

Triangle tilt and humeral surgery: Meta-analysis of efficacy and functional outcome

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Abstract

AIM: To systematically review and analyze the overall impact and effectiveness of bony surgical procedures, the triangle tilt and humeral surgery in a comparative manner in permanent obstetric brachial plexus injury (OBPI) patients.

METHODS: We conducted a literature search and identified original full research articles of OBPI patients treated with a secondary bony surgery, particularly addressing the limitation of shoulder abduction and functions. Further, we analyzed and compared the efficacy and the surgical outcomes of 9 humeral surgery

papers with 179 patients, and 4 of our secondary bony procedure, the triangle tilt surgical papers with 86 patients.

RESULTS: Seven hundred and thirty-one articles were identified, using the search term "brachial plexus" and obstetric or pediatric (246 articles) or neonatal (219 articles) or congenital (188 articles) or "birth palsy" (121 articles). Further, only a few articles were identified using the bony surgery search, osteotomy "brachial plexus" obstetric (35), "humeral osteotomy" and "brachial plexus" (17), and triangle tilt "brachial plexus" (14). Of all, 12 studies reporting pre- and post-operative or improvement in total Mallet functional score were included in this study. Among these, 9 studies reported the humeral surgery and 4 were triangle tilt surgery. We used modified total Mallet functional score in this analysis. Various studies with humeral surgery showed improvement of 1.4, 2.3, 5.0 and 5.6 total Mallet score, whereas the triangle tilt surgery showed improvement of 5.0, 5.5, 6.0 and 6.2.

CONCLUSION: The triangle tilt surgery improves on what was achieved by humeral osteotomy in the management of shoulder function in OBPI patients.

Key words: Meta-Analysis; Triangle tilt surgery; Humeral osteotomy; Obstetric brachial plexus injury; Birth palsy; SHEAR deformity; Shoulder function; Mallet score

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Core tip: We systematically reviewed, analyzed and compared the surgical outcomes of 9 humeral surgery papers with 179 permanent obstetric brachial plexus injury patients (OBPI), and 4 of our secondary bony procedure, the triangle tilt surgical papers with 86 OBPI patients. We used modified total Mallet functional score in this analysis. Studies with humeral surgery showed improvement of 1.4, 2.3, 5.0 and 5.6 total Mallet score,

whereas the triangle tilt surgery showed improvement of 5.0, 5.5, 6.0 and 6.2. The triangle tilt surgery improves on what was achieved by humeral osteotomy in the management of shoulder function in OBPI patients.

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INTRODUCTION

Bone deformities and their management in permanent obstetric brachial plexus injury children

Limitation to shoulder movement and function are the common secondary problems in permanent obstetric brachial plexus injury (OBPI) patients, as shoulder is the most frequently affected joint. If these infants do not receive early treatment, the chronic muscle imbalance leads to bone deformity and humeral head posterior subluxation.

To date, there has been no systematic evaluation of secondary bony surgical procedures that are involved in the treatment of shoulder function deficit in OBPI patients. Therefore, we attempted to systematically review and analyze the overall impact and effectiveness of bony surgical procedures, mainly the triangle tilt and humeral surgery in a comparative manner. The main goal of these secondary surgical procedures around the shoulder is to increase active abduction and external rotation in order to promote overall upper extremity functions.

Rotation/Derotational Humeral Osteotomy

Rotation osteotomy of the humerus has been described by several authors to treat the internal rotation contracture of the shoulder in OBPI^[1-15]. Eng *et al*^[2] reported that later surgical treatment with rotational osteotomy of the humerus seems to improve cosmesis but not function. Recently, Al-Qattan^[9] has also shown that this procedure mainly improves the cosmetic appearance of children with total brachial plexus birth palsy. In addition, Al-Qattan *et al*^[8] also found surprisingly, a significant ($P = 0.003$) decrease in shoulder abduction on long-term follow-up of his OBPI patients (the mean shoulder abduction was 135°, 146° and 109° measured pre-, early post- and late postoperatively, respectively). This technique has been used as a preferred procedure in older OBPI children^[1,11,12,14], and shown to improve shoulder function^[1,12], yet was not demonstrated as effective^[8,9,13] procedure comparatively^[16-18].

Waters *et al*^[12], Waters *et al*^[1] showed improvement of 5.0, and 5.6 in total Mallet score after humeral osteotomy. The efficacy and functional outcomes of the triangle tilt and humeral surgery are listed in Tables 1 and 2.

