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Reconstruction of shoulder abduction and external rotation with latissimus dorsi and teres major transfer in obstetric brachial plexus palsy

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Objectives: We evaluated the results of latissimus dorsi and teres major tendon transfer to the rotator cuff together with musculotendinous lengthening of the subscapularis and/or pectoralis major muscles in patients with internal rotation contracture and decreased external rotation and abduction secondary to obstetrical brachial plexus palsy.

Methods: Thirty patients (18 boys, 12 girls; mean age 9 years; range 4 to 15 years) with internal rotation contracture and loss of external rotation and abduction of the shoulder secondary to obstetrical brachial plexus palsy underwent transfer of the latissimus dorsi/teres major tendons to the rotator cuff. In addition, musculotendinous lengthening of the subscapularis and pectoralis major (n=15), pectoralis major (n=9), and subscapularis (n=6) were performed. Nine patients had upper plexus involvement (C_{5-6}), 14 had C_{5-7} involvement, and seven had complete plexus involvement (C_5-T_1). According to the Waters and Peljovich classification, all the patients had a congruent glenohumeral joint, which was classified as type 1 in one patient, type 2 in 15 patients, and type 3 in 14 patients. Pre- and postoperative range of motion values of the patients were measured and their motor functions were evaluated with the Mallet scoring system. The mean follow-up period was 47.8 months (range 9 to 84 months).

Results: Preoperatively, the mean active abduction was 75.8°, and the mean active external rotation was 25.2°. Postoperatively, the mean abduction and external rotation increased to 138.3° (by 62.5°, 82.5%) and 76.4 degrees (by 51.2°, 203.2%), respectively. Improvements in the degrees of abduction and external rotation were significant (p=0.000). According to the Mallet scoring system, the mean preoperative global abduction and global external rotation scores were 2.97 and 2.43, respectively; the mean Mallet scores for the ability to move the hand to the mouth, neck, and back were 2.50, 2.17, and 2.67, respectively. Postoperatively, the mean global abduction score increased to 3.97 (by 33.7%, p=0.000), and the mean global external rotation score increased to 3.77 (by 55.1%, p=0.000). The mean scores for the ability to move the hand to the mouth, neck, and back were 3.30 (increased by 32%, p=0.000), 3.73 (increased by 71.9%, p=0.000), and 2.30 (decreased by 13.9%, p=0.003), respectively. Postoperative changes in the Mallet scores were all significant. Improvements in abduction and external rotation were not significant between patients ≤9 years and >9 years of age (p>0.05).

Conclusion: Transfer of the latissimus dorsi and teres major tendons to the rotator cuff combined with musculotendinous lengthening of the subscapularis and/or pectoralis major provides satisfactory increases in shoulder abduction and external rotation, regardless of the age, in patients with no or minimal glenohumeral joint incongruency.

Key words: Birth injuries; brachial plexus neuropathies/surgery; child; contracture/surgery; paralysis/etiology/surgery; shoulder joint; tendon transfer/methods.

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Obstetrical brachial plexus injury occurs as a result of forceful traction of the upper extremity for a long period of time during delivery and/or compression injury.[1-4] Despite advances in the delivery methods, the incidence of obstetrical brachial plexus palsy is on the incline in parallel with increases in birth weight. Its incidence is reported to be 0.5 to 5 per 1,000 live births.[1,3-6]

Spontaneous recovery is seen in 80% to 90% of the cases with obstetrical brachial plexus injury. The clinical presentation of the patient may vary based on the extent of injury to the brachial plexus, number of injured nerves, and the degree of injury. The most frequent involvement occurs in the upper plexus (C_{5-6}).[6-9] In cases of upper plexus injuries without full recovery, the most common problems include decreased external rotation and abduction and deformity of the glenohumeral joint secondary to internal rotation contracture of the shoulder.[5,8-13] The latter results from the impaired balance between the paralytic external rotators and the internal rotators which maintain their strength.[5,7-9,11-13]

