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Long-term results of latissimus dorsi transfer for internal rotation contracture of the shoulder in patients with obstetric brachial plexus injury

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Background: This study evaluated the long-term outcome of patients with obstetric brachial plexus injury who underwent transfer of the latissimus/teres major tendon to restore shoulder external rotation and determined whether loss of internal rotation would affect their quality of life.
Methods: All patients with a history of obstetric brachial plexus injury who underwent latissimus dorsi transfer for internal rotation contracture were included. Results from 3 clinic visits (preoperative, and short-term and long-term postoperatively) were recorded. Quality of life was evaluated with a questionnaire. Internal rotation impairment was evaluated using the Activities of Daily Living which require active Internal Rotation scoring system.
Results: The study included 45 patients. At a mean 5 months postoperatively, shoulder motion was significantly improved in abduction and external rotation. This was associated with a significant loss of active internal rotation. These results deteriorated over time (at a mean 7.64 years postoperatively), especially in internal rotation (from being able to reach the sacrum to only being able to reach the trochanter) and in external rotation with the arm abducted. This decrease in function led 10 patients (22%) to undergo revision surgery. The mean score on the activities of daily living which require active internal rotation (ADLIR) at the last follow-up was 53.
Conclusion: Although the short-tem results of latissimus dorsi transfer and subscapularis release are encouraging, these gains deteriorated over a longitudinal follow-up period. Abduction is maintained over the long-term, but external rotation deteriorates. Internal rotation deteriorated over a long-term longitudinal follow-up, leading to functional impairment.

Internal rotation contracture of the shoulder may occur in up to 56% of patients with obstetric brachial plexus injury (OBPI).[23] This leads to posterior shoulder subluxation or dislocation secondary to varying degrees of glenohumeral bony deformity.[4,9,23,41,44,49] Although there are many reports on the management of these internal rotation contractures, most studies are small case series with short-term follow-up.[5,30,32,36,43] The most common surgical treatment involves the release of the subscapularis tendon, with or without release of the pectoralis major tendon, and transfer of the latissimus/teres major tendon to restore shoulder external rotation.

Although evaluation of this treatment shows short-term improvements in motion, the only long-term study on this procedure reported that results deteriorate progressively over time.[11] The main outcome measure used in these studies was the Mallet[31] score, a very common and popular score that most authors have used to evaluate functional outcome of the upper extremity in patients with OBPI. However, this score undervalues the importance of shoulder internal rotation in the global function of the shoulder.

There remains a paucity of long-term longitudinal studies evaluating the shoulder function in patients who have undergone internal rotation contracture release with latissimus/teres major tendon transfer. Furthermore, even the short-term studies do not comment on the functional disability that may result from the loss of shoulder internal rotation. The purpose of this study was to evaluate the long-term outcome of patients who underwent internal rotation contracture release with latissimus/teres major tendon transfer and to determine whether loss of internal rotation would affect their quality of life. We hypothesized latissimus dorsi transfer and subscapularis release would lead to increased external rotation with minimal loss of internal rotation over a long-term follow-up.

The Mayo Clinic Institutional Review Board approved this study (IRB Application #: 13-006565). All investigations were conducted in conformity with ethical principles of research.

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Materials and methods

A review examined all patients at our institution with a diagnosis of OBPI who underwent subsequent latissimus dorsi transfer to the rotator cuff between January 1, 1991, and December 31, 2005, with a minimum 2-year follow-up. Patients were included if they had a confirmed diagnosis of OBPI in the electronic medical record, did not experience spontaneous resolution of their symptoms, and were treated with a latissimus dorsi transfer for internal rotation contracture of the shoulder. The study excluded 11 patients because active assessment was not possible or reliable enough because of the young age of the patient.[34]

Demographics

During an 82-year period (from January 1, 1923, to December 31, 2005) we identified 56 patients who underwent subscapularis release and latissimus dorsi transfer for sequelae of OBPI. Although the time period was 82 years, the latissimus dorsi transfer only started to be performed in 1991. Among these 56 patients, 45 had a minimum 2-year follow-up with a reliable clinical examination. There were 23 male (51%) and 22 female (49%) patients. The right upper extremity was injured in 31 patients (69%). Every patient used the uninjured extremity as the dominant extremity. The patients were born at an average of 39.8 weeks, with an average birth weight of 4.22 kg. The mean age at the time of surgery was 3.4 years (range, 10 months-11 years).

