Minimally Invasive Subscapularis Release: A Novel Technique and Results

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Background: Shoulder imbalance secondary to residual brachial plexus birth palsy requires release of internal rotation contracture and tendon transfer. Subscapularis is considered as the prime element of internal rotation contracture and various methods have been described for subscapularis lengthening. It includes open subscapularis slide or lengthening and arthroscopic release. We hypothesized that subscapularis can be released through minimally invasive approach from the medial border of scapula and thus avoiding formal open procedures and risk of weakening the internal rotation strength.

Methods: Safety zones to avoid injury to important neurovascular structures while performing minimally invasive subscapularis release (MISR) were determined through cadaveric dissection. Between 2014 and 2016, 45 patients underwent MISR. A concomitant conjoined Latissimus Dorsi and Teres Major transfer was performed. Twenty patients with minimum 2-year follow-up were included in this study. Average age of patients was 6.4 years. A 5-point modified Mallet Score, degrees of active and passive rotations and abduction were used as outcome measures. Axial MRI imaging were available to classify the gleno-humeral deformity.

Results: Mean improvement in passive external rotation was 80 degrees and in active external rotation was 43 degrees (P <0.001) at 3 months, which was maintained at final follow-up. Average shoulder abduction improved from preoperative—101 degrees to postoperative—142 degrees. Aggregate 5-point Mallet Score improved from 12.8 points (range, 11 to 16) preoperatively to 18.5 points (range, 16 to 21) postoperatively. None of the patients developed external rotation contracture. The results were comparable with other existing techniques of subscapularis release with conjoint tendon transfer.

Conclusions: MISR with conjoined tendon transfer is an effective way of treating internal rotation contracture in children with congruent glenohumeral joints. This procedure has shown beneficial outcomes even in patients with noncongruous glenohumeral joints, when performed in children younger than 4 years. Advantages of MISR include less risk to neurovascular structures, minimal soft tissue trauma, directly addressing the medial tight subscapularis fibers, significantly less surgical time and minimum learning curve.

Levels of Evidence: Level III—retrospective comparative study.

Key Words: brachial plexus birth palsy, obstetric brachial plexus palsy, subscapularis release, minimally invasive, tendon transfer

(*J Pediatr Orthop* 2019;00:000–000)

Lack of active external rotation and abduction are the major limitations in children with residual brachial plexus birth palsy (BPBP).[1–3] Because of weakness of external rotators, internal rotation contracture can develop early in the infancy.[4–7] Persistence of internal rotation contracture ends up in various degrees of glenohumeral deformity in 60% to 70% of children.[8–10]

Hence, release of internal rotation contracture is an integral part of treatment in residual BPBP. Subscapularis is considered as the prime element of internal rotation contracture and various methods of subscapularis lengthening have been described in the literature.[11] These methods include an open subscapularis slide from its origin through the lateral border of scapula, anterior complete or "Z" lengthening from its insertion and an arthroscopic anterior release.[12–19] Conjoined or isolated Teres Major and Latissimus Dorsi transfers are done concurrently to balance the shoulder joint.[4,20,21]

Fairbank[11] first described the anterior release of subscapularis from the insertion along with shoulder capsular release in 1913. Sever[2] in 1927 described subscapularis tenotomy without capsular release.

Both these procedures were associated with high rates of external rotation contracture and internal rotator weakness.

Carlioz and Brahimi[13] introduced an open subscapularis slide from lateral border of scapula from its origin in 1971.[12] Gilbert and colleagues emphasized that subscapularis slide should only be performed if the shoulder joint

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No funding was received in support of this study.
The authors declare no conflicts of interest.

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Supplemental Digital Content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website, www.pedorthopaedics.com.

DOI: 10.1097/BPO.0000000000001458

is congruent.[15] High rates of recurrence have been found when subscapularis slide has been done in isolation.[14,16]

Immerman reported no recurrence when he combined subscapularis release with tendon transfers.[21] Arthroscopic release of subscapularis in younger children has shown to relieve internal rotation contracture and regression of glenohumeral deformity. In children older than 3 years, Latissimus Dorsi transfer was added to avoid recurrence or secondary surgery.[18]

Moderate loss of internal rotation was observed in all the patients, while it was severe in some requiring secondary osteotomy.

