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Original Article

THE EFFECT OF TENDON TRANSFERS AND GLENOHUMERAL REDUCTION IN CASES OF O.B.P.P. WITH INTERNAL ROTATION CONTRACTURE

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Abstract
***Background**: Brachial plexus birth palsy (BPBP) occurs in 1.5 per 1,000 live births, resulting from traction to the brachial plexus during delivery. Surgical treatment of the secondary shoulder dysfunction following BPBP aims to accomplish three goals: restoration of passive motion by contracture release, realignment of dysplastic glenohumeral joint, and augmentation of muscle power in the weak domains of shoulder movement. **Objectives**: To study the importance of reduction of the glenohumeral joint with soft tissue release and tendon transfer in treatment of internal rotation contracure deformity of shoulder in cases of O.B.P.P. **Patients and methods:** This prospective study was done in Microsurgery Unit Orthopedic department, Sohag University Hospitals including all patients with brachial plexus birth palsy with internal rotation contracure of the shoulder with mild to moderate glenohumeral dysplasia. The patients included in this series had a diagnosis of brachial plexus birth palsy and glenohumeral dysplasia classified as type II, III, or IV on the Waters scale; had undergone joint reduction, soft-tissue rebalancing, and tendon transfers; and the average follow up was three years. **Results:** Mean glenoid version improved from -33° to -7° following muscle rebalancing and soft-tissue releases. The percentage of the humeral head anterior to the middle of the glenoid improved from 8% to 43%. The average duration of clinical and radiographic follow-up was thirty-six months; improvements in both shoulder motion and glenohumeral joint morphology were seen early and were maintained during the follow up period. **Conclusion:** Latissimus dorsi and teres major tendon transfers to rotator cuff, combined with appropriate extra-articular musculotendinous lengthenings and joint reduction, result in improved shoulder function and glenohumeral joint remodeling in the majority of patients with brachial plexus birth palsy with mild to moderate dysplasia.*

Keywords: *Brachial plexus, Glenohumeral dysplasia, Glenoid, Osteotomy.*

1. Introduction

Brachial plexus birth palsy (B.P.B.P) occurs in approximately 1.5 per 1,000 live births [1] and is presumed to result from traction to the brachial plexus during delivery. The natural history of BPBP is less favorable than historically believed, with twenty to forty percent children experiencing incomplete neurological recovery [2,3]. In these children with persistent paralysis, secondary contractures can occur, most notably shoulder internal rotation contractures [4,5]. These contractures significantly impair function and quality of life and are the most common reason for surgery following BPBP [5-8]. Thus, historically, surgery for the so-called "secondary" problems at the shoulder have focused on restoring passive range of motion by releasing contractures and improving active range of motion by way of muscle transfers. These "palliative" interventions were typically performed only after optimal nerve reconstructive surgery had been exhausted or after spontaneous recovery had plateaued. However, the landscape has changed dramatically in recent years, spurred primarily by two quantum leaps in the understanding of the problem. First, the contracture at the shoulder has been clearly shown to be associated with progressive skeletal dysplasia of the glenohumeral joint [9]. This dysplasia begins with increased retroversion of the glenoid and leads to complete posterior dislocation of the glenohumeral joint with humeral head flattening, loss of glenoid concavity, and pseudoglenoid formation. Second, this dysplasia occurs much earlier than previously thought, with nearly 10 % of infants progressing to glenohumeral dislocation in the first year, even as early as 3 months. Thus, it is not unusual to be faced with a dislocated shoulder that needs to be addressed with "secondary" procedures even before the child is old enough to determine if "primary" nerve surgery is necessary [10,11]. Recognition of the early development of glenohumeral dysplasia is of critical importance in the management of the shoulder following BPBP, as early treatment of the glenohumeral joint deformity can alter the long-term course of shoulder development and function. Surgical management to address limitation of active external rotation depends on the severity of the problem, and the general functionality of the limb and the age of the child must be taken into consideration. However, it is still unknown beyond what age remodeling is no longer possible or the severity of glenohumeral deformity that can remodel. Nonetheless, the possibility of restoring normal skeletal structure with early surgery underscores the importance of early detection of glenohumeral dysplasia [12]. The waters scheme [9] is used to classify the severity of glenoid dysplasia on the basis of the degree of glenoid retroversion, posterior subluxation of the humeral head, and shape of the glenoid and humeral head. In the presence of mild glenohumeral dysplasia (Waters types I and II), recovery of functionally useful external rotation is reliably achieved with soft-tissue rebalancing, typically consisting of open or arthroscopic subscapularis tendon lengthening and transfer of the teres major and/or latissimus dorsi muscles to the posterior aspect of the rotator cuff or proximal part of the humerus [12,16]. For moderate deformity (Waters type III, IV), earlier soft-tissue rebalancing and tendon transfers in isolation yielded discouraging results because of their inability to reliably reduce the joint and restore external rotation function [9,14]. More recently, arthroscopic [112,17,18] and open [19-21] procedures involving joint reduction, with or without tendon transfer, have been shown to be effective at maintaining concentric reduction as well as at reducing and gradually remodeling dysplastic joint. The upper limit of dysplasia severity and patient age for the successful application of joint level procedures is not clear. Traditionally, the approach to severe glenohumeral dysplasia (Waters types V, VI and VII) has been to not attempt soft-tissue rebalancing, but rather to transpose the existing arc of motion to a more functional range by performing an external rotation osteotomy of the proximal part of the humerus [22-24]. Most of these good results were achieved in children younger than eight years of age, with the most robust radiographic remodeling noted in those younger than four years of age.