Clinical evaluation

Clinical analysis was performed through a review of the electronic and paper medical record. The medical record was examined to obtain other variables, including demographics, comorbidities, birth history, past surgical interventions for shoulder dysfunction, and shoulder function. Active abduction and external rotation were recorded in degrees. External rotation was measured with the elbow by the side and with 90° of abduction. Active internal rotation was measured as the most superior vertebral segment reached by the thumb. Results from 3 different clinic visits were recorded: the last preoperative clinic visit, the first postoperative clinic visit after removal of the spica cast, and the last clinic visit.

Subjective evaluation

Every patient participated in a telephone interview at the last follow-up in which they were asked the following questions:

- What motion is the hardest for you to do?
- During the last clinic visit it was noticed that you had inability to internally rotate the arm. Is this still a major problem? Better? Worse?
- Does it affect you in your everyday life?
- If we could give you this function without losing too much external rotation, do you think your shoulder function would be much better?

In addition, to better evaluate the effect on internal rotation of the transfer of latissimus dorsi at long-term follow-up, we asked patients to answer a questionnaire designed to evaluate their capacity to perform common tasks. A specific scoring system, the ADLIR (Activities of Daily Living which require active Internal Rotation) score, was designed with a given number of points according to the severity of the handicap to obtain a subjective assessment by the patient for his or her internal rotation function. A maximum score of 100 points indicated that the patient had no impairment in his or her daily life due to a limitation in internal rotation (Table I).

Table I
Postoperative quantification of activities of daily living which require active internal rotation

Activities of daily living requiring active internal rotation	Points
Does your loss of internal rotation affect the global function of the shoulder?	
Significantly	6
Moderately	10
Occasionally	15
Not at all	20
Is it difficult for you to reach the top of your back with the affected arm?	
Impossible	1
Very difficult	5
Difficult	6
Somewhat difficult	8
Not difficult	10
Is it difficult for you to reach your lower back with the affected arm?	
Impossible	1
Very difficult	5
Difficult	6
Somewhat difficult	8
Not difficult	10
Is it difficult for you to reach with the affected arm for personal hygiene?	
Impossible	1
Very difficult	5
Difficult	6
Somewhat difficult	8
Not difficult	10
Is it difficult for you to reach your opposite shoulder and/or axilla with the affected arm?	
Impossible	1
Very difficult	5
Difficult	6
Somewhat difficult	8
Not difficult	10
Is it difficult for you to button your shirt?	
Impossible	1
Very difficult	5
Difficult	6
Somewhat difficult	8
Not difficult	10
Is it difficult for you to fasten a belt?	
Impossible	1
Very difficult	5
Difficult	6
Somewhat difficult	8
Not difficult	10
Is it difficult for you to tie your shoes?	
Impossible	1
Very difficult	5
Difficult	6
Somewhat difficult	8
Not difficult	10
Is it difficult for you to open/close a door/curtains?	
Impossible	1
Very difficult	5
Difficult	6
Somewhat difficult	8
Not difficult	10

Surgical procedure

Nine patients (20%) had undergone a previous operation to restore shoulder function: neurolysis of the brachial plexus in 4 (44%), microsurgical nerve repair or neurotization in 4 (44%), and subscapularis release in 1 (12%). The mean age at the time of transfer was 51 months (range, 10 months-41 years). Subscapularis release was performed in 40 patients (89%) at the same time as the transfer by a subscapularis slide technique,[5,18] and 27 (60%) underwent concomitant transfer of the latissimus dorsi and teres major early on to attempt to create a strong and long-lasting external rotation function.