Patients with internal rotation contracture of the shoulder and loss of external rotation may benefit from reconstructive surgical procedures including arthroscopic or open release of the contracture, tendon transfers, and rotational osteotomy.[8,11,12,14,15]

By modifying the L'Episcopo procedure, Hoffer et al.[16] described a technique aiming to improve not only external rotation, but also abduction, which includes release of the pectoralis major, and transfer of the conjoined tendons of the latissimus dorsi and teres major to the rotator cuff. The amount of external rotation increases with increased rotation strength and the amount of abduction increases with greater efficacy of the deltoid muscle. Once the imbalance between internal and external rotation forces of the shoulder joint is restored in the early period, the glenohumeral joint undergoes remodeling.[11,12,17] It has been reported that, for cases with sequela of internal rotation contracture, the most convenient time for release of internal rotators and contracted tissues and tendon transfer is 4 to 10 years of age.[11,12,18] Tendon transfer can be performed around 9-10 years of age, even at later ages, if the congruity of the glenohumeral joint is still unimpaired.[5]

The present study evaluated the results of latissimus dorsi and teres major tendon transfer to the rotator cuff in combination with musculotendinous lengthening of the subscapularis and/or pectoralis major muscles in order to restore decreased external rotation and abduction due to internal rotation contracture of the shoulder secondary to obstetrical brachial plexus palsy in patients 4 to 15 years of age and having a congruent glenohumeral joint according to the Waters and Peljovich classification.[11] The effect of operation age on the results was also assessed.

Patients and methods

A total of 30 patients underwent surgical treatment between 2002 and 2008 for loss of external rotation and abduction as well as internal rotation contracture of the shoulder secondary to obstetrical brachial plexus palsy. Of these patients, 14 had additional elbow involvement, and seven had deformities of the elbow, wrist, and hand. In addition, two patients had Horner's syndrome, and one patient had torticollis. The mean operation age was 9 years (range 4 to 15 years). There were 18 males and 12 females. Eighteen patients had right and 12 patients had left upper extremity involvement. Nine of the patients had upper plexus involvement (C_{5-6}), 14 had C_{5-7} involvement, and seven had complete plexus involvement (C_5-T_1).

The patients presented with complaints of being unable to use the involved extremity in their daily activities due to loss of external rotation and abduction accompanying the internal rotation deformity.

The pre- and postoperative range of motion values of the patients were measured and their motor functions were evaluated with the Mallet scoring system.[11] The mean preoperative active abduction was 75.8° (range 25° to 130°), and the mean active external rotation was 25.2° (range 0° to 90°). According to the Mallet scoring system, the mean global abduction and global external rotation scores were 2.97 (Fig. 1a) and 2.43, respectively. The mean Mallet scores for the ability to bring the hand to the neck (Fig. 1b), to the back, and to the mouth were 2.17, 2.67, and 2.50, respectively. Tendon transfer was performed in patients with sufficient deltoid muscle strength (M3-M4 according to the British Medical Research Council grading system).[16]

During preoperative planning, bilateral anteroposterior and axillary direct radiographs of the shoulder were obtained. To evaluate the glenohumeral joint, magnetic resonance imaging (MRI) was performed in three patients who were five years old or younger,

