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Transfer of latissmus dorsi and teres major tendons without subscapularis release for the treatment of obstetrical brachial plexus palsy sequela

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Background: Patients with obstetrical brachial plexus palsy (OBPP) sequela exhibit adduction and internal rotation contractures. The muscular imbalance may result in secondary bony changes. Tendon transfers and muscular releases may improve shoulder function in these patients. The aim of this study is to evaluate the functional and radiological results of pectoralis major tendon Z-plasty with transfer of latissimus dorsi and teres major tendons to rotator cuff tendons without release of subscapularis muscle in patients with mild sequela of OBPP.

Materials and methods: Twenty-six consecutive patients, who were treated with tendon transfer and met the eligibility criteria, were included in the study. No additional humeral osteotomy or subscapularis tenotomy was performed. Functional evaluation is made according to range of motion and Mallet scoring system. Preoperative radiologic evaluation was made according to the grading system of Waters.

Results: A significant increase in shoulder function was found in all patients. Postoperative radiographs revealed glenohumeral congruity was maintained in all patients. Improvement in shoulder abduction and external rotation was higher in patients who were operated before the age of 7.

Discussion/conclusion: Pectoralis major tendon lengthening with transfer of latissimus dorsi and teres major tendons to rotator cuff is an effective and reproducible technique and can improve shoulder functions in patients with OBPP. Subscapularis release is not always required to overcome internal rotation contracture. Secondary glenohumeral changes might also be prevented with this approach.

Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Brachial; plexus; palsy; shoulder; tendon; transfer; Mallet

Despite the early diagnosis of deliveries at risk and measures taken to prevent shoulder dystocia, the prevalence of obstetrical brachial plexus palsy (OBPP) has not shown desirable decrease.[17] Although most cases are presented with spontaneous recovery, recent studies have reported that long term sequela risk is high.[10,19,20,23] Mostly, upper truncus involvement (C5-C6) causes shoulder problems which exhibit itself as weakness in abduction and external rotation due to impaired function of deltoid and rotator cuff muscles.[10,25] If untreated, this

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Table I Medical Research Council (MRC) scale for muscle strength

Grade 0	No movement is observed.
Grade 1	Only a trace or flicker of movement is seen or felt in the muscle or fasciculations are observed in the muscle.
Grade 2	Muscle can move only if the resistance of gravity is removed. As an example, the elbow can be fully flexed only if the arm is maintained in a horizontal plane.
Grade 3	Muscle strength is further reduced such that the joint can be moved only against gravity with the examiner's resistance completely removed. As an example, the elbow can be moved from full extension to full flexion starting with the arm hanging down at the side.
Grade 4	Muscle strength is reduced but muscle contraction can still move joint against resistance.
Grade 5	Muscle contracts normally against full resistance.

Table II Data on preoperative values of patients

	Side	Age	Abduction	Abduction score	External rotation	External rotation score	Hand-head score	Hand-mouth score	Internal rotation score	Lesion site	Radiology
1. Male	R	13	60	3	10	3	3	2	2	C5-C6-C7	Type 1
2. Male	L	5	70	3	0	2	3	2	3	C5-C6	Type 2
3. Male	R	17	150	4	10	3	3	3	4	C5-C6	Type 3
4. Female	R	6	60	3	0	2	2	2	2	C5-C6-C7	Type 2
5. Female	L	4	80	3	0	2	2	2	2	C5-C6-C7	Type 1
6. Female	R	6	70	3	10	3	3	3	2	C5-C6-C7	Type 1
7. Female	L	2	130	4	0	2	4	2	4	C5-C6	Type 1
8. Male	L	6	150	4	10	3	3	2	3	C5-C6	Type 1
9. Male	R	7	70	3	10	3	2	2	2	C5-C6-C7	Type 2
10. Female	R	9	20	2	0	2	2	2	2	C5-C6-C7	Type 2
11. Male	R	14	60	3	20	3	3	3	3	C5-C6	Type 2
12. Male	L	8	150	4	0	2	4	3	4	C5-C6	Type 1
13. Male	L	6	60	3	0	2	3	2	3	C5-C6-C7	Type 3
14. Female	R	8	160	4	30	4	4	4	4	C5-C6	Type 1
15. Female	R	4	80	3	0	2	3	2	4	C5-C6	Type 1
16. Female	L	1	50	3	0	2	3	2	3	C5-C6-C7	Type 3
17. Female	R	11	130	4	30	4	4	2	4	C5-C6	Type 1
18. Male	R	6	60	3	10	3	3	2	2	C5-C6-C7	Type 2
19. Male	L	4	80	3	0	2	2	2	2	C5-C6-C7	Type 1
20. Female	L	4	90	3	10	2	3	3	3	C5-C6-C7	Type 2
21. Male	R	7	90	3	0	2	2	3	2	C5-C6-C7	Type 2
22. Female	R	7	130	4	0	2	2	2	3	C5-C6	Type 1
23. Female	R	6	70	3	0	2	2	3	3	C5-C6-C7	Type 2
24. Female	R	15	100	4	10	3	3	3	4	C5-C6	Type 1
25. Female	R	6	110	4	0	2	2	2	4	C5-C6	Type 1
26. Male	L	5	60	3	5	3	2	2	2	C5-C6	Type 1

muscular imbalance will result in joint contractures and glenohumeral deformity.[10,26,27]