2. Patients and Methods

This prospective study had done in the Microsurgery unit, Orthopedic Department, Sohag University Hospitals and had included all patients with brachial plexus birth palsy with internal rotation contracure of the shoulder with mild to moderate glenohumeral dysplasia. The protocol of the study will be approved by the Scientific and Ethical committee at

Sohag Faculty of Medicine. An informed written consent will be obtained from all participants. After the end of the study, the study will be approved by the Scientific and Ethical committee. The patients included in this series had a diagnosis of brachial plexus birthpalsy and glenohumeral dysplasia classified as type II, III or IV on the Waters scale; had undergone soft-tissue rebalancing, and tendon transfers with open joint reduction and the average follow up was 3 years.

2.1. *Preoperative assessment*

Clinical evaluation will be done using the modified Mallet score and Toronto Active Movement Scale as well as passive and active shoulder range of motion. Radiological evaluation will be done by using axial plane imaging {MRI or CT} of both shoulders to measure glenoid version, the degree of subluxation, and waters type

2.2. *Surgical technique*

The child was placed in a supine position under general anesthesia with a small support under the ipsilateral scapula. The ipsilateral shoulder and the whole upper limb were sterilized and became free. A deltopectoral incision was made. The coracoid process was exposed, fig. (1). The periosteum was incised longitudinally. The medial part attached to the pectoralis minor was retracted medially. The lateral part attached to the coracoacromial ligament retracted laterally.

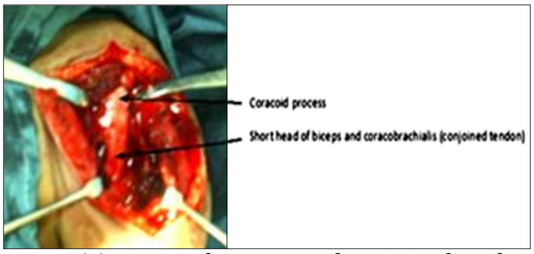

Figure (1) Coracoid process and conjoined tendon

The base of the coracoid was osteotomized. The coracobrachialis and the short head of the biceps attached to the coracoid were felt downward. The pectoralis minor with neurovascular was retracted medially. The subscapularis was exposed with external rotation of the shoulder, fig. (2).