We hypothesized that subscapularis slide can be performed through a small incision along the medial border of scapula to avoid formal open procedure and to lessen the risk of losing internal rotation strength. We tested this hypothesis by performing cadaveric dissection and ascertained the safety profile of the procedure. Based on our observations of cadaveric study, since 2014, we adapted a novel approach where in subscapularis slide is done through a centimeter incision from the medial border of scapula. This procedure is termed as “Minimally Invasive Subscapularis Release (MISR)”. A concomitant conjoined Latissimus Dorsi and Teres Major to Infraspinatus transfer was performed through axillary approach.

The purpose of this study is to evaluate the outcome of patients who underwent MISR and a conjoined tendon transfer. We also compared the outcome with currently existing other methods.

METHODS

Cadaveric Dissection

Dissection was carried out on 5 preserved cadavers (10 sides) to understand the plane of MISR and its relation to the nearby important neurovascular structures. Cadavers were positioned prone. A vertical midline incision was made from spinous process of C7 to T 12 (Figs. 1A–C).

Horizontal skin incisions were placed from the end points to create a laterally based flap. Trapezius and Levator scapulae were released from the medial border of scapula. Deltoid was released from spine of scapula and reflected laterally to see the sub deltoid anatomy. Muscles along the posterior triangle of shoulder were identified. Teres Minor was released from the lateral border of scapula and reflected laterally. A combined flap of Latissimus Dorsi and Teres Major was lifted from the lateral border of scapula to see the course of Circumflex Scapular Vessels and its branch to subscapularis muscle. It was found that Circumflex Scapular Vessels give subscapularis branch at the junction of upper 2/5 and lower 3/5 of the lateral border of scapula. It lay in the bed between Teres Minor and Teres Major. This was the typical starting point for the conventional lateral subscapularis slide. Thus, it makes these structures vulnerable while doing an open lateral Subscapularis slide. Supraspinatus was dissected subperiosteally to note the course of supraspinatus neurovascular pedicle.

We performed a typical MISR from the medial border of scapula. A purposeful penetration of the sharp periosteal elevator was performed to see the exit point of instrument along lateral border of scapula. It was found that if the entry point of the periosteal elevator (at the junction of upper 1/3 and lower 2/3) along the medial border of right scapula is considered as the center of a clock, the Circumflex Scapular Vessels lie at 3-o’clock position (Fig. 1). Supraspinatus neurovascular pedicle was located dorsally at 1-o’clock position. Thus, the operating surgeon needs to remain careful between 1-o’clock and 3-o’clock positions (this zone will be between 9-o’clock and 11-o’clock positions for the left scapula). One should also avoid proceeding beyond the thick lateral ridge of scapula to penetrate Circumflex Scapular Vessels.

Muscles from the medial border of scapula were then released to elevate the scapula and to observe the under surface. Periosteum was found intact along the volar surface of scapula at most places. Tiny muscle fibers found attached at few places, which suggests that the plane of dissection in MISR is extra periosteal and submuscular. Serratus anterior and rhomboids attachments were found intact except at the entry point.

Patient Details

A comprehensive brachial plexus clinic is functional at our center since 2009. Patients with internal rotation contracture and weak external rotation of shoulder were treated with anterior release of subscapularis at insertion along with capsulo-ligamentous structures between 2009 and 2013. A conjoined Latissimus Dorsi and Teres Major tendon was transferred to Infraspinatus in children who could not initiate active external rotation. Since 2014, we have started doing subscapularis slide from the medial border of scapula (MISR) and the conjoined tendon transfer was performed at the same stage. This subset of patients was the subject of current investigation. Patients with passive internal rotation of <30 degrees and those who could not initiate active external rotation were included in the study. Adolescents with noncongruous gleno-humeral joint on axial MRI were excluded. Regional review board approval was obtained to conduct this study.