All patients underwent a similar technique of latissimus dorsi transfer by fellowship-trained shoulder or pediatric orthopedic surgeons. Under general anesthesia, patients were positioned in lateral decubitus. An incision was made along the posterior axillary fold in line with the anterior border of the latissimus dorsi and teres major. The muscle belly of the of the latissimus dorsi was mobilized while protecting the neurovascular pedicle located on the anteromedial surface approximately 5 cm from the musculotendinous junction. The latissimus dorsi tendon was released from its insertion on the humerus while protecting the posterior cord branches (radial and axillary nerves). A transdeltoid approach was used to reach the greater tuberosity. Blunt scissors were used to create a path for the tendon transfer between the posterior deltoid and the teres minor, and the tendon was transferred to the greater tuberosity. Fixation was performed by using transosseous sutures or by direct suture to the tendons of the supraspinatus and infraspinatus. Patients were immobilized in external rotation for 6 weeks.

Statistical analysis

Pain and functional outcomes and the influence of different variables on these outcomes were assessed using the χ^2 test or the Fisher exact test for categoric variables and unpaired Student *t* tests for continuous variables. Statistical significance for all tests was set at an α level of 0.05.

Results

Clinical results

When preoperative shoulder function was compared with the shoulder function at the time of the first clinic visit after removal of the spica cast at a mean 5 months postoperatively (range, 1-14 months) motion was found to be significantly improved. Mean abduction and external rotation with the elbow on the side and with arm abducted at 90° improved significantly ($P < .001$). This was associated with a significant ($P = .048$) loss of internal rotation (Fig. 1). These results are detailed in Table II.

Results in external and internal rotation deteriorated over time, and a significant difference was observed between the short-term results and the results at the time of the last follow-up. At a mean 7.64 years (range, 2-16.5 years) after surgery, external rotation with the elbow on the side and with an abducted position had significantly deteriorated ($P < .001$ and $P = .002$, respectively). Internal rotation also decreased significantly ($P = .032$) with time. Abduction remained unchanged, however. These results are detailed in Table III.

Despite this worsening observed over time, when preoperative function was compared with the results at the last follow-up, latissimus dorsi transfer was still found to significantly improve abduction ($P < .001$) and external rotation with the elbow at the side ($P < .001$).

On one hand, external rotation with the arm abducted was also improved; however, this did not reach significance ($P = .495$). On the other hand, internal rotation was significantly ($P < .001$) worse at the last follow-up. These results are detailed in Table IV. At the time of the last follow-up, 36 patients (80%) were not able to reach their back, 28 (63%) could not reach their hip, and 13 (29%) could not reach their abdomen.

Revision surgery

Ten patients (22%) lost function over time and underwent revision surgery to improve their function. The mean time between latissimus dorsi transfer and revision surgery was 8.5 years (range, 5-12 years). These revision operations included arthroscopic or open anterior capsular release in 5, lengthening of the subscapularis tendon in 1, transfer of the pectoralis minor in 2 or of the sternal head of the pectoralis major in 1 for internal rotation, and derotational osteotomy in 1.

Long-term follow-up

Thirteen patients (29%) had a follow-up of ≥10 years. In this subgroup, mean follow-up was 11.8 years (range, 10-16.5 years). Simultaneous subscapularis release was performed in 12 of these patients (92%). Analysis of these patients showed that range of motion continued to deteriorate over time in abduction and in external rotation with the elbow on the side and with the arm abducted. These values were no longer significantly improved compared with preoperative values (85° vs. 119° for abduction at last follow-up, $P = .052$; 16° vs. 34° for external rotation with the elbow on the side, $P = .183$; 74° vs. 78° for external rotation with the arm abducted, $P = .703$). Revision operations were performed in 6 patients (46%) in this subgroup.

Subjective results

In the telephone interview, 70% of the patients stated that the hardest motion for them to do was to put their hand on their back,

Figure 1 A 5-year-old girl underwent subscapularis release and latissimus dorsi transfer for a C5-C6 left brachial plexus palsy. At 1 year postoperatively, she had full active external rotation but severe loss of internal rotation.

Table II
Preoperative and short-term postoperative active range of motion

Variable	Abduction	ER1	ER2	IR
	Mean (range), °	Mean (range), °	Mean (range), °	Mean (range)
Preoperative	89 (0-150)	12 (−20 to 60)	74 (40-95)	T10 (L4-T6)
Short-term	139 (75-180)	60° (40-80)	100° (80-120)	Sacrum (0-T8)
P value	**<.001**	**<.001**	**<.001**	**.048**

ER1, external rotation with the arm on the side; *ER2,* external rotation with the arm abducted at 90°; *IR*, internal rotation (0 means the patient was not able to touch his abdomen); *short-term*, first preoperative visit after removal of the spica cast: mean 5 months (range, 1-14 months) postoperatively.
Bolding represents values that are statistically significant ($P < .05$).