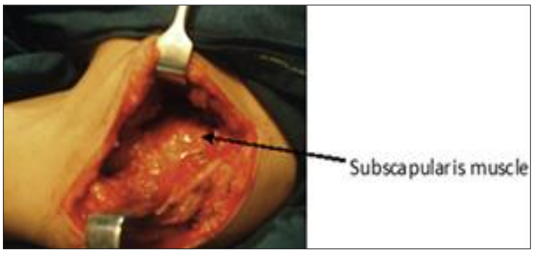

Figure (2) Intraoperative photograph showing subscapularis muscle

Long curved mosquito was passed below the subscapularis tendon. It made plain cleavage between the tendon and the capsule. A step-cut lengthening of the subscapularis tendon was made, leaving the laterally based flap superior. Then a closed reduction of the glenohumeral joint was done with keeping the arm in abduction and external rotation position. The subscapularis tendon was closed with the arm in the same position of external rotation and abduction. Re-attachment of the pectoralis minor with the coracobrachialis and short head of the biceps tendon was performed after excision of the attached coracoid. A second incision was made along the posterior axillary fold running downward along the anterior border of the latissimus dorsi and the teres major muscles, 4 cm in length**.** The latissimus dorsi and teres major tendons were easily identified with the arm abducted**.** They were well separated from the surrounding soft tissues until their insertion into the bone. They were detached from their insertion carefully after protecting the neurovascular bundle. It was important that there was no need to see the neurovascular bundles. Release of the latissimus dorsi and teres major tendons and muscles from the surrounding soft tissues, skin, and the lateral border of the scapula was necessary to gain enough length to do rerouting without the need for tendon graft or even tendon lengthening. Rerouting was performed with marked external rotation and suturing of the latissimus dorsi and teres major tendons to the periosteum of the lateral border of the humerus near the rotator cuff muscles, fig. (3).

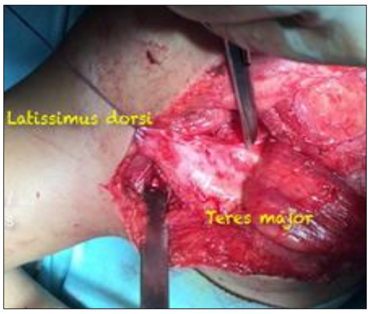

Figure (3) Harvesting the two tendons (the teres major and latissimus dorsi tendons) from their periosteal insertions in the humerus.

After subcuticular skin closure, the arm was placed in a cast connected to a body corset to maintain the shoulder in a 90-degree abduction and maximum external rotation. There were neither immediate nor late neurovascular complications. There was neither superficial nor deep infection. The cast was removed after 6 weeks. Home physiotherapy and passive exercise were carried out for further 2 weeks. Physiotherapy program and active exercise were performed 2 months postoperatively

2.3. *Postoperative plan*

Maintain the spica cast for five to six weeks; then initiate physiotherapy. *) The shoulder spica cast is maintained for five to six weeks. *) Initiate regular supervised physiotherapy immediately on removal of the spica cast. *) Over the first three months following cast removal, the patient undertakes progressive active and passive range of motion exercises, focusing on stretching in internal rotation to achieve hand to belly function and strengthening of the external rotators, flexors, and abductors.

2.4. *Outcomes*

Preoperative and postoperative functional data were recorded prospectively. The modified Mallet shoulder function score and the Active Movement Scale (AMS) score were recorded, as was active and passive shoulder motion. Surgical complications were documented. Radiographic parameters were measured on axial CT or MRI views of both glenohumeral joints of each patient. Recorded parameters included the degree of glenoid retroversion, the percentage of the humeral head anterior to the midscapular line, and the Waters type.

2.5. *Statistical analysis*

The Student t test was used to compare the preoperative and postoperative ranges of motion. Two-tailed p values were reported. The Wilcoxon signed-rank test was used to compare the preoperative Mallet and AMS scores with the post-operative scores. Paired t test analyses were performed to compare preoperative and postoperative radiographic continuous variables. As a result of the large number of comparisons that were performed, a false discovery rate adjustment was used to reduce the likelihood of a significant finding being due to chance alone. On the basis of the false discovery rate adjustment, all p values of < 0.004 were considered significant.