The ultimate purpose of treatment in OBPP is to improve upper extremity function. In upper truncus lesions, this is achieved by restoring shoulder functions. Treatment options differ according to age. Microsurgical nerve repair and reconstruction procedures are reserved for infants.[14,23] In untreated cases, as the child grows, the symptoms become permanent. In this situation, muscle releases, tendon transfers, and humeral derotational osteotomy have been developed to rebalance the muscular dysfunction and improve shoulder range of motion.[2,12,18,27] Hoffer et al described a procedure to transfer latissimus dorsi and teres major tendons to rotator cuff as high as possible.[9] This method was able to increase the stabilizing effect of rotator cuff, shoulder external rotation, and abduction by increasing the effectiveness of deltoid.[9] Subscapularis release was not advised even in cases of dislocations.[16] Glenohumeral derotational osteotomy is reserved for severe glenohumeral changes (posterior dislocation, glenoid hypoplasia, hooking of coracoid, flattening of humeral head) or if the previous interventions fail.[16,25,27]

In order to increase activity level with only tendon transfer around the shoulder, the glenohumeral joint should be free of

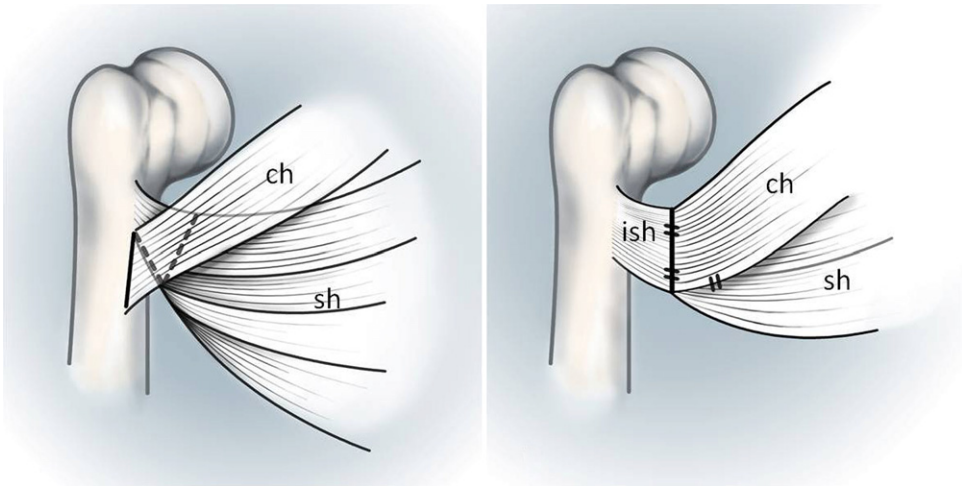

Figure 1 Lengthening of pectoralis major by Z-plasty (*sh*, sternal head; *ch*, clavicular head; *ish*, insertion of sternal head; muscle belly of sternal head is sutured to muscle belly of clavicular head).

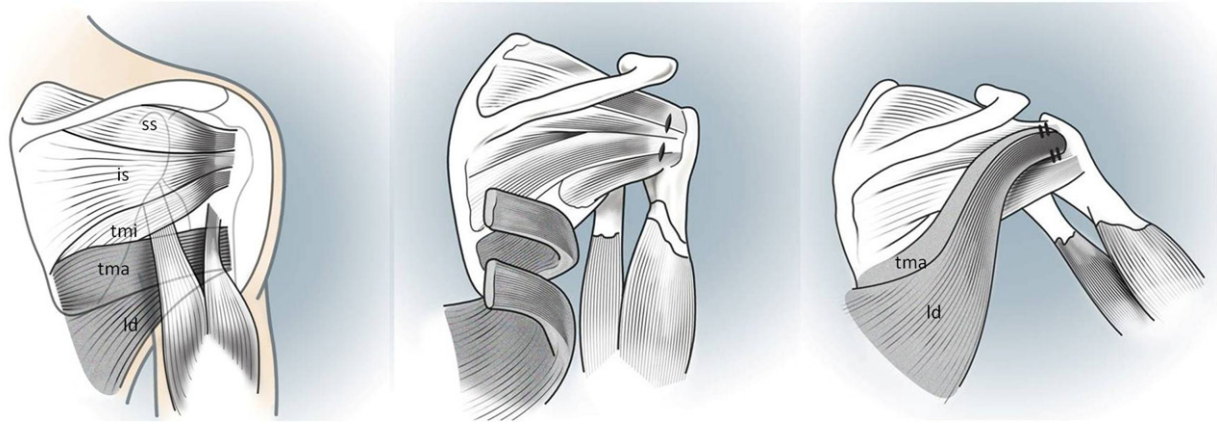

Figure 2 Transfer of latissimus dorsi and teres major tendons to rotator cuff (*ss*, supraspinatus; *is*, infraspinatus; *tmi*, teres minor; *tma*, teres major; *ld*, latissimus dorsi).

severe deformity and the patient should have intact elbow and hand function.[28] To achieve this goal and prevent progression of joint deterioration, we performed anterior lengthening of pectoralis major without violating subscapularis and transfer of latissimus dorsi and teres major to rotator cuff.[21] The aim of this study is to evaluate the functional and radiological results of pectoralis major tendon Z-plasty with transfer of latissimus dorsi and teres major tendons to rotator cuff tendons without release of subscapularis muscle in patients with mild sequela of OBPP.