Table III
Short-term and long-term postoperative active range of motion

Variable	Abduction	ER1	ER2	IR
	Mean (range), °	Mean (range), °	Mean (range), °	Mean (range)
Short-term	139 (75-180)	60 (40-80)	100 (80-120)	Sacrum (0-T8)
Long-term	135 (30-180)	37 (−25 to 90)	84° (0-115)	Troch (0-T8)
P value	.669	**<.001**	**.002**	**.032**

ER1, external rotation with the arm on the side; *ER2,* external rotation with the arm abducted at 90°; *IR*: internal rotation (0 means that the patient was not able to touch his or abdomen); *short-term*, first preoperative visit after removal of the spica cast: mean 5 months postoperatively (range, 1-14 months); *long-term*: 7.64 years (range, 2-16.5 years).
Bolding represents values that are statistically significant ($P < .05$).

Table IV
Preoperative and long-term postoperative active range of motion

Variable	Abduction	ER1	ER2	IR
	Mean (range), °	Mean (range), °	Mean (range), °	Mean (range)
Preoperative	89 (0-150)	12 (−20-60)	74 (40-95)	T10 (L4-T6)
Long-term postoperative	135 (30-180)	37 (−25 to 90)	84 (0-115)	Troch (0-T8)
P-value	**<.001**	**<.001**	.495	**<.001**

ER1, external rotation with the arm on the side; *ER2*, external rotation with the arm abducted at 90°; *IR*, internal rotation (0 means that the patient was not able to touch his or abdomen); *long-term*: 7.64 years (range, 2-16.5 years).
Bolding represents values that are statistically significant ($P < .05$).

20% could not straighten their arm because of an elbow contracture, and 10% did not find any motion difficult to perform. Of these patients, 30% stated that it was not a major problem anymore, 20% felt that it was still a major problem, and 50% felt that it had worsened over time.

On one hand, the same 30% were not affected in their everyday life. On the other hand, 70% of the patients were handicapped in their everyday life for a wide a range of bimanual activities that they could no longer perform or that they learned to perform with 1 hand, such as mopping, hugging, putting their hand on their hip while dancing, holding a ball tight with their hands, fixing their hair, putting on their pants, or pulling clothing over their contralateral shoulder.

Sixty percent of the patients felt that their shoulder function would be much better if they could gain internal rotation without losing too much external rotation.

The mean ADLIR score at last follow-up was 53 (range; 27-83), demonstrating that internal rotation was greatly impaired in these patients at the last follow-up.

Discussion

OBPI occurs in 0.3 to 4 per 1000 live births in developed countries.[6,15,16,22,24,37] Most patients experience full nerve recovery in the first few months of life and progress with their upper extremity function without sequelae.[48] However, the absence of recovery or even delayed recovery in patients with upper trunk involvement can lead to shoulder contracture with various degrees of severity[23] causing limitation in abduction and external rotation. 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.[19,25] However, there remains a paucity of long-term studies examining the maintenance of these improvements over time.

Although the initial results after surgery in our series seemed promising, these deteriorated over longitudinal long-term follow-up. Initially, we found at the first postoperative visit after removal of the spica cast at a mean 5 months after surgery (range, 1-14 months) there was improvement in abduction (49°) and external rotation (47°) comparable with short-term results previously described in the literature.[8,10,11,25,26,35,46] However, Pagnotta et al[32] reported progressive worsening of the abduction of their patients at 6 years postoperatively, while external rotation remained unchanged. Our study supports these findings of progressive deterioration of the range of motion over time. This was seen in the longitudinal follow-up of all patients as well as in the subgroup of patients with ≥10 years of follow-up. This deterioration of the shoulder function over time also led to a high rate of revision operations observed in this population, reaching almost 50%.