3. Results

Twenty patients Table (1) were followed postoperatively for a mean of 36 months (rnage, 20-39 months). The median age at the time of surgical intervention was 6.8 years (range, 4-8 years). Twelve patients (60%) were female, and fifteen (75%) of the twenty injuries affected the right upper extremity. Sixteen patiens aggregate Mallaet score improved by 4 points (3-4.9). Table (2) compared between preoperative and postoperative shoulder function parameters. The mean aggregate Mallet score improved by 4 points (3 to 4.9) from 13.4 to 17.3 points ($p< 0.001$). There were considerable changes in all segments of the Mallet score, fig. (4). *) On average, the Mallet abduction score improved by 1 point from 3.1 to 4.1 points ($p< 0.001$). *) The Mallet external rotation score improved by 1.6 points from 2.5 to 4.1 points ($p< 0.001$). *) The Mallet hand to neck score improved by 0.85 points from 2.75 to 3.6 points ($p< 0.001$). *) The Mallet hand to mouth score improved by 0.9 point from 2.75 to 3.7 points ($p< 0.001$). *) The Mallet hand-to-back score decreased by 0.7 point from 2.3 to 1.6 points ($p< 0.001$).

AMS contains three parameters for shoulder function, fig. (5). External rotation improved by a mean of 4 points from a mean of 0.8 to 4.8 ($p < 0.001$). No differences in AMS abduction or internal rotation were identified, although this study was not powered to detect small magnitudes of change on the AMS scale.

Some planes of passive and active shoulder motion were significantly changed following surgery, fig. (6). Radiographic parameters improved significantly following surgery. As demonstrated by axial imaging, glenoid retroversion improved by a mean of 26° from 33° preoperatively to 7° one-year postoperatively ($p<0.001$), fig. (7).

Table (1) Patient demographics

	No	%
Total no. patients, n (%)	20	100%
Mean age, y	Mean = 6.8	
Sex, n (%)		
- Male	8	40%
- Female	12	60%
Side, n (%)		
- Right	15	75%
- Left	5	25%
- Bilateral		0
Gestation, wk		
- >37	2	10%
- 37 to 42	14	70%
- >42	4	20%
Presentation, n (%)		
- Vertex	16	80%
- Breech	4	20%
Birth weight, g		
- <4000	14	70%
- >4000	6	30%
Assistance, n (%)		
- Forceps	1	5%
- Suction	2	10%

Table (2) Preoperative and postoperative scores according to the modified Mallet classification

Case	**Global Mallet**	**Preoperative Scores (points)**				**Hand to Mouth**	**Global Mallet**	**Postoperative Scores (points)**				**Hand to Mouth**
		Abduct.	*Ext. Rot.*	*Hand to Neck*	*Hand to Spine*			*Abduct.*	*Ext. Rot.*	*Hand to Neck*	*Hand to Spine*	
1	11	3	2	2	2	2	15	4	4	3	1	3
2	13	3	3	2	3	2	17	4	5	3	2	3
3	14	3	3	3	2	3	18	4	5	4	1	4
4	15	3	3	3	2	4	18	4	5	4	1	4
5	12	3	2	3	2	2	18	4	5	4	1	4
6	15	3	2	4	3	3	20	5	5	4	2	4
7	15	4	3	3	2	3	18	5	4	3	1	5
8	16	4	3	3	3	3	20	5	5	4	2	4
9	13	3	2	2	3	3	17	4	4	3	2	4
10	13	3	2	2	3	3	18	4	4	4	2	4
11	15	3	3	4	2	3	20	5	5	4	2	4
12	12	2	2	3	2	3	18	4	4	4	2	4
13	14	3	3	3	2	3	16	4	4	4	1	3
14	13	3	2	3	2	3	17	4	4	4	1	4
15	14	4	2	2	3	3	18	4	5	4	2	3
16	13	3	3	3	2	2	16	4	4	4	1	3
17	11	3	2	2	2	2	13	3	3	2	2	3
18	14	3	3	3	2	3	19	4	5	4	2	4
19	11	3	2	2	2	2	13	3	3	2	2	3
20	14	3	3	3	2	3	18	4	4	4	2	4
Ave.	**13.4**						**17.3**					

