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Comparing the Surgical Outcomes of Modified Quad and Triangle Tilt Surgeries to Other Procedures Performed in Obstetric Brachial Plexus Injury

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ABSTRACT

Purpose: To compare results from our surgical treatment experiences in children with obstetric brachial plexus injuries (OBPI), to those who have had other surgical treatments. **Methods:** We conducted a retrospective study in our medical records consisting of two groups of OBPI patients. **Group 1**: 26 OBPI children (16 girls and 10 boys), age range between 2.0 and 12.0 (mean age 6.9), who have undergone surgical treatments at other institutions between 2005 and 2010. **Group 2**: 45 OBPI children (20 boys and 25 girls), age between 0.7 and 12.9 (mean age 3.7), who have had modified Quad and triangle tilt surgical treatment between 2005 and 2010 at our institution. In both groups Mean modified Mallet scores and radiological scores were measured and compared. All measurements were made at least one year post surgery in both groups. **Results:** Post-operative mean modified Mallet score was 11.8 ± 2.4 in group 1 patients, whereas post-mean modified Mallet score was 20 ± 2.7 ($P < 0.0001$) following modified Quad and triangle tilt surgeries in group 2 patients. Further, their radiological scores such as posterior subluxation, and glenoid version were 13.4 ± 21.3 and −30.2 ± 19.1 in group 1, whereas 32.1 ±13.5 ($P < 0.0004$), and −16.3 ± 11.5 ($P < 0.008$) in group 2 patients, when compared to normal values of 50, and 0 respectively. **Conclusion:** Patients who have had mod Quad and triangle tilt for OBPI obtained significantly better functional outcomes in modified total Mallet score as well as in radiological scores, when compared to those OBPI children, who underwent other procedures such as posterior glenohumeral capsulorrhaphy, biceps tendon lengthening, humeral osteotomy, anterior capsule release, nerve transfer/graft, botox and muscle/tendon transfer and release.

Keywords: Obstetric Brachial Plexus Injury; Triangle Tilt Surgery; Modified Quad Surgery; Modified Mallet; Radiological Score

1. Introduction

Obstetric brachial plexus injuries (OBPI) occur during the delivery process, and the incidence has been reported to vary between 0.38 and 5.8 for every 1000 live births [1-4]. The most frequent pattern of nerve injury occurs in the upper C5-C6 roots (Erb's palsy). Many of these injuries are transient, and therefore several patients recover spontaneously within the first three months of life. However, a significant proportion of these children tend to retain persistent limb deficits, never recover full function and develop permanent injuries [1,5,6].

Inadequate recovery of neurological function in these patients lead to long-term morbidity by causing muscle imbalances and weakness around the shoulder (the deltoid and external shoulder rotators) [7-10], and bony deformities (glenohumeral dysplasia and joint incongruity) [5,11,12]. Early surgical interventions have been shown to improve the limb functions in this group of patients [13,14].

We and other investigators have demonstrated that soft tissue procedures such as muscles release and tendon transfers [15-22] including the modified Quad procedure first described by Narakas and modified by the senior author (RKN) lead to better shoulder abduction and flexion through releasing the existing contractures. However, this procedure does not realign the deformed glenohumeral joint (GHJ). The triangle tilt surgery, developed by the senior author and the surgeon (RKN) has been shown to effectively address these bony deformities, which greatly improves overall functions of the shoulder [23-33]. In

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addition, we have previously demonstrated that this surgical procedure improves shoulder function in OBPI patients with SHEAR deformity [30], and is a salvage procedure in failed humeral osteotomy patients [23,31-33].

2. Patients and Methods

A retrospective study was conducted on children diagnosed with OBPI who came to our clinic with a history of prior operative procedures in other hospitals to correct their deformities before presenting to our institute (group 1), and OBPI children who came to our institute without prior surgeries and undergone triangle tilt and mod Quad surgery to correct their deformities (group 2).

Group 1: 26 OBPI children (16 girls and 10 boys), age range between 2.0 and 12.0 (mean age 6.9), who have undergone surgical treatment at other institutions between 2005 and 2010.

Group 2: 45 OBPI children (20 boys and 25 girls), age between 0.7 and 12.9 (mean age 3.9), who have had modified Quad and triangle tilt surgical treatment between 2005 and 2010 at our institution.