Indeed, simple, efficient, and reproducible therapeutic options have been described to address recurrence of internal rotation contracture.[13] However, external rotation contracture or loss of internal rotation has yet to be reported as a major complication in the long-term of latissimus dorsi and subscapularis release, because all of the outcome classifications focus on abduction and external rotation.[17,31] This is despite many reports suggesting the risk for loss of internal rotation after these procedures.[29,33,47] To prevent this detrimental loss, it has been recommended to preserve parts (lateral and inferior aspects)[29] or even the whole subscapularis and to release instead exclusively the anterior capsule and coracohumeral ligament.[1,28] The importance of internal rotation in activities of daily life (ability to perform perineal care, to dress) has been very seldom described.[38] Poor internal rotation is a known cause of unsatisfactory results after derotational osteotomy of the humerus,[2] scapulothoracic fusion,[7,21,40,42] and more recently after reverse shoulder arthroplasty.[45] Our studies show that external rotation contracture associated with loss of subscapularis function is a very common complication after latissimus dorsi transfer and subscapularis release, because 76% of the patients were not able to reach their back and 24% were not able to reach their abdomen at the last follow-up, leading to limitations in their daily activities, hobbies, and work.

Loss of internal rotation of the shoulder poses a very challenging problem, because no satisfactory treatment exists for external rotation contracture. Several tendon transfers have been described to restore internal rotation, particularly in the setting of massive subscapularis tears, including pectoralis major,[3,27,39,50] minor,[3,39] trapezius,[20] latissimus dorsi,[12] or teres major[12] transfers. Although pectoralis major transfer is the most commonly reported, the functional success at this transfer restoring internal rotation has been questioned.[14] An anatomic study proposed the latissimus dorsi transfer as an alternative to the pectoralis major transfer because its line of pull is more consistent in keeping with the line of pull of the subscapularis than that of the pectoralis major transfer.[12] However, this transfer is no longer an available option in these patients because the latissimus was used to recover external rotation.

In the light of our findings, the combination of latissimus dorsi transfer and subscapularis release may not be the best option to treat internal rotation contracture in these patients, and other therapeutic options should be considered to restore a more balanced shoulder. Indeed, just as imbalance between strong internal and weak external rotators leads to the onset of internal rotation contracture in the first place, the release of an internal rotator in 89% of the patients (subscapularis) and the conversion of 1 (latissimus dorsi) or 2 (teres major in 60% of the patients) internal rotators into external rotators can be responsible for an imbalance in the other direction, explaining the high rate of external rotation contractures in our series. Better balance could potentially be obtained by sparing the subscapularis or transfer for active external rotation of a muscle that is not an internal rotator, such as the lower trapezius.[13] However, further study is needed to elicit the optimal reconstruction method for this complex patient population.

Considering the functional impairment resulting from loss of active internal rotation and the absence of effective treatment, it appears important to modify the classifications used to report and evaluate these procedures, because they do not incorporate internal rotation as an end point.

Our study has several limitations. It is retrospective and has the inherent weaknesses of such an analysis and is a single-center study, which could induce a referral bias. Furthermore, there is the relatively small number of patients without a true control group, despite this study being the one of the largest studies with the longest follow-up to examine this technique in the setting of OBPI.

Another limitation is the paucity of imaging in this study, because the surgeons did not want to expose the children to excessive radiation at follow-up visits.

However, the strengths of this study involve its focus aim assessing outcome in active internal rotation after latissimus dorsi transfer over a long-term follow-up period. In addition, the ADLIR score is a very subjective score, but this score is not more subjective than the Disabilities of the Arm, Shoulder and Hand score, and patients did not seem to have more difficulty with this questionnaire than with other questionnaires commonly used (Disabilities of the Arm, Shoulder and Hand, American Shoulder and Elbow Surgeons, Patient-Rated Wrist Evaluation).

Conclusion

Although the results of latissimus dorsi transfer and subscapularis release are encouraging in the short-term, our hypothesis was proved wrong, because these tend to deteriorate over a longitudinal follow-up period. The initial gains in abduction and external rotation diminish over time after this procedure. Internal rotation, a motion usually well preserved in children with internal rotation contracture, is markedly affected by this procedure, with very profound functional impairment noted at the long-term follow-up. Surgical management of internal rotation contracture in the setting of OBPI should focus on restoring a well-balanced joint through a combination of transfers and releases that optimize both internal and external rotation of the shoulder.