Materials and methods

Twenty-six patients with OBPP, treated with transfer of latissimus dorsi and teres major tendons to rotator cuff muscles with Z-plasty of pectoralis major tendon, were evaluated retrospectively. Patient selection criteria for this study dictated that patients had reasonable elbow and hand function, glenohumeral changes were grade 3 (according to the radiological grading system developed by Waters et al[27]) or milder, the abduction and external rotation could be maximized by passive motion, and deltoid function was equal or more than 3/5 according to the British Medical Research Council (MRC) scale for muscle strength (Table I).[11] Patients were excluded from the study for the following reasons: if any of humeral osteotomy, subscapularis release, or capsular plication was necessary during surgery; if patient was lost to follow-up or operated within 6 months before the onset of the study; if there was pan-plexus involvement; or if the deltoid power was 2/5 or less. A total of 26 patients (12 male and 14 female) who met the inclusion criteria were included in the study. There were 16 patients with right-side and 10 patients with left-side involvement. Median age at the time of operation was 6 years (range, 1-17). Fifteen patients were operated before the age of 7, whereas 11 patients were operated at or after 7 years of age. All patients had functional limitation in the involved arm due to muscle paralysis and contracture. Half of the patients had C5-C6 nerve root lesions while the other half had C5-C6-C7 nerve root lesions according to their neurological examination. Demographic data and preoperative functional and radiological findings of patients are given in Table II.

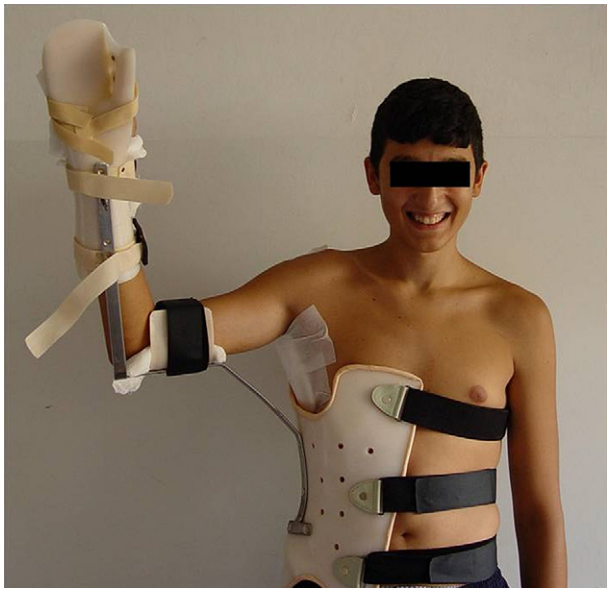

Figure 3 Postoperative immobilization in brace.

Preoperative radiologic evaluation to assess glenohumeral congruity and to check the presence of a posterior dislocation was made using the anteroposterior (AP), oblique, and axillary views and the magnetic resonance image (MRI) of shoulder. Glenohumeral joint congruity was assessed according to the grading system of Waters et al.[27] Fourteen patients had grade 1 glenohumeral changes while 9 had grade 2 and 3 had grade 3 glenohumeral changes. Median age of patients with grade 3 changes was 6 (range, 1-17) and median age of patients with grade 2 changes was 6 (range, 4-14). Postoperative radiological control was made by AP, oblique, and axillary views of the shoulder to assess if there was any posterior glenohumeral subluxation.

Surgical technique

All patients were prepared in general anesthesia, in lateral decubitus position with the involved arm facing upwards. A deltopectoral incision was performed to expose pectoralis major tendon, and a Z-plasty was performed in the following manner. Pectoralis major has 2 insertions: the clavicular head, which inserts more distally, and sternal head, which inserts more proximally. The clavicular head is tenotomized at the insertion point on humerus and the sternal head is tenotomized at the musculotendinous junction. Then, a Z-plasty to the free tendon ends was performed (Fig. 1). Afterwards, an incision on the posterior axillary fold was made to expose teres major and latissimus dorsi tendons. These 2 tendons were dissected separately and tenotomized at their insertion points. They were transferred over the long head of triceps and beneath the deltoid muscle, and sutured with nonabsorbable Ethibond (Ethicon Inc, Sommerville, NJ, USA.) sutures into a slot opened in rotator cuff tendons while the shoulder was held in maximum external rotation (Fig. 2). Finally, tenotomized tendon of pectoralis major was lengthened and sutured. In our technique, subscapularis release was not performed. Immediately after the skin closure and wound dressing, patients were put in a cast holding the arm at 60° abduction on the scapular axis and at maximum external rotation, which was prepared before the surgery for 6 weeks. Older patients were immobilized with a brace in the same position, which was also prepared preoperatively (Fig. 3). After cast/brace removal, a rehabilitation program aiming to improve shoulder range of motion and strengthening of external rotators and abductors was encouraged.