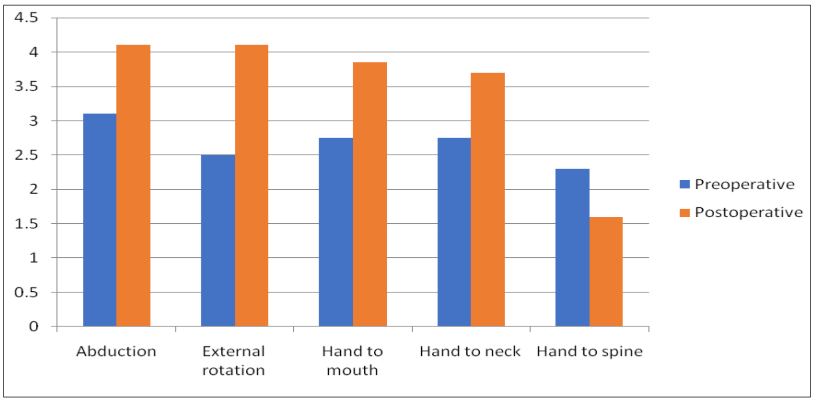

Figure (4) Preoperative and postoperative Mallet scores

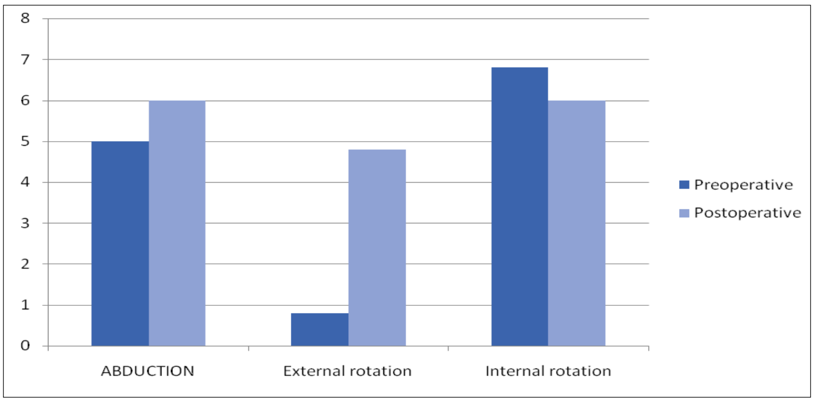

Figure (5) Preoperative and postoperative active movement scale scores

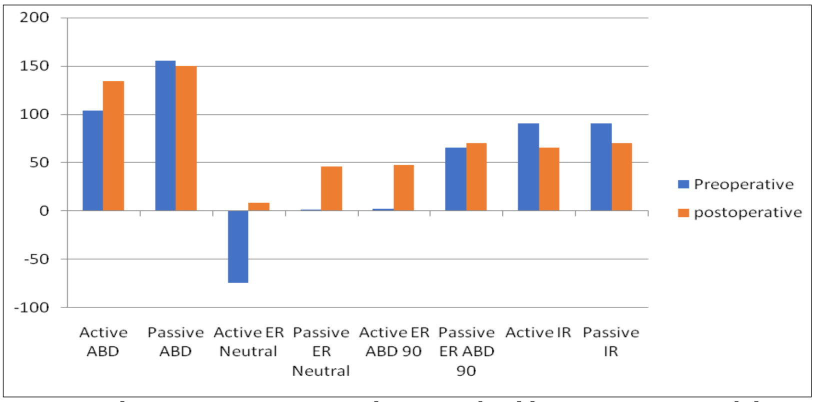

Figure (6) Preoperative and postoperative active and passive shoulder motion. **ABD**= abduction, **ER**= external rotation, and **IR**= internal rotation