Disclaimer

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References

1. Abid A, Accadbled F, Louis D, Kany J, Knörr J, Cahuzac JP, et al. Arthroscopic release for shoulder internal rotation contracture secondary to brachial plexus birth palsy: clinical and magnetic resonance imaging results on glenohumeral dysplasia. J Pediatr Orthop B 2012;21:305-9. https://doi.org/10.1097/BPB.0b013e328353688e
2. Abzug JM, Chafetz RS, Gaughan JP, Ashworth S, Kozin SH. Shoulder function after medial approach and derotational humeral osteotomy in patients with brachial plexus birth palsy. J Pediatr Orthop 2010;30:469-74. https://doi.org/10.1097/BPO.0b013e3181df8604
3. Aldridge JM 3rd, Atkinson TS, Mallon WJ. Combined pectoralis major and latissimus dorsi tendon transfer for massive rotator cuff deficiency. J Shoulder Elbow Surg 2004;13:621-9. https://doi.org/10.1016/j.jse.2004.04.003
4. Babbitt DP, Cassidy RH. Obstetrical paralysis and dislocation of the shoulder in infancy. J Bone Joint Surg Am 1968;50:1447-52.
5. Carlioz H, Brahimi L. Place of internal disinsertion of the subscapularis muscle in the treatment of obstetric paralysis of the upper limb in children]. Ann Chir Infant 1971;12:159-67 [in French].
6. Christoffersson M, Rydhstroem H. Shoulder dystocia and brachial plexus injury: a population-based study. Gynecol Obstet Invest 2002;53:42-7. https://doi.org/10.1159/000049410
7. Clare DJ, Wirth MA, Groh GI, Rockwood CA Jr. Shoulder arthrodesis. J Bone Joint Surg Am 2001;83A:593-600.
8. Covey DC, Riordan DC, Milstead ME, Albright JA. Modification of the L'Episcopo procedure for brachial plexus birth palsies. J Bone Joint Surg Br 1992;74:897-901.
9. Dunkerton MC. Posterior dislocation of the shoulder associated with obstetric brachial plexus palsy. J Bone Joint Surg Br 1989;71:764-6.
10. Edwards TB, Baghian S, Faust DC, Willis RB. Results of latissimus dorsi and teres major transfer to the rotator cuff in the treatment of Erb's palsy. J Pediatr Orthop 2000;20:375-9.
11. El-Gammal TA, Saleh WR, El-Sayed A, Kotb MM, Imam HM, Fathi NA. Tendon transfer around the shoulder in obstetric brachial plexus paralysis: clinical and computed tomographic study. J Pediatr Orthop 2006;26:641-6. https://doi.org/10.1097/01.bpo.0000229975.86188.c4
12. Elhassan B. Lower trapezius transfer for shoulder external rotation in patients with paralytic shoulder. J Hand Surg Am 2014;39:556-62. https://doi.org/10.1016/j.jhsa.2013.12.016
13. Elhassan B, Christensen TJ, Wagner ER. Feasibility of latissimus and teres major transfer to reconstruct irreparable subscapularis tendon tear: an anatomic study. J Shoulder Elbow Surg 2014;23:492-9. https://doi.org/10.1016/j.jse.2013.07.046
14. Elhassan B, Ozbaydar M, Massimini D, Diller D, Higgins L, Warner JJ. Transfer of pectoralis major for the treatment of irreparable tears of subscapularis: does it work? J Bone Joint Surg Br 2008;90:1059-65. https://doi.org/10.1302/0301-620X.90B8.20659
15. Evans-Jones G, Kay SP, Weindling AM, Cranny G, Ward A, Bradshaw A, et al. Congenital brachial palsy: incidence, causes, and outcome in the United Kingdom and Republic of Ireland. Arch Dis Child Fetal Neonatal Ed 2003;88:F185-9. https://doi.org/10.1136/fn.88.3.F185