The preoperative and postoperative functional assessments were made using the Mallet scoring, which consists of 5 parameters: abduction, external rotation, ability to carry hand to mouth, ability to carry hand to head, and internal rotation (Fig. 4).[13] The postoperative follow-up included controls at 2nd week (wound control), 6th week (cast removal), 6th month, 1st year, and annually after 1st year. The last control was performed in April 2010. Functional values of the patients at the last follow-up control are given in Table III.

Statistical analysis

All statistical analyses were performed by statistical software (SPSS 11.0.1 for windows; SPSS, Chicago, IL, USA). Continuous variables were expressed as mean ± standard deviation. Shoulder abduction and external rotation degree values are expressed, as median ± standard deviation Wilcoxon test (for comparison of nonparametric data among 2 related groups) and Mann-Whitney U test (for comparison of nonparametric data between 2 independent groups) were used to assess the statistical differences. A P value $<.05$ was considered as statistically significant.

Results

Median follow-up period was 43 months (range, 6-192). Median shoulder abduction values showed a significant increase with operation (from 80° [range, 20-150°] to 115° [range, 20-160°], $P < .005$). Similarly, median external rotation value also increased significantly from the preoperative values of 0° [range, 0-60°] to postoperative values of 35° [range, 0-80°], $P < .005$) (Fig. 5).

According to Mallet classification, mean abduction score was 3.3 ± 0.5 preoperatively and 3.7 ± 0.5 postoperatively. The increase in abduction scores was also significant ($P < .05$). Mean external rotation score increased significantly with operation (from 2.5 ± 0.6 to 3.5 ± 0.8, $P < .05$). The preoperative mean hand to head score (2.8 ± 0.7) also increased significantly after operation (3.4 ± 0.7, $P < .05$). Similarly, mean hand to mouth score also showed a significant increase with operation (2.4 ± 0.6 vs 3.0 ± 0.7; $P < .05$). Mean internal rotation score decreased from 2.9 ± 0.8 to 2.8 ± 0.7 after operation; but the difference did not reach statistical significance (Figs. 6-9).

In 15 patients, who were younger than 7 years of age, mean increases in abduction and external rotation were 38.0° ± 30.5° and 41.7° ± 25.6°, respectively. In the remaining 11 patients, who were 7 years of age or older,