Between 2014 and 2016, 45 patients underwent this procedure. Twenty patients with minimum follow-up of 2 years were included in this study. Average age of patients at the time of surgery was 6.5 years (1.3 to 18 y). A total of 12 patients were boys. Nineteen patients were diagnosed as Narakas-1 and 1 patient as Narakas-3.[22] Patients were followed every 3 months after surgery at comprehensive brachial plexus clinic. Comprehensive clinic comprises of a Pediatric Orthopaedic Surgeon, a Plastic Surgeon, and a Pediatric physical therapist. Assessments were done at follow-up visits by physical therapist. Average follow-up was 30.4 months (24 to 49 mo).

Statistical Methods

All the patients underwent a detailed preoperative and postoperative clinical and radiological evaluation. Shoulder function was assessed by 5-point Modified

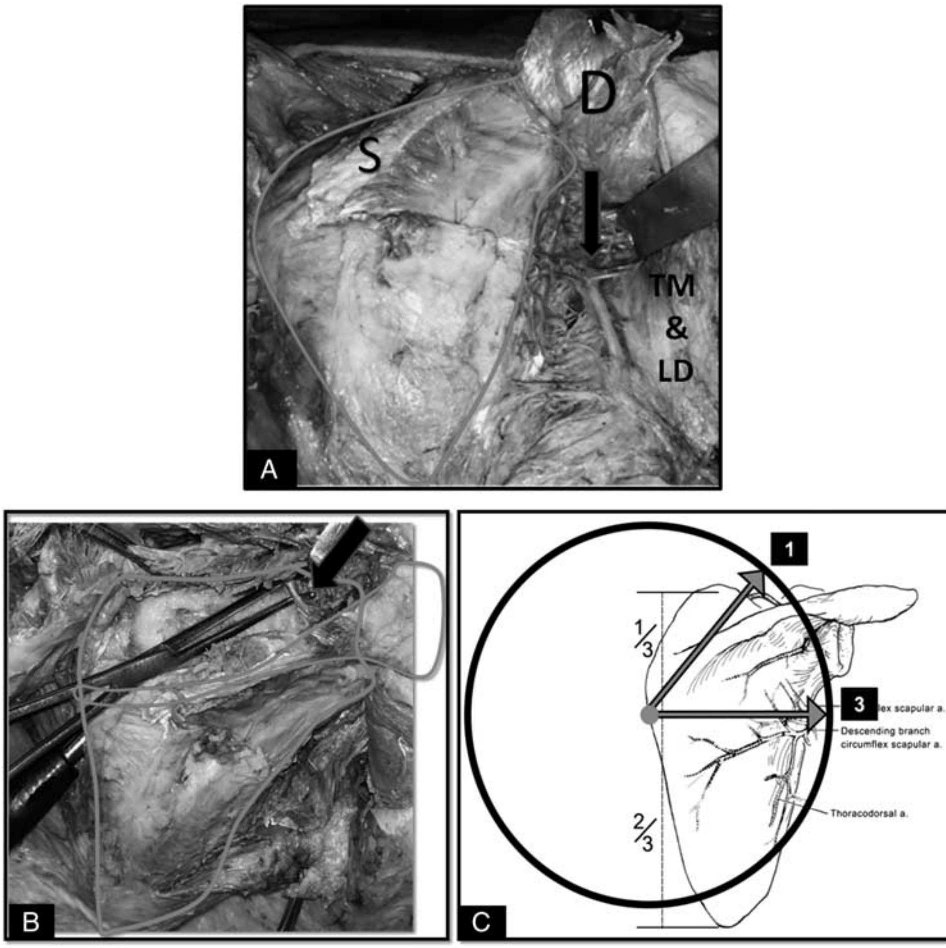

FIGURE 1. A–C, Cadaveric dissection of right scapula to study MISR plane and safety zone of the procedure. A, Circumflex Scapular Vessels (black arrow) enter the substance of subscapularis between the bed of Teres Minor and Teres Major, at the junction of upper two fifth and lower three fifth of lateral border of scapula and continues distally as thoracodorsal vessels. Circumflex Scapular Vessels lie diagonally opposite side to the entry of periosteal elevator from medial border. If we consider the entry point for MISR as a center of the clock, it lies at 3-o'clock position (for right scapula). D—reflected posterior deltoid from spine of scapula (S), TM and LD—reflected Teres Major and Latissimus Dorsi. B, Suprascapular neurovascular bundle lies dorsally over the supraspinous part of scapula. If we consider the entry point for MISR as a center of a clock it lies at 1.30 position. C, One needs to exercise caution between 1 and 3-o'clock position (for right scapula) to avoid injury to major neurovascular structures while doing MISR. MISR indicates minimally invasive subscapularis release.