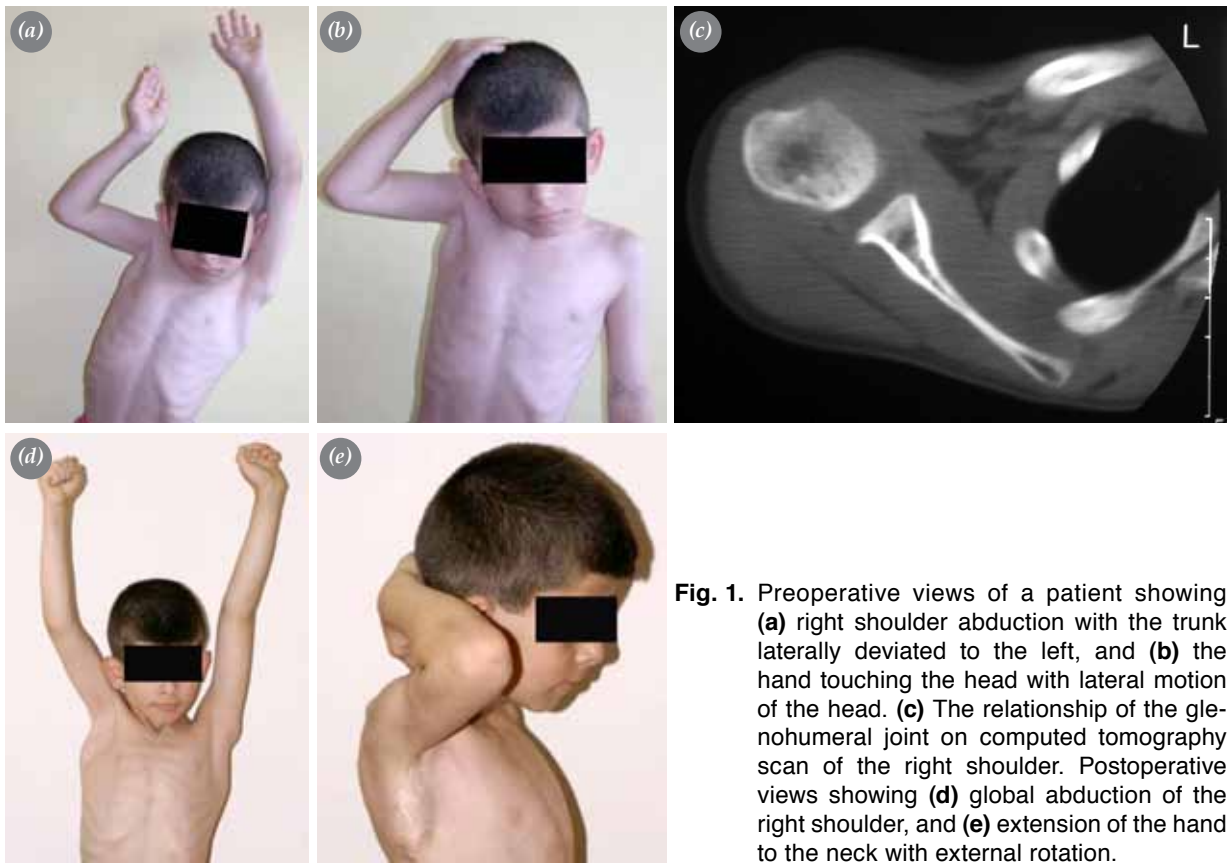

Fig. 1. Preoperative views of a patient showing **(a)** right shoulder abduction with the trunk laterally deviated to the left, and **(b)** the hand touching the head with lateral motion of the head. **(c)** The relationship of the glenohumeral joint on computed tomography scan of the right shoulder. Postoperative views showing **(d)** global abduction of the right shoulder, and **(e)** extension of the hand to the neck with external rotation.

and computed tomography was performed in 27 patients who were beyond five years of age (Fig. 1c). Based on these assessments, one patient was classified as type 1, 15 patients as type 2, and 14 patients as type 3 according to the Waters and Peljovich grading system.[11]

Surgical procedure

An axillary zigzag incision was made parallel to the scapula with the patient in the supine position and the shoulder elevated by a support. The conjoint tendon of the latissimus dorsi and teres major was separated from its humeral attachment. To release the internal rotation contracture, the shoulder was brought to abduction, and a musculotendinous lengthening of the subscapularis and/or pectoralis major muscles was performed until more than 90° of passive external rotation of the shoulder was obtained, according to the method described for the subscapularis muscle by Carlioz and Brahmi.[19] The deltoid muscle was longitudinally separated 3 to 4 cm following a transverse incision in the greater tubercle. A tunnel was opened to the axilla through the deltoid muscle and the humeral head and behind the long head of the triceps muscle. Preserving the neurovascular pedicle, the widely released muscle tendon unit of the conjoined latissimus dorsi and teres major was inserted through the tunnel and fixed to the greater tubercle with a suture anchor (QuickAnchor, Johnson & Johnson) while the upper extremity was in 90° abduction and full external rotation, and the conjoined tendon was sutured to the infraspinatus tendon in the rotator cuff.