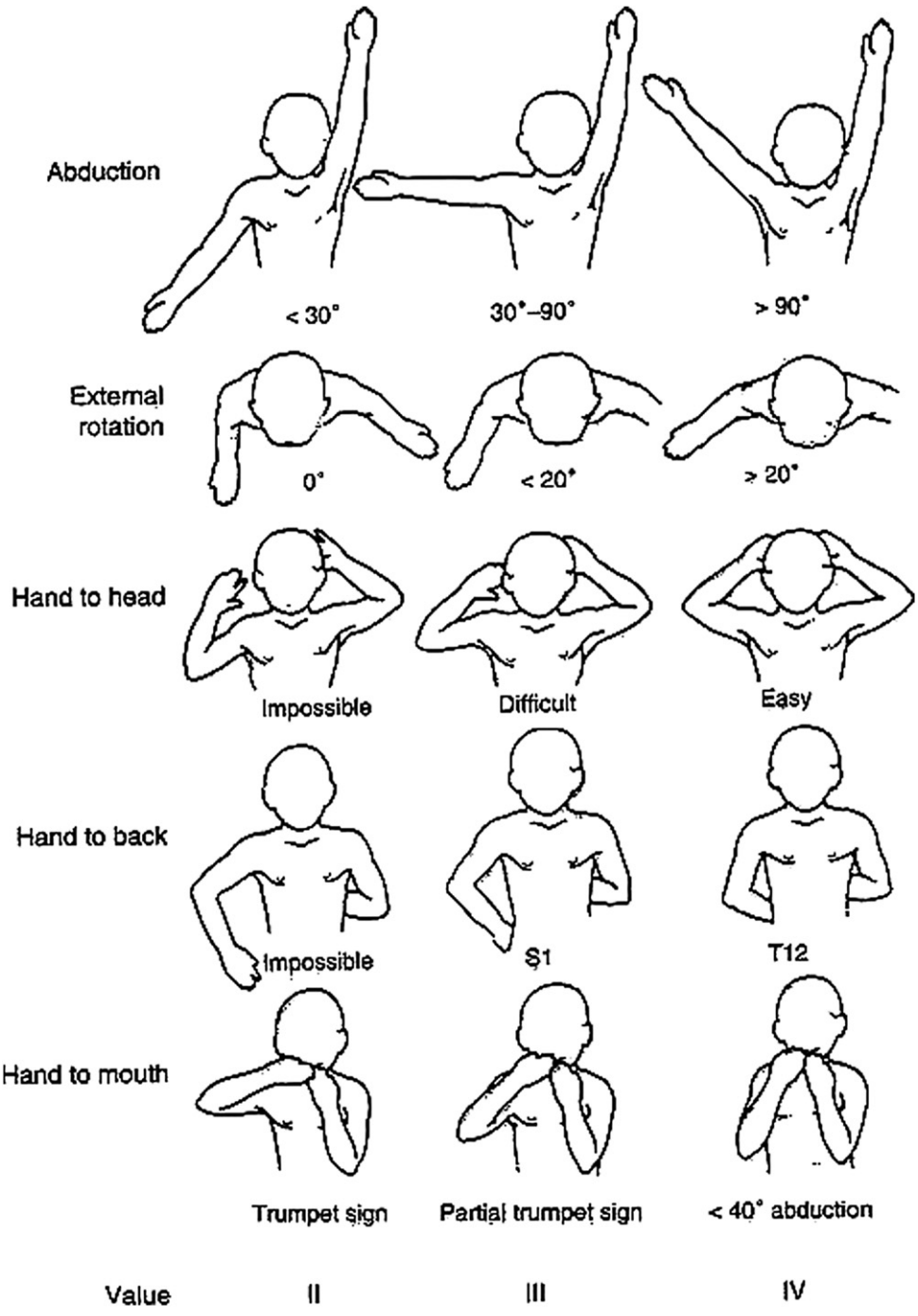

Figure 4 Mallet scoring system.

mean increases in abduction and external rotation were 13.6° ± 22.9° and 26.4° ± 19.6°, respectively. The mean increase in abduction was significantly higher in patients operated before the age of 7 than the patients operated after the age of 7 ($P = .032$) (Fig. 10).

According to the radiological findings at the last control performed in April 2010, no posterior subluxation was observed in any of the patients (Fig. 11).

Discussion

The search for the treatment of shoulder problems seen in OBPP sequela continues. We planned a stepped operation for patients with mild OBPP sequela. In the 1st step, we performed pectoralis major lengthening with Z-plasty to overcome internal rotation contracture. In the 2nd step, we performed latissimus dorsi and teres major tendon transfers

Table III Data on postoperative values of patients

Patient	Follow-up	Abduction	Abduction score	External rotation	External rotation score	Hand-head score	Hand-mouth score	Internal rotation score
1. Male	192	60	3	30	4	2	2	2
2. Male	57	160	4	50	4	4	3	3
3. Male	66	160	4	40	4	4	3	3
4. Female	32	80	3	0	2	3	2	2
5. Female	46	110	4	80	4	4	3	2
6. Female	47	110	4	80	4	4	4	2
7. Female	50	120	4	70	4	4	3	3
8. Male	54	160	4	60	4	4	2	2
9. Male	140	80	3	10	3	2	2	2
10. Female	99	20	2	10	3	2	2	2
11. Male	111	90	4	30	4	3	3	3
12. Male	24	150	4	20	3	4	4	4
13. Male	24	60	3	10	3	3	2	2
14. Female	24	160	4	80	4	4	4	4
15. Female	17	120	4	50	4	3	4	3
16. Female	6	80	3	20	3	3	3	2
17. Female	17	160	4	80	4	4	4	4
18. Male	40	100	4	30	4	3	3	3
19. Male	38	130	4	40	4	3	3	2
20. Female	11	110	4	50	4	3	3	3
21. Male	71	110	4	30	4	3	3	3
22. Female	49	100	4	10	2	3	3	3
23. Female	89	140	4	80	4	4	3	3
24. Female	6	160	4	70	4	4	4	4
25. Female	6	150	4	20	3	3	4	3
26. Male	11	160	4	30	1	4	3	3

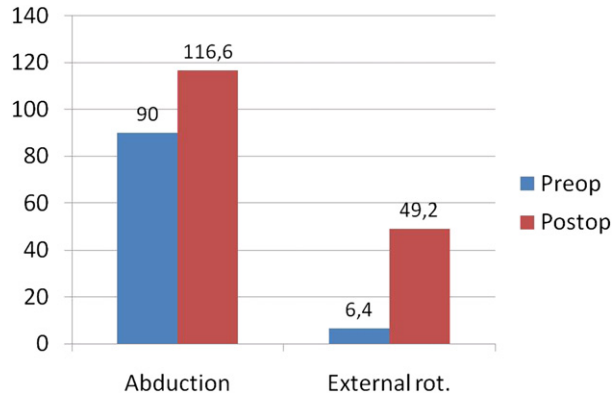

Figure 5 Mean increase in shoulder abduction and external rotation values (expressed in degrees).

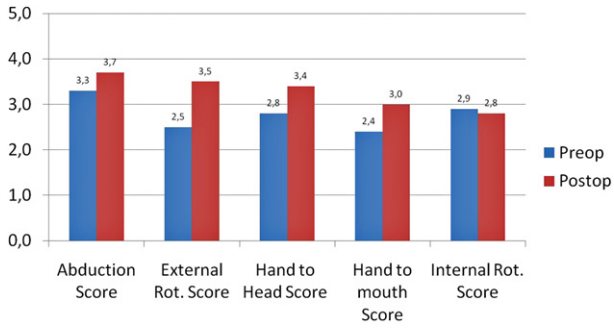

Figure 6 Improvement in mean Mallet scores.

to rotator cuff to improve shoulder function. We did not release subscapularis. We found improved shoulder abduction and external rotation as well as hand to mouth and hand to head function in our patient group. We did not observe glenohumeral deformity progression after the operation.