Triangle tilt surgery

The triangle Tilt is a novel osseous procedure, consists of osteotomy of the clavicle at the junction of the middle and

outer thirds, osteotomy of the acromion at its junction with the spine of the scapula, osteotomy of the superomedial angle of the scapula and splinting of the limb in adduction, 5° of external rotation and full forearm supination.

Humeral surgeries do not address the SHEAR deformity^[19] and its central influence in the pathophysiology of the medial rotation contracture, and the shoulder deformity. In our experience, successful restoration of position and function in failed humeral osteotomy patients has followed from surgically addressing the SHEAR deformity. It may be inferred that the SHEAR correction, the triangle tilt surgery is a more specific operation because it addresses the root cause of the medial rotation.

We have shown improvement of 5.0, 5.5, 6.0 and 6.2 Mallet score following short and extended-long term (5 years) follow-up of triangle tilt surgery respectively in OBPI patients, age between 0.9 and 17 year^[16-18]. Further, the triangle tilt surgery is a salvage procedure in failed humeral osteotomy patients^[16,20].

MATERIALS AND METHODS

We performed a search of the English language literature published up to December 2013 using mainly the Pubmed to identify full original research articles related to OBPI, using the following keywords “brachial plexus” and obstetric or pediatrics or neonatal or congenital or “birth palsy”. We conducted search for also keywords specific to bony surgeries addressing the shoulder deformities in OBPI: “humeral osteotomy”, “rotational/derotational osteotomy of the humerus”, “humeral relocation”, and “triangle tilt”. Databases such as Scopus and Google scholar were also referred. We do not find any of the articles not published in Pubmed appeared in Scopus. If any such articles appear in Scopus, mostly they are either non-English or with animal experiments. Of all the articles, we found 9 studies with humeral and 4 with triangle tilt surgery, reporting pre- and post- operative or change in total Mallet score (Table 3).

Inclusion and exclusion criteria

Review articles, letter, technical and non-English language papers were excluded. Research articles using animal experiments and cadaver were also excluded. Articles reporting data from idiopathic or traumatic brachial plexus injuries in children were excluded as well (Table 4).

We included only articles using the triangle tilt and humeral surgery, reporting pre- and post- operative or change in total Mallet functional score in OBPI patients. 8 studies described the rotational osteotomy of the humerus with 166 patients, 1 described the relocation of the humerus with 13 patients, and 4 described triangle tilt surgery with 86 patients were included. Modified Mallet classification system was considered to assess the shoulder functions in this analysis (Table 1).

RESULTS

Seven hundred and thirty-one articles were identified, using the search term “brachial plexus” and obstetric or

Table 1 Bony surgical procedures and outcomes in obstetric brachial plexus injury patients

Name of the surgery	Ref.	No. of patients (age at surgery)	Follow-up (yr)	Surgical outcomes
Internal/external rotational/ derotational osteotomy of the humerus	Abzug <i>et al</i> ^[13]	23 patients Mean age 10.1	2.2	13.8 ± 2.8, 16.1 ± 2.5 ($P = 0.002$), Mallet increased about 2.3
	Al-Qattan ^[7]	15 patients mean age 6.5	3	Mallet increased about 4.0
	Al-Qattan <i>et al</i> ^[9]	13 patients mean age 6 (4.5-9)	2	Improved the cosmetic appearance
	Al-Qattan ^[8]	17 patients mean age 6 (range 8-14) Recalled back to the clinic at a mean of 10 yr (range 8-14) after surgery. Mean age of 16, (range 13-20)	10	Found surprisingly, a significant ($P = 0.003$) decrease in shoulder abduction on long-term follow-up (the mean shoulder abduction was 135°, 146° and 109° measured pre-, early post- and late postoperatively, respectively)
	Waters <i>et al</i> ^[11]	16 patients mean age 8.4	3	Mallet improved 9.5 to 15.1 ($P < 0.001$)
	Waters <i>et al</i> ^[12]	27 patients mean age 7.6 range 2. 3-17	3.7	Mallet improved 13 to 18 ($P = 0.01$). External rotation achieved with osteotomy was 64° (range, 35° to 90°)
	Pöyhiä <i>et al</i> ^[15]	5 patients	3.8	Mallet increased about 1.4 ($P = 0.1$)
	Kirkoset <i>et al</i> ^[14]	22 patients mean age 10.0 age range 5-12	Vary, no mean	Increase in active abduction of the arm was 27° (range, 0 to 60), and the average increase in the arc of rotation was 25° (range, 5 to 85)
	Al-Zahrani ^[6]	12 patients age range 0.5 to 6	3.5 (1-5)	Cosmetic and functional improvement. ER improved 32° (20-40), abduction improved about 61° (60-70). Mallet increased about 5.5 ($P = 0.003$)
	Pöyhiä <i>et al</i> ^[15]	13 patients	3.8	Mallet improved 12.8 to 18.3 ($P < 0.05$)
Relocation of the humerus Triangle Tilt surgery	Nath <i>et al</i> ^[16]	4 patients, mean age 10.2 (range 7.9-11.9)	< 1.0	Mallet improved 13.6 to 18.6 ($P < 0.000$)
	Nath <i>et al</i> ^[17]	40 patients, mean age 6.5 (range 2.2-10.3)	1.3	Mallet improved about 6.0 ($P < 0.001$)
	Nath <i>et al</i> ^[20]	20 patients, mean age 5.0 (range 1.3-13)	1.5	Mallet improved 14.1 to 20.3 extended long term follow-up (5 yr, $P < 0.0001$)
	Nath <i>et al</i> ^[18]	22 patients, mean age 5.8 (range 2.1-11.8)	5	