In all the patients, the latissimus dorsi and teres major tendons were transferred to the rotator cuff. Additionally, releases of the subscapularis and pectoralis major (n=15), pectoralis major (n=9), and subscapularis (n=6) were performed. In one patient, the latissimus dorsi and teres major tendons which had been fixed to the lateral humeral diaphysis at another center were removed from the attachment site and transferred to the greater tubercle.

After closing surgical incisions, a shoulder spica or thermoplastic splint were used to secure the shoulder in 90° abduction and complete external rotation, and the elbow in 90° flexion. Following its full-day use for six weeks, an exercise program was initiated in the gravity-eliminated position without allowing

any antagonist activity until the week 8, followed by gentle strengthening exercises and light functional use between weeks 8 and 10. Along with this program, nocturnal bracing was continued until week 12. Stretching exercises were initiated after week 12, and the use of extremity was encouraged in daily activities. The mean follow-up period was 47.8 months (range 9 to 84 months).

The data obtained from the patients were statistically evaluated by the paired samples test using the SPSS 15.0 software.

Results

At final evaluations, the mean abduction increased by 62.5° (82.5%) and the mean external rotation increased by 51.2° (203.2%). Improvements in the degrees of abduction and external rotation were significant (p=0.000).

According to the Mallet classification, the global abduction and global external rotation scores were 3.97 (Fig. 1d) and 3.77, respectively, and the scores for the ability to move the hand to the neck, mouth, and back were 3.73 (Fig. 1e), 3.30, and 2.30, respectively. Postoperative changes were all significant, showing increases by 33.7% in global abduction and by 55.1% in global external rotation (p=0.000). The scores for the ability to move the hand to the neck and mouth increased by 71.9% (p=0.000) and 32% (p=0.000), respectively, while the score for the back decreased by 13.9% (p=0.003).

The mean abduction improved from 77.6° to 139.4° (by 61.8°) and from 73.4° to 136.9° (by 63.5°), and the mean external rotation increased from 24.7° to 80.7° (by 56°) and from 25.8° to 71.8° (by 46°) in patients ≤9 years and >9 years of age, respectively. Changes in abduction and external rotation were not significant between patients ≤9 years and >9 years of age (p>0.05).

Discussion

In later periods of life, deformity of the shoulder joint and loss of function are among the most important problems in patients having partial recovery from obstetrical brachial plexus injuries. The development of this deformity impedes daily activities required for body care such as moving the hand over the shoulder, extending it to the head or behind the head.

It has been shown in MRI studies of shoulder joints that patients older than three months and having a partial recovery develop secondary deformities such as glenoid convexity, biconcavity, and humeral head subluxation after five months of obstetrical brachial plexus injuries.[20] Arthroscopy, arthrography and MRI studies have shown that glenohumeral joint deformity occurs before the age of one year in patients with internal rotation contracture.[12,15,20] This results from the impaired balance between the internal rotator muscles, which maintain their strength, and external rotator muscles, which lose their strength.[5,7-9,11-13] The prevalence of shoulder contracture greater than 10° has been reported to be 56%, and the prevalence of osseous deformity to be 33%.[10] Shortening of the dominant subscapularis muscle fibers along with increased stiffness occurs due to initial paralysis or late recovery of the external rotators.[21] Passive correction may be helpful in improving the initial adduction and internal rotation posture associated with changes in the muscle structure. However, this posture frequently results in contracture of the glenohumeral joint over time. The fixed internal rotation position of the shoulder has a negative impact on the anatomic structure and development of the glenohumeral joint.[22] Progression in muscle imbalance results in permanent deformities such as glenoid dysplasia, deformation, humeral head subluxation, and posterior dislocation.[1,8,10,11,23] The severity of the glenohumeral joint deformity is closely related to the selection and success of the reconstruction procedure.[8,13,17] Glenohumeral joint remodeling and reduction in increased glenoid version were achieved by early tendon transfer and musculotendinous lengthening and/or open reduction and capsulorrhaphy.[11,12,17] Zancolli[8] released the pectoralis major from humeral insertion and sutured it distal to the subscapularis for the treatment of internal rotation contracture. To increase the external rotation, he rotated the latissimus dorsi tendon, that was lengthened 10 cm with Z-plasty, from the lateral to the posterior of the humerus and sutured it again onto itself in full external rotation and 90 degrees of abduction. As a result, he obtained 50° active abduction and 45° active external rotation.[8] Covey et al.[24] separated the tendinous part of the latissimus dorsi, re-routed the distal end of the latissimus dorsi to the posterior of the humerus, and anastomosed it there to the conjoined tendons of the latissimus dorsi and teres major. Of 19 patients, five did not benefit