16. Foad SL, Mehlman CT, Ying J. The epidemiology of neonatal brachial plexus palsy in the United States. J Bone Joint Surg Am 2008;90:1258-64. https://doi.org/10.2106/JBJS.G.00853
17. Gilbert A. Results of repair to the obstetrical plexus. In: Gilbert A, editor. Brachial plexus injuries. London: Martin Duniz; 2001. p. 211-6
18. Gilbert A, Brockman R, Carlioz H. Surgical treatment of brachial plexus birth palsy. Clin Orthop Relat Res 1991;264:39-47.
19. Gilbert A, Romana C, Ayatti R. Tendon transfers for shoulder paralysis in children. Hand Clin 1988;4:633-42.
20. Goutallier D, De Abreu L, Postel JM, Le Guilloux P, Radier C, Zilber S. Is the trapezius transfer a useful treatment option for irreparable tears of the subscapularis? Orthop Traumatol Surg Res 2011;97:719-25. https://doi.org/10.1016/j.otsr.2011.05.012
21. Groh GI, Williams GR, Jarman RN, Rockwood CA. Treatment of complications of shoulder arthrodesis. J Bone Joint Surg Am 1997;79:881-7.
22. Hardy AE. Birth injuries of the brachial plexus: incidence and prognosis. J Bone Joint Surg Br 1981;63B:98-101.
23. Hoeksma AF, Ter Steeg AM, Dijkstra P, Nelissen RG, Beelen A, de Jong BA. Shoulder contracture and osseous deformity in obstetrical brachial plexus injuries. J Bone Joint Surg Am 2003;85A:316-22.
24. Hoeksma AF, Wolf H, Oei SL. Obstetrical brachial plexus injuries: incidence, natural course and shoulder contracture. Clin Rehabil 2000;14:523-6.
25. Hoffer MM, Phipps GJ. Closed reduction and tendon transfer for treatment of dislocation of the glenohumeral joint secondary to brachial plexus birth palsy. J Bone Joint Surg Am 1998;80:997-1001.
26. Hoffer MM, Wickenden R, Roper B. Brachial plexus birth palsies. Results of tendon transfers to the rotator cuff. J Bone Joint Surg Am 1978;60:691-5.
27. Jost B, Puskas GJ, Lustenberger A, Gerber C. Outcome of pectoralis major transfer for the treatment of irreparable subscapularis tears. J Bone Joint Surg Am 2003;85A:1944-51.
28. Kany J, Kumar HA, Amaravathi RS, Abid A, Accabled F, de Gauzy JS, et al. A subscapularis-preserving arthroscopic release of capsule in the treatment of internal rotation contracture of shoulder in Erb's palsy (SPARC procedure). J Pediatr Orthop B 2012;21:469-73. http://dx.doi.org/10.1097/BPB.0b013e328353a19f
29. Kozin SH, Boardman MJ, Chafetz RS, Williams GR, Hanlon A. Arthroscopic treatment of internal rotation contracture and glenohumeral dysplasia in children with brachial plexus birth palsy. J Shoulder Elbow Surg 2010;19:102-10. https://doi.org/10.1016/j.jse.2009.05.011
30. L'Episcopo JB. Tendon transplantation in obstetrical paralysis. Am J Surg 1934;25:122-5.
31. Mallet J. Obstetrical paralysis of the brachial plexus. II. Therapeutics. Treatment of sequelae. Priority for the treatment of the shoulder. Method for the expression of results]. Rev Chir Orthop Reparatrice Appar Mot 1972;58(Suppl. 1):166-8.
32. Pagnotta A, Haerle M, Gilbert A. Long-term results on abduction and external rotation of the shoulder after latissimus dorsi transfer for sequelae of obstetric palsy. Clin Orthop Relat Res 2004;426:199-205. https://doi.org/10.1097/01.blo.0000138957.11939.70
33. Pearl ML, Edgerton BW, Kazimiroff PA, Burchette RJ, Wong K. Arthroscopic release and latissimus dorsi transfer for shoulder internal rotation contractures and glenohumeral deformity secondary to brachial plexus birth palsy. J Bone Joint Surg Am 2006;88:564-74. https://doi.org/10.2106/JBJS.D.02872