Table 2 Improvement in functional score of triangle tilt and humeral surgery

Surgery	Ref.	Total Mallet improved
Humeral osteotomy	Abzug <i>et al</i> ^[13]	2.3 ($P < 0.002$)
Humeral osteotomy	Waters <i>et al</i> ^[11]	5.6 ($P < 0.001$)
Humeral osteotomy	Waters <i>et al</i> ^[12]	5.0 ($P = 0.01$)
Humeral osteotomy	Pöyhiä <i>et al</i> ^[15]	1.4 ($P = 0.1$)
Relocation of the humerus	Pöyhiä <i>et al</i> ^[15]	5.5 ($P = 0.003$)
Triangle tilt	Nath <i>et al</i> ^[16]	5.5 ($P < 0.05$)
Triangle tilt	Nath <i>et al</i> ^[17]	5.0 ($P < 0.000$)
Triangle tilt	Nath <i>et al</i> ^[20]	6.0 ($P < 0.001$)
Triangle tilt	Nath <i>et al</i> ^[18]	6.2 ($P < 0.0001$)

pediatric (246 articles) or neonatal (219 articles) or congenital (188 articles) or “birth palsy” (121 articles). Further, only a few articles were identified using the bony surgery search, osteotomy “brachial plexus” obstetric (35), “humeral osteotomy” and “brachial plexus” (17), and triangle tilt “brachial plexus” (14).

Of all, 12 studies reporting pre- and post- operative or improvement in total Mallet functional score were included in this study. Among these, 9 studies reported humeral surgery and 4 were triangle tilt surgery. We used modified total Mallet functional score in this analysis. Various studies with humeral surgery showed improve-

Table 3 Research articles in English only included

Search term	Pubmed	Scopus
“Brachial plexus” obstetric	731	620
“Brachial plexus” pediatric	246	176
“Brachial plexus” neonatal	219	226
“Brachial plexus” congenital	188	259
“Brachial plexus” “birth palsy”	121	115
Bony Surgery search		
Osteotomy “brachial plexus” obstetric	35	34
“Humeral osteotomy” “brachial plexus”	17	23
Osteotomy “brachial plexus” “birth palsy”	11	13
Osteotomy “brachial plexus” congenital	8	14
Osteotomy “brachial plexus” pediatric	10	8
Osteotomy “brachial plexus” neonatal	0	3
Triangle tilt “brachial plexus”	14	8

Table 4 Inclusion Criteria

Article parameters	Original full research paper with secondary bony surgical outcome of obstetric brachial plexus injury patients, English language publication, published till December 2013 in PubMed
Treatment options	Surgical-bony, humeral, triangle tilt
Patient age range	9 mo-18 yr old
Functional outcome	Improvement in total Mallet score