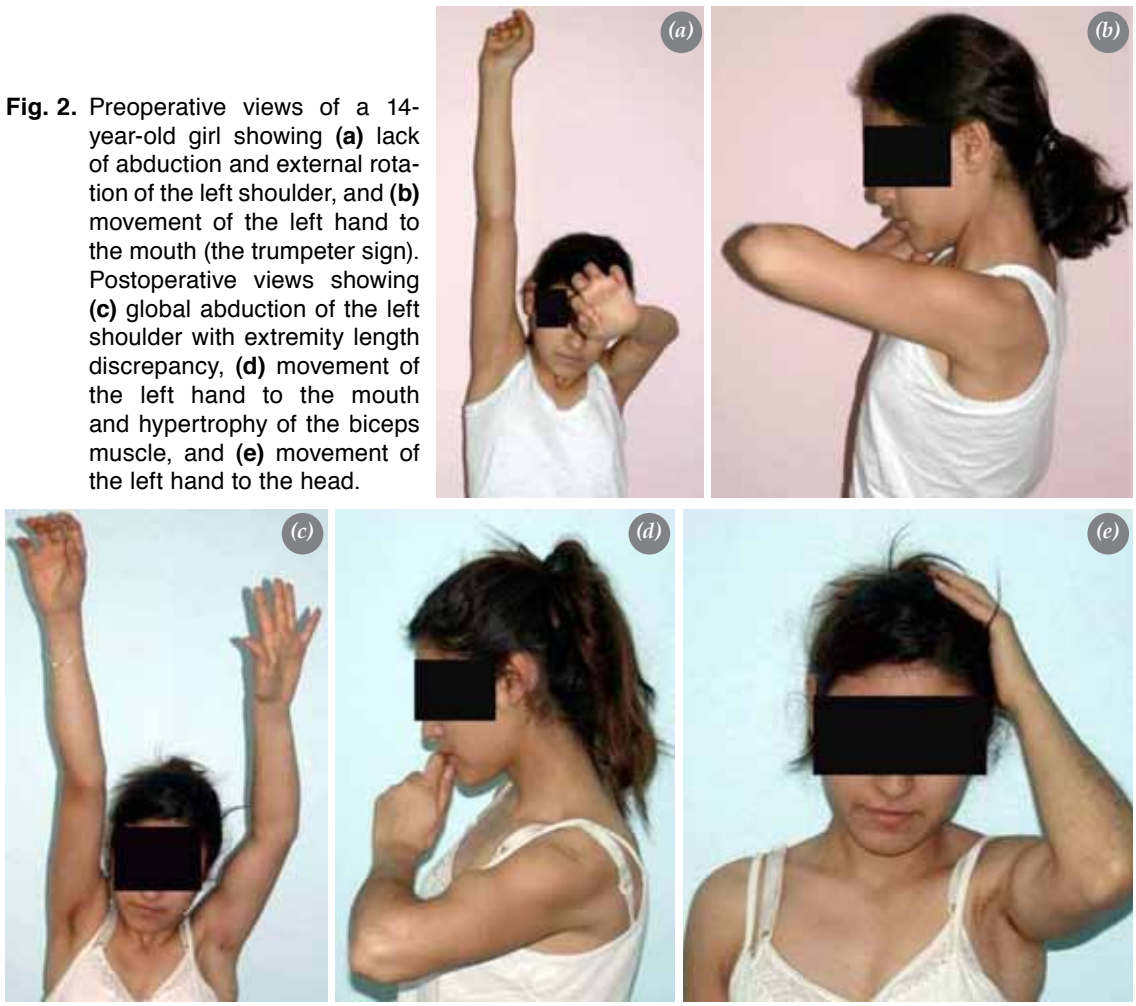

Fig. 2. Preoperative views of a 14-year-old girl showing **(a)** lack of abduction and external rotation of the left shoulder, and **(b)** movement of the left hand to the mouth (the trumpeter sign). Postoperative views showing **(c)** global abduction of the left shoulder with extremity length discrepancy, **(d)** movement of the left hand to the mouth and hypertrophy of the biceps muscle, and **(e)** movement of the left hand to the head.

from the procedure, but the remaining patients had increases of 26° and 29° in abduction and external rotation, respectively.

In patients with obstetrical brachial plexus palsy who have weakness of external rotation and abduction due to internal rotation contracture, transfer of the latissimus dorsi and/or teres major to the rotator cuff along with musculotendinous lengthening of the subscapularis and/or pectoralis major is associated with improvement in functions of the shoulder joint and glenohumeral joint remodeling.[5,11,13,16,22,25] For the treatment of internal rotation contracture, Gilbert et al.[19] recommended open release for children less than four years of age if the congruity of the glenohumeral joint and roundness of the humeral head were preserved; they recommended latissimus dorsi transfer in addition to release of the contracture in children greater than four years of age. Pearl et al.[12] obtained an increase of 67° in external rotation in 15 of 19 patients (mean age 1.5 years) undergoing arthroscopic capsular and subscapular releases. In four patients with recurrence, external rotation increased to 78° following repeat arthroscopic capsular and subscapular releases combined with latissimus dorsi transfer. In the same study, 14 patients, with a mean age of 6.7 years, who were initially treated with arthroscopic release and latissimus dorsi transfer had an external rotation of 81°. It was found that 12 of 15 patients with pseudoglenoid deformity exhibited marked remodeling of the deformity on MRI scans obtained after two years.[12]

