (−0.27, $P = .19$), hand to neck (±0.00, $P = 1.0$), hand to spine (±0.00, $P = 1.0$), hand to mouth (0.33, $P = .13$), MM sum (−0.55, $P = .44$), and shoulder abduction (+10°, $P = .42$) (Table 1).

1TT Preoperative and Postoperative Comparison

Within the 1TT group, the statistically significant differences between the preoperative and postoperative MM categories were shoulder abduction (+0.45, $P = .017$), external rotation (+1.45, $P < .005$), internal rotation (−0.82, $P < .005$), and MM sum (+2.55, $P < .005$). The differences were not statistically significant between the preoperative and postoperative MM categories of hand to neck (+0.36, $P = .053$), hand to spine (±0.00, $P = 1.0$), and hand to mouth (+0.30, $P = .25$). The difference in shoulder abduction ROM was +23° from preoperative to postoperative but was not statistically significant ($P = .10$) (Table 2).

2TT Preoperative and Postoperative Comparison

Within the 2TT group, the statistically significant differences between the preoperative and postoperative MM categories were shoulder abduction (+0.55, $P < .005$), external rotation (+1.55, $P < .005$), internal rotation (−1.18, $P < .0005$), hand to neck (+0.45, $P < .05$), MM sum (+1.82, $P < .0005$), and shoulder abduction ROM (+28°, $P = .005$). The difference between the preoperative and postoperative MM category of hand to spine (±0.00, $P = 1.0$) was not statistically significant (Table 3).

1TT Versus 2TT Postoperative Comparison

Between the 1TT and 2TT groups, there was no statistically significant difference in the postoperative MM categories of shoulder abduction (±0.00, $P = 1.0$), external rotation

Table 1. Modified Mallet and Shoulder ROM Preoperative Single Versus Double Tendon Transfer.

	Shoulder abduction	External rotation	Internal rotation	Hand to neck	Hand to spine	Hand to mouth	Sum	Shoulder abduction ROM
Single tendon	3.27	2.18	3.55	2.00	2.00	2.33	14.55	96
Double tendon	3.18	2.09	3.82	2.00	2.00	2.00	15.09	86
Difference	0.09	0.09	−0.27	0.00	0.00	0.33	−0.55	10
P value	.63	.56	.19	1.00	1.00	.13	.44	.42

Note. ROM = range of motion.

Table 2. Modified Mallet and Shoulder ROM Preoperative Versus Postoperative Single Tendon Transfer.

	Shoulder abduction	External rotation	Internal rotation	Hand to neck	Hand to spine	Hand to mouth	Sum	Shoulder abduction ROM
Preoperative	3.27	2.18	3.55	2.00	2.00	2.33	14.55	96
Postoperative	3.73	3.64	2.73	2.36	2.00	2.64	17.09	119
Difference	+0.45	+1.45	−0.82	+0.36	0.00	+0.3	+2.55	+23
P value	.017	<.005	<.005	.053	1.0	.25	<.005	.10

Note. ROM = range of motion.

Table 3. Modified Mallet and Shoulder ROM Preoperative Versus Postoperative Double Tendon Transfer.

	Shoulder abduction	External rotation	Internal rotation	Hand to neck	Hand to spine	Hand to mouth	Sum	Shoulder abduction ROM
Preoperative	3.18	2.09	3.82	2.00	2.00	2.00	15.09	86
Postoperative	3.73	3.64	2.64	2.45	2.00	3.0	16.91	114
Difference	+0.55	+1.55	−1.18	+0.45	0.00	+1.0	+1.82	+28
P value	<.005	<.005	<.0005	<.05	1.0	.09	<.0005	.005

Note. ROM = range of motion.

Table 4. Modified Mallet and Shoulder ROM Postoperative Single Versus Double Tendon Transfer.

	Shoulder abduction	External rotation	Internal rotation	Hand to neck	Hand to spine	Hand to mouth	MM sum	Shoulder abduction ROM
Single tendon	3.73	3.64	2.73	2.36	2.00	2.64	17.09	119
Double tendon	3.73	3.64	2.64	2.45	2.00	3.0	16.91	114
Difference	0.00	0.00	+0.09	−0.09	0.00	0.36	0.18	5
P value	1.0	1.0	.72	.72	1	.44	.83	.64

Note. MM = Modified Mallet; ROM = range of motion.