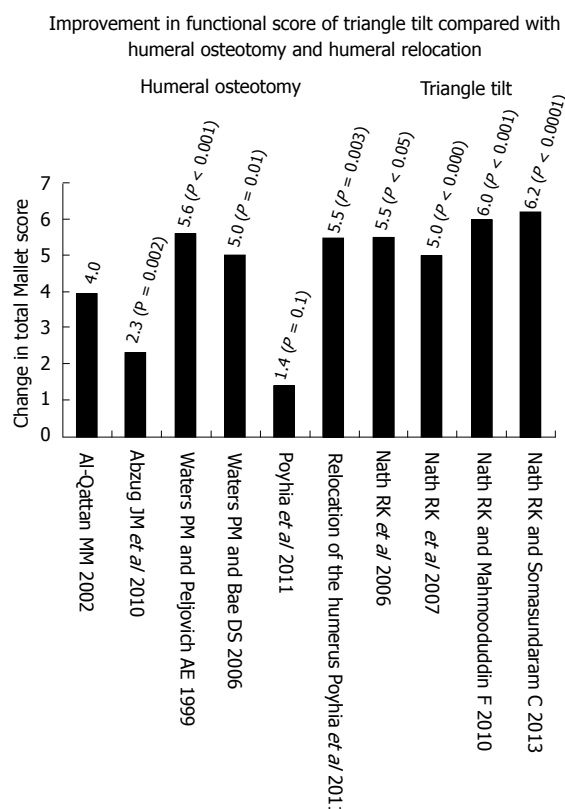


Figure 1 Improvement in functional score of triangle tilt compared with humeral osteotomy and humeral relocation.

ment of 1.4, 2.3, 5.0, and 5.6 total Mallet score, whereas the triangle tilt surgery showed improvement of 5.0, 5.5, 6.0 and 6.2 (Table 2 and Figure 1).

DISCUSSION

To our knowledge, this is the first attempt to review and analyze the surgical outcomes of the humeral and triangle tilt surgical procedures, that are involved in the management of shoulder function of OBPI patients. In examining restoration of shoulder function, the results of the meta-analysis suggest that the triangle tilt surgery improves on what was achieved by humeral osteotomy.

COMMENTS

Background

Limitation to shoulder movement and function are the common secondary problems in permanent obstetric brachial plexus injury (OBPI) patients, as shoulder is the most frequently affected joint. If these OBPI infants do not receive early treatment, the chronic muscle imbalance leads to bone deformity and humeral head posterior subluxation. To date, there has been no systematic evaluation of secondary bony surgical procedures that are involved in the treatment of shoulder function deficit in OBPI patients. Therefore, the authors attempted to systematically review and analyze the overall impact and effectiveness of bony surgical procedures, mainly the triangle tilt and humeral surgery in a comparative manner. The main goal of these secondary surgical procedures around the shoulder is to increase active abduction and external rotation in order to promote overall upper extremity functions.

Research frontiers

The authors systematically reviewed, analyzed and compared the surgical outcomes of 9 humeral surgery papers with 179 permanent OBPI, and 4 of this

secondary bony procedure, triangle tilt surgical papers with 86 OBPI patients. The authors used modified total Mallet functional score in this analysis. Studies with humeral surgery showed improvement of 1.4, 2.3, 5.0 and 5.6 total Mallet score, whereas triangle tilt surgery showed improvement of 5.0, 5.5, 6.0 and 6.2. The triangle tilt surgery improves on what was achieved by humeral osteotomy in the management of shoulder function in OBPI patients.

Innovations and breakthroughs

Triangle tilt surgery, a novel osseous surgical procedure developed by the lead author and surgeon, improves on what was achieved by humeral osteotomy in the management of shoulder function in OBPI patients. This is the first report comparing the secondary bony surgical procedures in OBPI patients.

Applications

The triangle tilt surgery showed significant improvement of shoulder functions when compared to humeral surgery in OBPI patients.

Terminology

Meta-analysis, Triangle tilt surgery, humeral osteotomy, obstetric brachial plexus injury, Birth palsy, SHEAR deformity, Shoulder function, Mallet score. Triangle tilt surgery: This operative technique includes osteotomies of the clavicle, neck of the acromion and scapula in order to release the distal acromioclavicular triangle and allow it to reorient itself in a more neutral position into the glenoid.

Peer review

This is a review concerning the beneficial effect of the triangle tilt surgery and humeral surgery in permanent OBPI patients from the literature. The review was comprehensive and should be published.

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