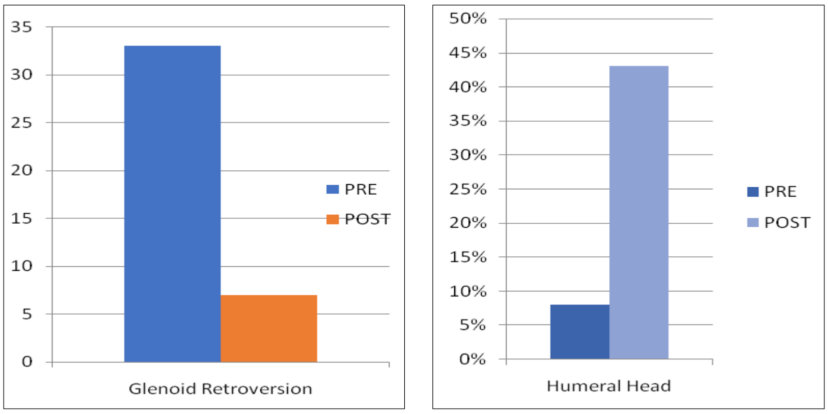

Figure (7) Preoperative and postoperative percentage of the humeral head anterior to the midscapular line and preoperative and postoperative glenoid retroversion

4. Discussion

treatment of the secondary Surgical shoulder dysfunction following O.B.P.P. aims to accomplish three goals: restoration of passive motion by contracture release, realignment of the dysplastic glenohumeral joint, and augmentation of muscle power in the weak domains of shoulder movement. If these goals cannot be accomplished, palliative surgery in the form of humeral osteotomy can improve global shoulder function without addressing the glenohumeral joint deformity and dysfunction. Reconstructive operations of the shoulder have been used since the early 20th century to palliate the sequelae of brachial plexus palsy at birth. From the early 1900s, Fairbank [25] and Sever [26] addressed the secondary shoulder deformities and attempted contracture releases of the pectoralis major and subscapularis muscles.