34. Pearl ML, van de Bunt F, Pearl M, Lightdale-Miric N, Rethlefsen S, Loiselle J. Assessing shoulder motion in children: age limitations to Mallet and ABC Loops. Clin Orthop Relat Res 2014;472:740-8. http://dx.doi.org/10.1007/s11999-013-3324-9
35. Phipps GJ, Hoffer MM. Latissimus dorsi and teres major transfer to rotator cuff for Erb's palsy. J Shoulder Elbow Surg 1995;4:124-9.
36. Pichon F, Carlioz H. Disinsertion of the subscapularis muscle in the treatment of obstetric paralysis of the upper limb (author's transl). Chir Pediatr 1979;20:135-41 [in French].
37. Pöyhiä TH, Koivikko MP, Peltonen JI, Kirjavainen MO, Lamminen AE, Nietosvaara AY. Muscle changes in brachial plexus birth injury with elbow flexion contracture: an MRI study. Pediatr Radiol 2007;37:173-9. https://doi.org/10.1007/s00247-006-0374-0
38. Raiss P, Rettig O, Wolf S, Loew M, Kasten P. Range of motion of shoulder and elbow in activities of daily life in 3D motion analysis. Z Orthop Unfall 2007;145:493-8 [in German]. https://doi.org/10.1055/s-2007-965468
39. Resch H, Povacz P, Ritter E, Matschi W. Transfer of the pectoralis major muscle for the treatment of irreparable rupture of the subscapularis tendon. J Bone Joint Surg Am 2000;82:372-82.
40. Richards RR, Beaton D, Hudson AR. Shoulder arthrodesis with plate fixation: functional outcome analysis. J Shoulder Elbow Surg 1993;2:225-39.
41. Ruchelsman DE, Grossman JAI, Price AE. Glenohumeral deformity in children with brachial plexus birth injuries. Bull NYU Hosp Jt Dis 2011;69:36-43.
42. Rühmann O, Schmolke S, Bohnsack M, Flamme C, Wirth CJ. Shoulder arthrodesis: indications, technique, results, and complications. J Shoulder Elbow Surg 2005;14:38-50. https://doi.org/10.1016/j.jse.2004.05.008
43. Sever JW. The results of a new operation for obstetrical paralysis. Am J Orthop Surg 1989;S2-16:248-57.
44. Sheehan FT, Brochard S, Behnam AJ, Alter KE. Three-dimensional humeral morphologic alterations and atrophy associated with obstetrical brachial plexus palsy. J Shoulder Elbow Surg 2014;23:708-19. https://doi.org/10.1016/j.jse.2013.08.014
45. Sirveaux F Molé D. Failures of the reverse prosthesis: identifying the problems. In: Cofield RH, Sperling JW, editor. Revision and complex shoulder arthroplasty. Philadelphia: PA: Lippincott Williams & Wilkins; 2010. p. 18-28. ISBN-13: 978-0781777476, ISBN-10: 078177747X.
46. Vallejo GI, Toh S, Arai H, Arai K, Harata S. Results of the latissimus dorsi and teres major tendon transfer on to the rotator cuff for brachial plexus palsy at birth. Scand J Plast Reconstr Surg Hand Surg 2002;36:207-11. https://doi.org/10.1080/02844310260259860
47. van der Sluijs JA, van Ouwerkerk WJ, de Gast A, Nollet F, Winters H, Wuisman PI. Treatment of internal rotation contracture of the shoulder in obstetric brachial plexus lesions by subscapular tendon lengthening and open reduction: early results and complications. J Pediatr Orthop B 2004;3:218-24. https://doi.org/10.1097/01202412-200405000-00015
48. Waters PM. Update on management of pediatric brachial plexus palsy. J Pediatr Orthop B 2005;14:233-44. https://doi.org/10.1097/01202412-200507000-00001
49. Waters PM, Smith GR, Jaramillo D. Glenohumeral deformity secondary to brachial plexus birth palsy. J Bone Joint Surg Am 1998;80:668-77.
50. Wirth MA, Rockwood CA. Operative treatment of irreparable rupture of the subscapularis. J Bone Joint Surg Am 1997;79:722-31.