The most popular salvage surgical procedure around the shoulder is the L'Episcopo procedure and its modifications. The modification by Hoffer et al.[16,25] used in the present study includes musculotendinous lengthening of the subscapularis and/or pectoralis major, and transfer of the teres major and latissimus dorsi tendons to the rotator cuff in order

to strengthen the paralyzed external rotators. This results in not only increased active external rotation, but also increased abduction because of increases in the stabilizing effect of the rotator cuff and the efficacy of the deltoid muscle. Hoffer et al.[16] reported the mean improvements as 64° in abduction and 45° in external rotation in 11 patients. In our study, the mean gain was 62.5° in abduction, and 51.2° in external rotation. In patients younger than nine years of age, the mean external rotation increased from 24.7° to 80.7° with a gain of 56°. The corresponding increase was 46° (from 25.8° to 71.8°) in patients older than nine years. There was no significant difference with respect to abduction gain between the two age groups ($p<0.05$).

Chen et al.[26] suggested that transfer of the trapezius be added to the transfer of the latissimus dorsi and teres major tendons in order to enhance the amount of abduction in patients with a preoperative abduction of less than 90°. In our study, preoperative abduction was less than 90° in 20 patients, and 90° or greater in 10 patients. In the former group, the mean abduction increased from 62° to 137.8°, and in the latter, the mean abduction increased from 100.5° to 139.5°. The final degrees of abduction were similar in the two groups. It was also reported by other studies that abduction gains following conjoined tendon transfer were similar in patients having a preoperative abduction of <90° and ≥90°.[27,28] We believe that no additional tendon transfer is necessary in patients with a preoperative abduction of less than 90°, as an efficient outcome is already obtained with release of the internal rotators and transfer of the latissimus dorsi and teres major tendons to the rotator cuff.