In 1934, L'Episcopo [22] proposed subscapularis release with transfer of the teres major and later the latissimus dorsi to the posterolateral aspect of the humerus. Anterior release (release of the subscapularis) combined with latissimus dorsi transfer to the rotator cuff has been the historical standard of care to restore abduction and external rotation in these patients based on small studies with short-term follow up [15,22]. However, there remains a paucity of long-term studies examining the maintenance of these improvements over time. The increasing awareness of glenohumeral dysplasia over the past decade has created an opportunity to evaluate the effects of these surgical procedures on glenohumeraldysplasia progression. Noaman, et al [5]. in his study in 76 children use the same approach with doing some modification in the form of **(1)** both latissimus dorsi and teres major tendons were rerouted together in all children, **(2)** both tendons should be released from the surrounding soft tissues and skin to gain sufficient length, **(3)** there was no need to do lengthening of the 2 original tendons to avoid their weakness, and **(4)** suturing of both tendons directly to the periosteum of the humerus. In 2005, Waters and Bae [4] reported a series of 25 children who underwent latissimus dorsi and teres major tendon transfers with or without lengthening of the subscapularis or pectoralis major. At 2-year follow-up. Clinically, all patients demonstrated improved global shoulder function, with the mean aggregate Mallet score improving from 13 points preoperatively to 18 points postoperatively ($p < 0.01$). As seen radiographically, the mean glenoid retroversion improved from 22° preoperatively to 16.5° postoperatively ($p= 0.012$). The mean posterior humeral head subluxation improved from 30% to 37% ($p= 0.03$). No patient had progressive worsening of the glenohumeral deformity. They concluded that muscle rebalancing surgery only halted the progression of dysplasia but did not allow substantial remodeling. Similarly, Kozin et al. [23]. in 2006 described a complete lack of glenohumeral remodeling at 1-year follow-up in 23 children treated with a similar combination of procedures. At 1-year study after tendon transfers and joint alignment, noted no change in glenoid retroversion measuring 24.8 ± 13.0 degrees before surgery and 24.8 ± 13.6 degrees at follow-up. Humeral head subluxation (PHHA) did not change measuring 29.1% ± 14.9% before surgery and 28.2% ± 15.6% at follow-up. Clinical evaluation showed significant improvements in external rotation and abduction. Our results demonstrate that, in appropriately selected patients, latissimus dorsi and teres major tendon transfers to the rotator cuff combined with musculotendinous lengthenings and glenohumeral reduction not only improve upper extremity function but also result in remodeling of glenohumeral dysplasia in the majority of patients. In the current investigation the mean aggregate Mallet score improved by 4 points from 13.4 to 17.3 points ($p< 0.001$). The Mallet abduction score improved by 1 point from 3.1 to 4.1 points ($p< 0.001$). The Mallet external rotation score improved by 1.6 points (from 2.5 to 4.1 points ($p<0.001$). The Mallet hand to neck score improved by 0.85 points from 2.75 to 3.6 points ($p< 0.001$).The Mallet hand to mouth score improved by 0.9 point, from 2.75 to 3.7 points ($p< 0.001$).The Mallet hand-to-back score decreased by 0.7 point, from 2.3 to 1.6 points ($p< 0.001$). Radiographic parameters improved significantly following surgery. As demonstrated by axial imaging, glenoid retroversion improved by a mean of 26° from -33° preoperatively to 7° one-year postoperatively ($p< 0.001$). The percentage of the humeral head anterior to the middle of the glenoid improved from 8% to 43%, fig. (7). Waters et al. [19] in 2008 suggested that remodeling may indeed be possible. Validation of remodeling potential has now been provided by a number of recent reports. Waters and Bae recently reported a series of 23 patients who underwent subscapularis/pectoralis major lengthenings and latissimus dorsi/teres major transfers but with the addition of open glenohumeral reduction. Radiographically, the mean glenoid version improved from -39 preoperatively to 18 postoperatively ($p< 0.01$). The mean percentage of the humeral head anterior to the middle of the glenoid similarly improved from 13% to 38% ($p< 0.01$). With these caveats in mind, the current study demonstrates that surgical intervention in the form of tendon transfers, soft-tissue releases, and and glenohumeral reduction effective for improving shoulder function and leads to glenohumeral remodeling in the majority of younger patients with mild-to-moderate dysplasia. It should be noted that the patients in the present study underwent surgery relatively late in life. Indeed, the average age at the time of surgery in this patient cohort was 6 years, and the oldest patient was 8 years. Thus, the findings of the current investigation may not be applicable to brachial plexus birth palsy patients of all ages. However, early surgical intervention is warranted for younger patients with glenohumeral deformity and loss of passive shoulder external rotation despite extensive therapy aimed at maintaining glenohumeral motion. Previous analyses of older patients have demonstrated that glenohumeral dysplasia is progressive, and the opportunity to perform soft-tissue releases and musculotendinous lengthenings may be lost with advancing deformity. On the basis of Noaman [5] literature, it is difficult to compare different surgical approaches. Outcome variables differ between studies; there is also a variation in indications of surgery, as well as operative techniques between centers, and a high likelihood of observer bias due to lack of blinded assessments in most of the research up to date, which is mostly retrospective. Also, a deterioration of shoulder function was observed at follow-up at 12 years, this phenomenon is not specifically associated with anterior compartment releases. This was possibly due to a lack of compliance with physiotherapy programs, especially in teenagers who generally preferred to use their healthy arm. It should be recognized that the long-term consequences of glenohumeral joint dysplasia in patients with brachial plexus birth palsy are still unknown. It is unclear whetherlong-standing glenohumeral dysplasia predisposes to shoulder pain or arthrosis in adulthood. Additional analysis and longer-term follow-up are needed to determine the clinical course of glenohumeral joint dysplasia in these patients. Future efforts in this area should be directed toward the evaluation of a larger number of patients with longer follow up. As greater numbers of patients are assessed, additional analysis may reveal specific risk factors for persistent or progressive glenohumeral joint deformity following tendon transfers, such as the pattern of brachial plexus involvement, the severity of involvement, the age of the patient at the time of treatment, or the degree of dysplasia. Given the inherent limitations of any case series, future randomized clinical trials should be considered to ascertain the efficacy of this procedure as compared with tendon transfers and musculotendinous lengthenings performed without glenohumeral joint reduction. Finally, long-term outcomes analysis is needed to determine if glenohumeral deformity, even when treated early and arrested, portends a worse prognosis in terms of upper extremity dysfunction, joint instability, or arthrosis.

5. Conclusion

Latissimus dorsi and teres major tendon transfers to the rotator cuff, combined with appropriate extra-articular musculotendinous lengthenings and open joint reduction, result in improved shoulder function and glenohumeral joint remodeling in the majority of patients with brachial plexus birth palsy with mild-to-moderate dysplasia.

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