The nerve involvement in group 1 was C5-6 (n = 6), C5-7 (n = 7), and total (n = 13): and in group 2 C5-6 (n = 16), C5-7 (n = 20) and total (n = 9). Prior surgical procedures that the patients in group 1 have undergone at other clinics are included posterior glenohumeral capsulorrhaphy (N = 2), biceps tendon lengthening (N = 1), humeral osteotomy (N = 5), and anterior capsule release (N = 3), nerve transfer/graft (N = 13), botox (6) and muscle/tendon transfer and release (N = 7). We compared statistically the results from other procedures performed in other institutes to the results from our procedures at least with a follow up of one year. In addition, their radiological scores such as posterior subluxation, and glenoid version were measured from CT scans and Magnetic resonance imaging in both groups and compared.

2.1. Clinical Assessment

Patients were evaluated with a physical exam, and through the modified Mallet clinical assessment with video recordings of patients performing the following movements pre- and post-operatively: external rotation, hands to mouth, hands to neck, hands to spine, and supination. For each functional Mallet parameter, patients were scored on a scale of 1 - 5 with 5 as normal function and 1 denoting lack of any movement.

2.2. Radiological Evaluation

CT or MRI images were used to measure the posterior humeral head subluxation (PHHA), glenoid version [34], and SHEAR deformity [35], which evaluate the bony deformities of the patients' shoulder joint before and after triangle tilt surgery. Posterior subluxation of the humeral head, expressed as percentage of humeral head anterior to the glenoid (normal value = 50), was calculated from the ratio of the distance between the scapular line to the anterior aspect of humeral head and the greatest diameter of the head multiplied by 100. The scapular deformity, also referred to as SHEAR deformity, was measured from the 3D reconstructions of the CT images. The area of the scapula visible above the clavicle was measured and divided with the total area of the scapula for both affected and normal sides. The ratio of the affected side was subtracted from that of the normal side and multiplied with 100 to obtain SHEAR deformity (normal value = 0).

2.3. Operative Technique

Group 2 patients have undergone the triangle tilt surgery. This was developed by the lead author, and this procedure has been shown to have successful outcomes in OBPI patients [23-33]. The operative technique includes clavicle osteotomy at the intersection of its middle and distal third, acromion osteotomy at its intersection with the scapular spine and osteotomy of the scapula followed by splinting of the limb in adduction [23-33]. Group 2 patients have also undergone the transfer of the latissimus dorsi and teres major muscles, release of contractures of subscapularis pectoralis major and minor and axillary nerve decompression and neurolysis (the modified Quad procedure) [17,36]. The surgeon and the lead author (RKN), who has over 17 years of experiences in this field with several thousand OBPI patients performed all surgical procedures.

2.4. Statistical Analysis

The Student's t test statistic was applied to compare the mean Mallet scores and bony parameters between the both groups using the "Analyse it" plugin (Leeds, UK) for Microsoft Excel 2003. A value of $P < 0.05$ was considered to be statistically significant.

3. Results and Discussion

The 26 OBPI patients from group 1 in our present study have had one or multiple surgical treatments with other surgeons before visiting our clinic (**Table 1**). These patients have undergone at least one of the following traditional approaches that are aimed to treat OBPI such as nerve transfer, contracture release, axillary nerve decompression, and external derotational osteotomy of the humerus.

Conventional surgical approaches fail to address the scapular hypoplasia, elevation and rotation (SHEAR) deformity [35] associated with most OBPI cases. Therefore, these patients had poor functions (mean modified

Table 1. Surgical outcome of other surgeons.

Patient	Gender	Age	Surgeries at other clinic	Modified Total Mallet
1	F	2.5	Humeral head reposition	13
2	M	6.5	Nerve graft, Shoulder capsular release	11
3	F	4.1	Nerve transfer	13
4	F	12	Nerve graft	11
5	F	2.0	Nerve graft	12
6	M	12	Nerve graft	11
7	M	10.5	Nerve transfer	5
8	F	7.1	Nerve graft	11
9	M	5.5	Humeral osteotomy, coracoacromion release	14
10	F	10.5	Humeral osteotomy	8
11	F	9.0	Humeral osteotomy	14
12	M	11.2	Muscle transfer & release	10
13	F	5.0	Nerve graft	10
14	M	3.5	Botox	12
15	M	1.9	wrist capsular release	12
16	F	2.0	Neurolysis	11
17	F	12.3	Nerve graft	9
18	F	8.5	Capsular release	12
19	F	12.0	Acromionclavicular release	14
20	M	4.3	Tendon transfer & Neurolysis	13
21	F	4.5	Brachial Plexus Exploration	17
22	F	6.7	Nerve transfer	11
23	F	6.8	Tendon transfer	14
24	M	7.9	Muscle transfer & release	15
25	M	2.0	Brachial Plexus Exploration	13
26	F	10.0	Muscle & tendon transfer & release	12

Mean: 11.8; STD: 2.4.