Latissimus dorsi and teres major tendon transfer with anterior release is an accepted method to increase shoulder abduction and external rotation in OBPP sequela. Considering the anterior release techniques, there are different methods of tendon lengthening.[1,7,15,18] Most of these procedures involved subscapularis release. Those studies including subscapularis release reported increase in global shoulder function. Sever performed subscapularis and pectoralis major tendon lengthening.[18] El-Gammal et al performed subscapularis tendon release in addition to tendon transfer in 109 patients with OBPP.[7] They found that global shoulder function increased in all patients. Pearl

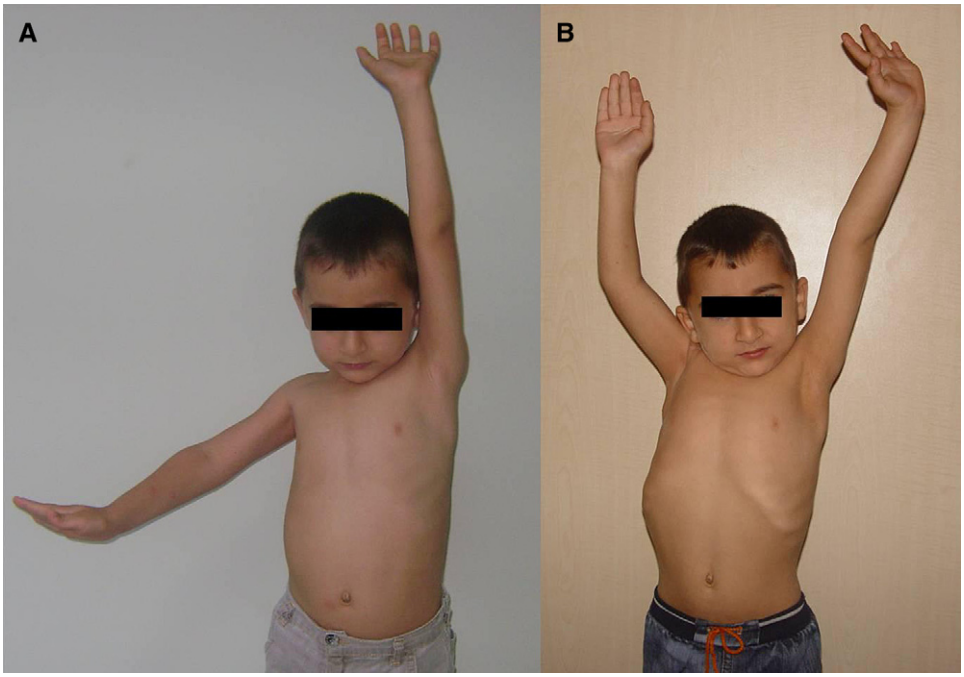

Figure 7 Improvement in shoulder abduction (**A**, preoperative; **B**, postoperative).

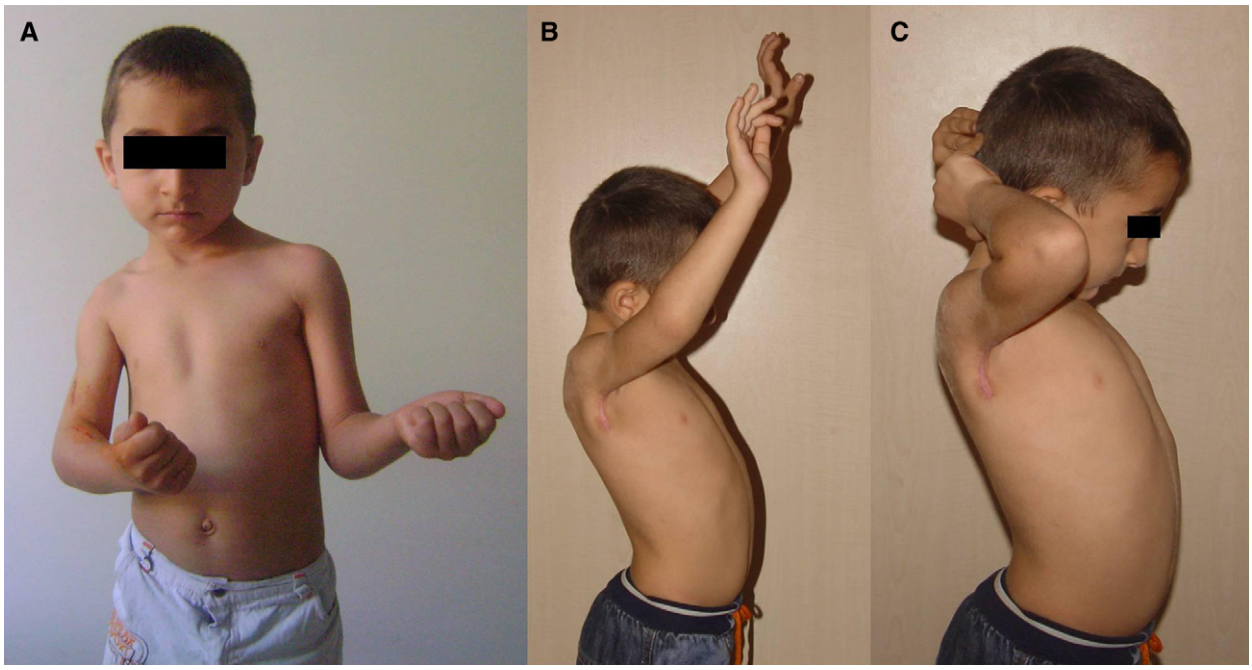

Figure 8 Improvement in shoulder external rotation (**A**, preoperative; **B**, **C**, postoperative).