(±0.00, P = 1.0), internal rotation (+0.09, P = .72), hand to neck (−0.09, P = .72), hand to spine (±0.00, P = 1.0), hand to mouth (−0.36, P = .44), MM sum (+0.18, P = .83), and shoulder abduction (−5°, P = .64). Overall, there were no complications found within this cohort (Table 4).

Discussion

Loss of midline function can be a serious source of morbidity to the child because many daily activities such as buttoning, dressing, and personal care depend on that movement. However, weakness in external rotation greatly limits the child's ability to reach, throw, and play. Iatrogenic causes of external rotation contracture have been shown in cases when an anterior capsule release and tendon transfer was performed for internal rotation contracture with posterior glenohumeral deformity. Zancolli and Zancolli[9,10] reported on 14 cases, 9 of whom were treated with an anterior capsule release and external rotator muscle transfer. These cases resulted in anterior-inferior subluxation or dislocation of the humerus, which greatly limited internal rotation of the joint. The authors even argued that the "inability to bring the hand over the anterior aspect of the body" was more disabling than the original deficit of external rotation.[9,10] Kambhampati et al[11] treated 183 patients with internal rotation contractures using a subscapularis recession and concurrent derotation osteotomy. The authors noted exceptionally high rates of loss of medial rotation without the osteotomy. Even with the osteotomy, they reported an average of a 10° loss of internal rotation on follow-up.

Our study demonstrates that both 1TT and 2TT show similar and clear improvements in external rotation and decreases in internal rotation following surgical intervention.

A slight correlation between greater improvements in shoulder abduction MM scores and shoulder abduction ROM measures in the 2TT group was found compared with the 1TT group. Significance was found between the preoperative and postoperative shoulder abduction ROM measures for the 2TT group ($P = .005$), whereas the 1TT group did not demonstrate statistical significance in postoperative shoulder abduction ROM changes ($P = .1$). Similarly, there was a greater change observed postoperatively in the MM shoulder abduction category in the 2TT group ($P < .005$) than in the 1TT group ($P = .017$). However, a trend toward increased loss in internal rotation based on the MM categories of internal rotation and hand to mouth for the 2TT group was also observed (MM internal rotation: $P < .0005$; MM hand to mouth: $P = .09$). Meanwhile, the 1TT group demonstrated lesser changes in loss of internal rotation based on the same parameters (MM internal rotation: $P < .005$; MM hand to mouth: $P = .25$). As in the existing literature, no differences were seen in either group in hand-to-spine MM scores postoperatively. Despite these conclusions, this study has a limited number of patients, and therefore, additional studies should be performed to confirm or reject these findings.

While these data do not definitively show 2TT results in increased losses in internal rotation compared with 1TT, it is also possible that the MM scoring system is just not sensitive or specific enough to judge finer increases or decreases in shoulder movement. In general, many authors argue all BPBP movement scales are subject to the user estimates, particularly as young patients can have difficulty in eliciting certain movements.[4] Current literature, along with this study, demonstrates that, ultimately, external rotation contracture can be rebalanced with rotational osteotomy.[1,4]

In conclusion, 1TT and 2TT procedures result in substantial gains in upper extremity functions for patients as measured by the MM score, specifically within the global abduction and external rotation subcategories; however, a significant loss occurs in internal rotation for both groups. The 1TT and 2TT procedures have similar outcomes, and therefore, one should consider performing 1TT surgery in patients with C5-7 to mitigate risk of further decreases in midline function.

Author Contributions

Abzug, Miller, Zlotolow, and Kozin provided substantial contributions to the conception or design of work; helped in acquisition, analysis, or interpretation of data for the work and drafting the work or revising it critically for important intellectual content; and provided the final approval of the version to be published. Case and Hogarth helped in acquisition, analysis, or interpretation of data for the work and drafting the work or revising it critically for important intellectual content and provided the final approval of the version to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethical Approval

This study was approved by the University of Maryland Institutional Review Board.

Statement of Human and Animal Rights

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 (5).

Statement of Informed Consent

Informed consent was obtained when necessary.

Declaration of Conflicting Interests

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