Mallet score.[23] Degrees of passive and active external rotation with arm adducted and abducted were measured.

Improvement in degrees of shoulder abduction were also noted. Sixteen out of 20 patients had preoperative and postoperative axial MRI to assess the effect of surgical procedure on gleno-humeral remodeling as per Waters Classification.[8,24] Wilcoxon signed rank test was used to assess the significance of paired differences between preoperative and postoperative measures within each surgery group. Comparison of differences in these paired changes among both the surgery groups were performed using Mann-Whitney *U* test. All statistical analysis was performed with SPSS software version 20 (IBM).

Surgical Technique

Patient was given lateral position. The affected shoulder, chest, and back were prepared till midline and about 5 cm below the lower end of scapula. The whole upper extremity was painted and kept free. The arm was internally rotated and forward flexed to make the medial border of scapula prominent. One centimeter incision was placed at the junction of upper one third and lower two third of medial border of scapula. A blunt curved hemostat was advanced through rhomboids to reach the undersurface of scapula. Hemostat was widened and withdrawn. A 4 mm curved periosteal elevator was introduced with its concave surface facing the body of scapula. In a clockwise manner, subscapularis slide was performed (Figs. 2A–D) (Video 1, Supplemental Digital Content 1, http://links.lww.com/BPO/A240).

Subsequently a broader (6 mm) curved periosteal elevator was introduced and rest of the thicker septae at superomedial and inferior angle were released. It was followed by gentle stretching of shoulder internal rotators and anterior capsule for 5 minutes. For this, shoulder was stabilized with