performed arthroscopic subscapularis tenotomy and release of anterior capsular ligaments.[15] Cohen et al stated that subscapularis release is related with functional and clinical improvement.[4] Hoffer et al applied tendon transfer and pectoralis major release without subscapularis release in 11 patients and demonstrated improved external rotation in all patients.[9] We also performed only pectoralis major tendon lengthening without violating subscapularis muscle. In this way, we aimed to prevent from occurrence of additional anterior adhesions. The lengthening of only pectoralis

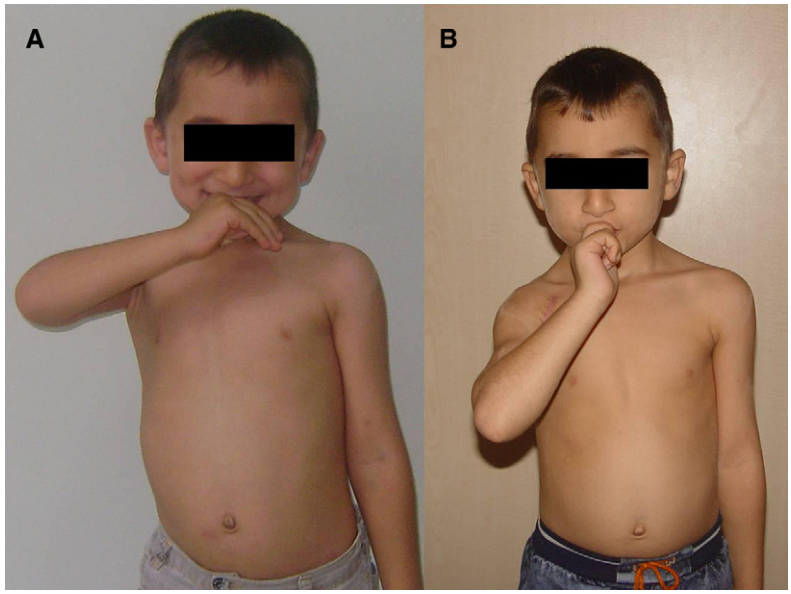

Figure 9 Improvement in hand to mouth function (**A**, preoperative, **B**, postoperative)

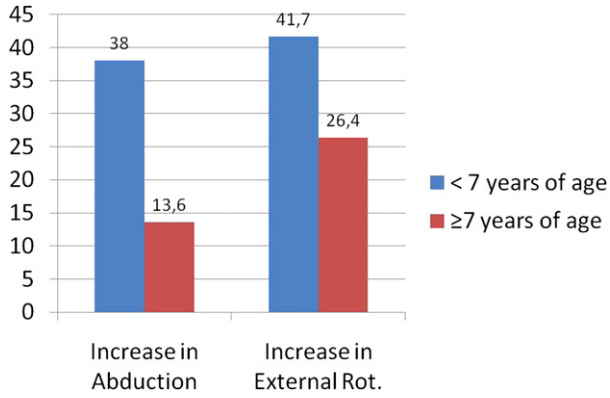

Figure 10 Graph showing mean increase in abduction and external rotation in patients operated before the age of 7 and in patients operated at or after the age of 7 (expressed in degrees).

major tendon enabled significant improvement in external rotation in our patient group. Furthermore, during surgery, with this release we achieved adequate external rotation in scapular plane to obtain optimal length of transferred latissimus dorsi – teres major muscle tendon units. Moreover, the preservation of pectoralis muscle function is important in breast cosmesis, especially in female patients.

In addition to release procedures, there are different techniques of tendon transfers.[3,5,6,12,14,22] The detached tendons of teres major and latissimus dorsi can be attached to proximal humerus or tuberculum majus.[12,22] Covey et al modified L'Episcopo technique and transected latissimus dorsi at the muscluotendinous junction, attached belly of latissimus dorsi to teres major, and passed its tendon through a bony tunnel.[5] They found improvement in shoulder abduction and external rotation. Ozkan et al used anchor to fix the tendons to tuberculum majus.[14] We transferred the tendons of teres major and latissimus dorsi as high as possible to weakened infraspinatus and supraspinatus tendons, which caused more functional limitations as described by Hoffer et al.[9] We did not use any anchor since the anchor would migrate inferiorly causing loss in abduction as the bone grew. We believe that our method is more effective than bony fixation and elicits enough force to overcome internal rotators and simulate the effect of supraspinatus and infraspinatus, namely to strengthen abduction and external rotation. Hoffer et al declared that this transfer increased the stabilizing effect of rotator cuff and the affectivity of deltoid.[9] A classic bony fixation will not improve the force couple effect on rotator cuff[16]; therefore, abduction will not increase as desired. However, to achieve increase in abduction and external rotation with this method, a deltoid force level at least 3 and 45° increase in passive external rotation are required preoperatively.[16]