Mallet score was 11.8 ± 2.4 (**Table 1**, **Figures 1** and **2**), and anatomical structures (mean PHHA 13.4 ± 21.3, version −30.2 ± 19.1, and SHEAR 15.5 ± 15.1; **Table 2**, **Figures 3** and **4**). Normal values are PHHA 50, glenoid version 0 and SHEAR 0.

In group 2 all the patients had poor shoulder abduction and flexion due to C5 injury present in all patients prior to surgery. The mod Quad procedure addresses these deformities, yet it does not address the SHEAR, and does not realign the deformed glenohumeral joint (GHJ). Therefore, the triangle tilt surgery was performed on these patients. This procedure has been shown to effectively address these bony deformities, and improves overall functions of the shoulder [23-33]. The functional benefits of mod Quad [17], and triangle tilt surgeries have been extensively discussed in our previous publications [23-33]. After undergone these two surgical proce-

Figure 1. Modified Mallet functions performed by OBPI children, who have had surgeries at other clinic before presenting to us.

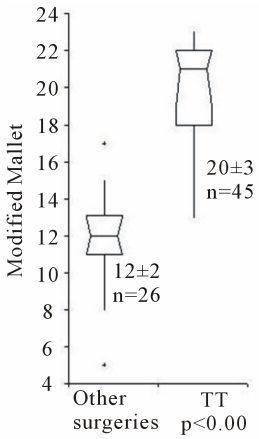

Figure 2. Statistical comparison of modified total Mallet of OBPI patients, who have had surgeries at other clinic with OBPI patients, who have had modified Quad and triangle tilt surgeries at our clinic.

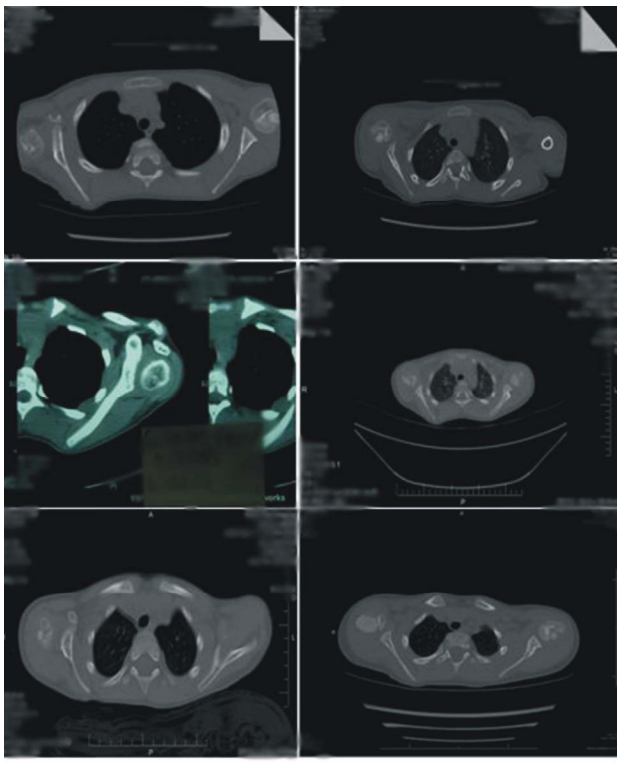

Figure 3. Comparison of CT images of OBPI patients, who have had surgeries at other clinic with OBPI patients, who have had modified Quad and triangle tilt surgeries at our clinic.

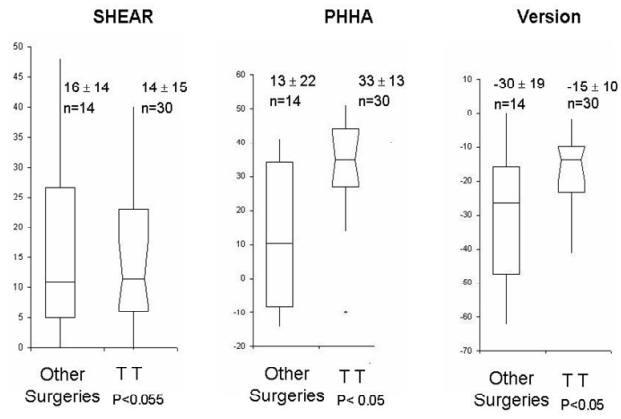

Figure 4. Statistical comparison of radiological scores of OBPI patients, who have had surgeries at other clinic with OBPI patients, who have had modified Quad and triangle tilt surgeries at our clinic.

dures with us, the group 2 patients have better results (mean Mallet score was 20 ± 2.7; **Table 3**, **Figures 2** and **5**), which is statistically significant ($P < 0.0001$), when compared to the group 1 patients (mean Mallat score 11.8 ± 2.4; **Table 1**, **Figures 1** and **2**).