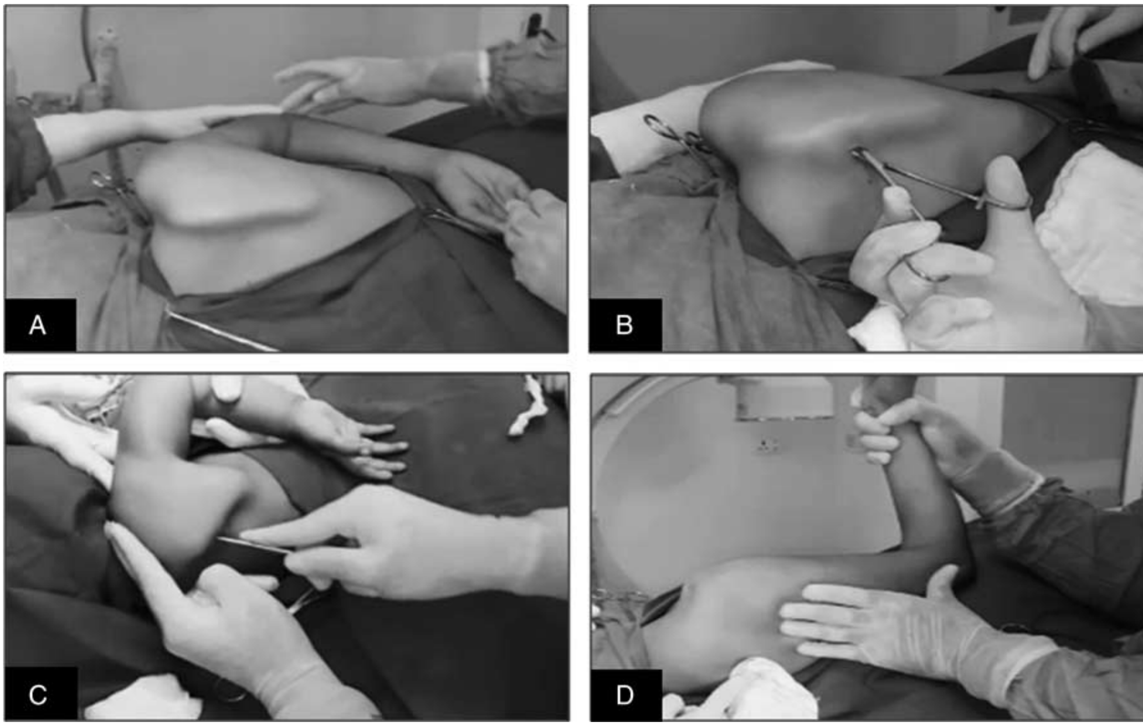

FIGURE 2. A–D, Technique of minimally invasive subscapularis release. A, Arm is internally rotated and forward flexed to make the medial border of scapula prominent. B, A curved artery forceps is introduced through subcutaneous tissue and rhomboids to reach the under surface of scapula and widened. C, Periosteal elevator is introduced to release subscapularis in a clockwise manner. D, 90 degrees passive external rotation achieved after MISR. Elbow flexed at 90 degrees and gentle stretching of anterior shoulder capsule and ligaments done over 5 minutes, after stabilizing the elbow joint. MISR indicates minimally invasive subscapularis release.

arm adducted, elbow was flexed at 90 degrees and the forearm was kept in full supination. The procedure lasts for about 8 to 10 minutes. Five minutes for MISR and further 5 minutes for gentle stretching of arm. One should achieve 70 to 80 degrees of free external rotation and the last 10 to 20 degrees may remain springy. Wound was closed with a single skin suture. This procedure was followed by a conjoined tendon transfer through axillary approach.[16] A shoulder spica was applied in 45 degrees of abduction, 60 degrees of external rotation and 90 degrees of elbow flexion for 5 weeks. Thereafter, a customized splint to keep arm in abduction and external rotation was worn at night time for 3 months. Patient received regular physiotherapy for 3 months and was monitored by therapist monthly for 1 year.

To exactly define the plane of MISR, we have done arthroscopic visualization of subscapular area after doing a typical procedure in 2 patients. We used 2 portals, one from the supero-medial angle of scapula and the other from the MISR entry point. This examination revealed that a few muscle fibers were still attached to the undersurface of scapula, whereas in the remaining areas we were subperiosteal with only bone visible.

RESULTS

Average preoperative passive external rotation was 1.25 degrees (range, −20 to 30 degrees) and active external rotation with arm adduction was −10.25 degrees (range, −30 to 15 degrees). Active and passive external rotation range improved by 58 and 69 degrees, respectively at 3 months postsurgery.

Improvement in external rotation at 3 months was maintained at final follow-up (Table 1). Average shoulder abduction improved from preoperative—99.75 degrees to postoperative—145.5 degrees. Aggregate 5-point Mallet Score shown improvement from 12.8 points (range, 11 to 16) preoperatively to 18.6 points (range, 16 to 22) at final follow-up. Different elements of modified Mallet Score also demonstrated expected improvement. Global External Rotation and Hand to Neck scores improved from 2.1 to 4 points each. Similarly, Hand to Mouth score improved from 2.3 to 3.5 points at the most recent follow-up. There was no deterioration of Hand to Spine score.

Twelve out of 16 patients had type-II or type-III morphology on axial MRI, signifying a congruent gleno-humeral joint with glenoid retroversion or retroversion with subluxation, respectively. Four patients had type-IV gleno-humeral morphology suggestive of pseudo-glenoid formation. Eight out of 12 patients with congruent joints improved to type-I morphology whereas 4 to type-2 morphology on postoperative axial scan. All the patients with noncongruous joints improved to type-3 morphology except 1 which was found to have type-I morphology. (Figs. 3A, B).

TABLE 1. Comparison of Improvements After MISR With Tendon Transfer and ASTR With Tendon Transfer

	Mean ± SD							
Treatment Group	**Age (mo)**	**Follow-up (mo)**	**PER (deg.)**	**AER (deg.)**	**ABD (deg.)**	**GERM**	**GABM**	**AMS**
ASTR+TT	61.75 ± 43	31.95 ± 12	84.75 ± 12	71.25 ± 18	39.25 ± 21	1.75 ± 0.44	0.70 ± 0.66	6.25 ± 1.49
MISR+TT	76.73 ± 56	30.40 ± 5.6	80.00 ± 11	64.25 ± 14	45.75 ± 20	1.80 ± 0.41	0.70 ± 0.66	5.75 ± 1.52
P	0.35	0.53	0.34	0.24	0.21	0.79	0.99	0.28

ABD indicates abduction; AER, active external rotation; AMS, Active Mallet Score; ASTR, anterior soft tissue release; GABM, global abduction Mallet; GERM, global external rotation Mallet; MISR, minimally invasive subscapularis release; PER, passive external rotation; TT, tendon transfer.