In our study, we did not perform any humeral osteotomy. We observed that although 3 patients had type 3 changes (posterior subluxation of the humeral head) before the operation, at the last control, radiographic imaging showed glenohumeral deformity did not progress in these patients. The shoulder functions of these patients were also improved. In addition, in 9 patients with type 2 changes, the glenohumeral congruity was maintained. Our results were consistent with Waters and Bae, who found improved shoulder function in 23 patients with preexisting glenohumeral deformity treated with tendon transfer.[24] Similarly, Hoffer and Phipps were able to maintain glenohumeral reduction in 8 patients with posterior dislocation by only tendon transfer.[8]

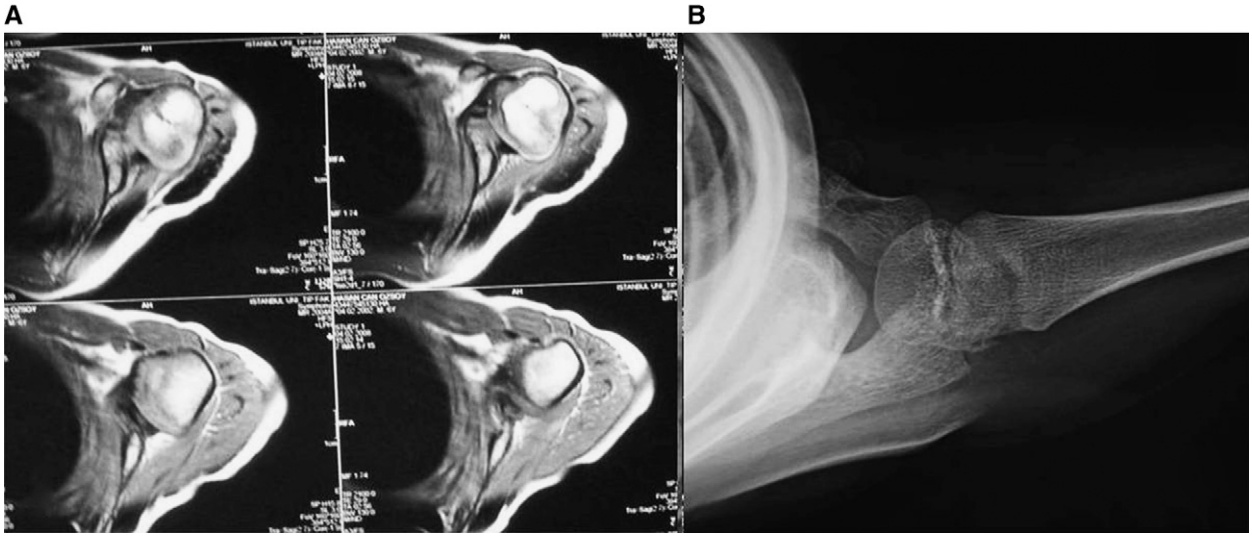

Figure 11 Axillary view showing that the deformity did not progress in a shoulder with type 3 glenohumeral deformity (**A**, postoperative MRI; **B**, postoperative axillary view).

Our results showed a decrease in internal rotation. However, this difference was not significant. It is also predictable that, the resulting effect of the transfer of 2 major internal rotators will be decrease in internal rotation. Terzis and Kokkalis also found decrease in internal rotation as a result of latissimus dorsi and teres major transfer.[20]

There is also debate about the timing of the procedure. Most authors emphasize the importance of early surgical intervention. Terzis and Kokkalis concluded the best timing for rerouting was between 18 months and 4 years of age.[20] Covey et al reported 3-4 years of age was the best for improving function.[5] Javid and Shahcheraghi concluded that this procedure could prevent the development of glenohumeral incongruity if performed at younger age.[10] El-Gammal et al declared that, if performed before the age of 2, this procedure can prevent the formation of secondary bony changes in glenohumeral joint.[7] Although we found improvement in shoulder function in all patients, the increase in abduction and external rotation in patients operated before the age of 7 was higher than the older patients. However, only increase in abduction in this patient group is found to be of statistical significance. This is most probably due to the small number of patients, which is obviously a limitation of our study. Another limitation of this study is that we could not perform postoperative MRI to assess the glenohumeral congruity. The absence of a control group, which would undergo additional subscapularis release to compare with the group that did not undergo subscapularis release, is another limitation. However, in our patient population, we believe that our results are similar to those in literature that demonstrate the results of subscapularis release, in addition to tendon transfers in milder cases of OBPP sequela. A longer follow-up period would give a better idea of the long-term effects of the procedure.

Conclusion

Release of pectoralis major tendon with Z-plasty and transfer of latissimus dorsi and teres major tendons to rotator cuff is an effective and reproducible procedure. Overall shoulder function in patients with obstetrical brachial plexus palsy may be improved, and the results do not deteriorate in time. Subscapularis tenotomy is not required to improve external rotation, particularly in patients with grade 3 or milder glenohumeral deformity. Although, patients younger than 7 years may benefit more, functions of the older patients may also improve with this treatment. However, studies with larger sample size and longer follow-up periods are needed to further prove the effectiveness of this procedure.

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