There was statistically significant improvement anatomically in group 2 patients, who have undergone train-

Figure 5. Modified Mallet functions performed by OBPI children, who have had modified Quad and triangle tilt surgeries at our clinic.

Table 2. Anatomical outcome (radiological scores) of other surgeries in OBPI.

Patient	Gender	Age at TT	Surgeries at other clinic	PHHA affected	Version affected	SHEAR affected
1	M	6.5	NG	8	−47	
2	F	2.0	NG	−7	−62	8
3	M	12	NG	34	−20	0
4	M	10.5	NT	33	−16	15
5	M	5.5	NG	−12	−51	30
6	F	10.5	HO	13	−20	7
7	M	9.0	HO	39	0	9
8	F	5.0	NG	38	−10	0
9	M	3.5	BO	−8	−38	11
10	F	2.0	NL	−14	−33	25
11	F	12	NG	0	−45	32
12	F	12	ACR	−11	−53	48
13	M	3.0	NL	33	−18	1
Mean ± STD				11.2 ± 21.3	−31.8 ± 19.1	15.5 ± 15.1

gle tilt (mean PHHA, and glenoid version were 32.1 ± 13.5 and −16.3 ± 11.5 respectively; **Table 2** and **Figures 3** and **4**) than those who have undergone other procedures (mean PHHA and glenoid version were 13.4 ± 21.3 and −30.2 ± 19.1 respectively; **Table 4**, **Figures 3** and **4**). There was no significant difference in the outcome of SHEAR deformity between these two groups.

4. Conclusion

We have demonstrated in this report, the triangle tilt and modified Quad surgeries resulted in significantly better glenohumeral congruity and shoulder abduction respect-

Table 3. Surgical outcome of triangle tilt.

No	Gender	Age at TT	Post-TT Total Mallet
1	F	1.3	23
2	F	2.8	21
3	M	7.5	18
4	F	1.5	21
5	F	3.0	19
6	M	12.9	16
7	F	2.5	23
8	F	1.3	23
9	M	2.2	21
10	M	7.3	19
11	F	0.8	23
12	F	9.3	17
13	M	1.7	19
14	F	1.9	22
15	M	3.0	23
16	F	1.3	22
17	F	3.6	20
18	M	0.7	21
19	M	11.6	16
20	F	1.5	15
21	M	3.5	21
22	F	3.8	19
23	F	2.3	16
24	M	1.6	23
25	F	3.2	18
26	M	1.3	23
27	F	0.9	16
28	M	3.8	16
29	F	2.5	23
30	F	1.8	23
31	F	7.5	21
32	F	2.8	22
33	F	8.5	19
34	M	1.1	18
35	F	3.0	22
36	F	1.8	17
37	M	2.0	22
38	M	7.9	21
39	F	5.8	16
40	M	2.8	23
41	M	1.3	21
42	M	7.3	13
43	M	2.8	21
44	M	1.7	22
45	F	7.9	22

Mean ± STD: 20 ± 2; P value: <0.0001.

Table 4. Anatomical outcome (radiological scores) of traingle tilt.

No	Gender	Age at TT	Post-op PHHA-affected	Post-op version affected	Post-op SHEAR-affected
1	F	9.39	29	−22	24
2	M	1.72	31	−12	29
3	F	1.90	38	−2	6
4	F	5.90	43	−6	9
5	F	1.87	46	−13	23
6	M	7.37	15	−45	37
7	M	2.82	38	−7	0
8	M	8.02	−10	−41	18
9	M	3.81	17	−30	3
10	F	2.80	50	−4	21
11	M	2.21	38	−7	0
12	M	3.08	27	−16	17
13	F	3.82	42	−11	5
14	F	2.35	46	−12	6
15	F	1.50	34	−10	−1
16	M	1.33	50	−5	23
17	M	1.11	34	−20	11
18	F	1.34	21	−39	18
19	F	2.58	36	−19	7
20	M	1.65	27	−19	12
21	F	0.78	26	−10	9
22	F	2.53	14	−27	40
23	F	1.36	44	−14	8
24	M	1.28	45	−10	7
25	F	3.29	49	−31	30
26	F	3.68	33	−26	12
27	M	13.10	28	−23	11
28	F	2.88	44	−13	17
29	M	1.66	51	−3	3
30	M	1.92	28	−20	25
Mean		32.1		−16.3	14.1
STD		13.5		11.5	10.9
P value		0.0004		0.008	0.76

ively, and thus overall shoulder functions, when compared to the results obtained in those OBPI patients who have had other traditional surgeries at other institutes.

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