P-value < 0.05 is significant.

None of the patients developed external rotation contracture or inability to reach midline after this procedure. There were 2 episodes of subcutaneous hematoma along the entry site of the periosteal elevator, which resolved spontaneously. There was 1 incident of inadvertent penetration of scapular body without any consequence. No patient demonstrated postoperative winging of scapula or weakness of rhomboids.

Comparison With Other Methods

Between 2009 and 2013, patients with internal rotation contracture and weak external rotation were treated with subscapularis release at insertion and release of capsuloligamentous structures (Table 1). A conjoined Latissimus Dorsi and Teres Major tendon was transferred to Infraspinatus. Since 2014, we have performed the MISR instead of anterior open release. These 2 subsets of patients are distinct and different. Details of both the groups are in the Appendix (Supplemental Digital Content 2, http://links.lww.com/BPO/A241).

No statistically significant difference was observed in the outcome of these groups, in terms of global Mallet score, Active and passive external rotation at final follow-up ($P > 0.05$).

Four out of 20 patients who underwent ASTR and tendon transfer, ended up in external rotation contracture.

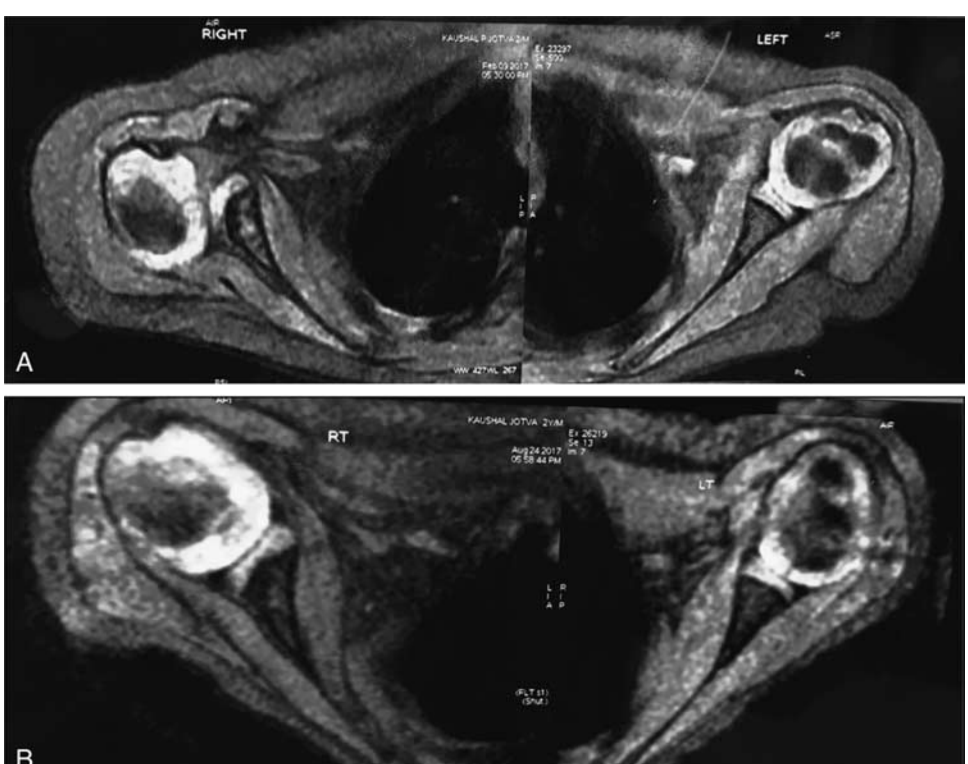

FIGURE 3. A, 2-year-old boy with residual BPBP, presented with restricted shoulder abduction and external rotation. His passive external rotation was −20 degrees. Axial MRI scan suggestive of Pseudoglenoid formation with posterior subluxation of humeral head, consistent with Waters type-IV schema. B, 1-year follow-up (post-MISR and conjoint tendon transfer) axial MRI scan shows well reduced glenohumeral joint with glenoid retroversion difference of 5 degrees. Excellent remodeling of glenohumeral joint was observed in this case. LT indicates left; RT, right.