Waters and Peljovich[11] stated that, with tendon transfer, the muscle balance between the internal and external rotators could be best achieved in the age bracket of 2 to 5 years prior to any development of joint deformity. Chuang et al.[18] suggested that the most convenient age range for salvage surgery of soft tissues was 4 to 10 years, as the transfer of the teres major muscle to the infraspinatus became difficult beyond 10 years of age due to excessive shortening. In an analysis after an average follow-up period of 15 years, Pagnotta et al.[7] concluded that the clinical results were related with the type of paralysis and preoperative shoulder functions, but not with age. In our series with an average age of nine years, the severity of bone and joint deformities was minimal. In patients who underwent surgery ≤9 years of age, the mean abduction angle increased from 77.6° to 139.4° with a gain of 61.8°. A gain of 63.5° (from 73.4° to 136.9°) was obtained in the mean abduction of patients older than 9 years. Increases in abduction did not differ significantly between the two age groups ($p>0.05$). We believe that tendon transfer and release surgery of internal rotators in patients with no or minimal joint contracture and osseous deformity can be performed regardless of age (Fig. 2).

In this technique which allows restoration of external rotation as well as global abduction, loss of internal rotation is seen particularly in patients who undergo release surgery together with tendon transfer. The degree of this loss can be usually reduced by physical therapy.[19,29] If sufficient internal rotation cannot be achieved, then transfer of the pectoralis major to the subscapularis or an internal rotation osteotomy of the humerus can be performed.[19] In order to reduce the limitation of internal rotation, Chen et al.[26] preferred not to transfer the teres major tendon which was electromyographically found to lack simultaneous contraction during abduction. In our cases, loss of internal rotation presented as a decreased Mallet score by 13.8% in the ability to move the hand to the back. Although this loss was statistically significant, no additional therapy was considered as the patients did not complain of such limitation during their daily activities. Despite this loss in internal rotation, the quality of life was highly improved in our patients due to significant increases of 71.9% and 32% in the ability to move the hand to the neck and mouth, respectively.

There is no consensus in the literature as to the transfer site and fixation method of the tendon. In the L'Episcopo procedure, the tendon is passed posterior to the lateral of the humerus behind the long head of the conjoined triceps, and fixed with a surgical stapler or screw, or sutured onto the removed periosteal flap.[30] In the modification of Hoffer et al.,[16] the combined tendon is fixed to the anterosuperior of the rotator cuff by nonabsorbable 2/0 sutures. In a study of 10 patients, Demirhan et al.[31] fixed the conjoined tendon onto the infraspinatus tendon with a 2/0 Ethibond suture and obtained a mean postoperative abduction of 134.5° and external rotation of 70°. As reported by Özkan et al.,[29] we preferred to fix the conjoined tendon to the greater tubercle by a suture anchor and sutured it to the infraspinatus tendon. Özkan et al.[29]

reported the increases as 60.3° in abduction and 58.7° in external rotation in 70 patients. In our patients, gains in abduction and external rotation were 62.5° and 51.2°, respectively.

Loss of external rotation has been reported after long-term follow-up of patients undergoing release and tendon transfer.[7,32] Bertelli[32] performed transfer of the lower part of the trapezius muscle to the infraspinatus and Z-plasty lengthening of the subscapular muscle in seven patients who developed recurrent internal rotation contracture following a subscapular release and transfer of the latissimus dorsi, and achieved an external rotation of 54.3°. Strecker et al.[30] reported axillary nerve lesions, being temporary in three patients and permanent in one patient, following transfer of the latissimus dorsi and teres major tendons. In our study, complications such as recurrent internal rotation contracture or axillary nerve lesion were not encountered.

In conclusion, transfer of the latissimus dorsi and teres major tendons to the rotator cuff and musculotendinous lengthening of the subscapularis and/or pectoralis major for restoration of residual internal rotation contracture of the shoulder and loss of external rotation secondary to obstetrical brachial plexus palsy provides satisfactory degrees of external rotation and abduction, regardless of age, in patients with no or minimal impairment in the congruity of the glenohumeral joint.

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