Two of them were severe enough to warrant a secondary internal-rotation humeral osteotomy.

DISCUSSION

Because of relative early recruitment of shoulder internal rotators in residual BPBP, patients usually develop an internal rotation contracture. Subscapularis receives innervations from C5 to C7, making it prone to undergo contracture in typical Erb Palsy involving C5 and C6.[25]

Persistent internal rotation contracture leads to progressive gleno-humeral deformity. It is imperative to consider timely release of internal rotation contracture.

Gilbert and colleagues advocated the use of subscapularis release only in congruent glenohumeral joint. After an open subscapularis slide procedure, 47% of the patients did not require subsequent soft tissue rebalancing surgeries. This effect was observed mainly in children younger than 2 years. Therefore, they recommended isolated soft tissue release as primary intervention.[13,14] Other studies have suggested reduced rate of recurrence when subscapularis release is combined with tendon transfer.[21] In our series, most of the patients failed to initiate active external rotation at presentation. Hence, we combined a conjoined tendon transfer with MISR. We have not come across recurrence of deformities in our study group. MISR does not risk the neurovascular pedicle of subscapularis muscle, which lies in proximity of conventional slide entry point.[14,26]

Lengthening of subscapularis at insertion with open reduction of humeral head has been performed in few series.[7,11,15,20] Although this procedure showed good improvement in shoulder function, a high percentage of patients developed external rotation contracture and anterior instability.[15,16,27] Loss of active internal rotation and ability to reach midline was found in rates as high as 50%.[16] Van der Slujis and colleagues required secondary internal rotation humeral osteotomy in 42% patients, whereas Birch and colleagues reported this rate to be 21%. We did not come across any incidence of external rotation contracture in current series.

All but 1 patient could easily reach midline and there was no deterioration in hand-to-spine score. The unaltered tendon-muscle length ratio after MISR prevents weakening of the subscapularis.

In their series, Pearl and colleagues reported improved external rotation range; however, there was substantial reduction in internal rotation range. Significant remodeling of gleno-humeral joint was observed in 12 out of 15 joints.[18] Kozin et al[19] also reported loss of midline function in their earlier patients after arthroscopic complete release of subscapularis and they subsequently limited their release to lower half. Outcome of MISR and tendon transfer in patients with congruent gleno-humeral joint (Waters—I–III) are comparable with that of arthroscopic release and tendon transfers. In noncongruent joints, arthroscopic release yields better joint reduction. Three out of 4 patients in our series with noncongruent joints had persistent internal rotation posture of arm. Two patients required a secondary humeral external rotation osteotomy. One patient (age, 2 y) showed improvement in glenohumeral morphology from Waters IV to Waters I. This significant remodeling can be attributed to the young age of patient. Thus, for older children with noncongruent joints, MISR alone is inadequate and anterior capsulo-ligamentous release should be added.

MISR offers several advantages over other existing methods. It is minimally invasive and obviates need of lateral open slide. It can be safely executed without endangering surrounding neurovascular structures. Strength of internal rotation is maintained after MISR as the muscle-tendon unit ratio is not changed. We believe that by doing MISR from the medial border of scapula, one can easily access to the main tight supero-medial septae of subscapularis, which at times may become difficult to access from lateral approach. By performing slide from medial border, chances of iatrogenic injury to circumflex scapular neurovascular pedicles are minimized.

CONCLUSIONS

MISR with conjoined tendon transfer is an effective way of treating internal rotation contracture in children with congruent glenohumeral joints. It has also shown beneficial outcomes in patients with noncongruous glenohumeral joints, when performed in children younger than 4 years.

ACKNOWLEDGMENT

The authors thank Dr Dhiren Ganjwala and Dr Santosh Raibagkar for helping them in preparing this manuscript.

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