Original Article

Open Anterior Subscapularis Release for Adduction and Medial Rotation Shoulder Contracture in Neonatal Brachial Plexus Palsy

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Abstract

Introduction: Adduction and medial rotation shoulder contracture are prevalent in unresolved neonatal brachial plexus palsy (NBPP). Various surgical options exist, including open anterior subscapularis release, to address this condition. This study assessed the outcomes of this procedure. **Materials and Methods:** This cross-sectional, observational study focused on a cohort of children aged over 12 months who underwent open anterior subscapularis release to remedy residual shoulder contracture from upper or global NBPP over 11 years. The Mallet score was utilised to appraise deficits in shoulder function. **Results:** The study included 32 patients. The sex ratio was 0.78. The median age at surgery was 36 months (25; 56). The right side was affected in 75% of cases. The median improvement in the Mallet score after subscapularis release was 4 (2; 6). This enhancement was statistically significant ($P < 0.001$), with a median follow-up duration of 78 months (72; 82). There was a substantial increase in shoulder abduction ($P < 0.001$) and lateral rotation ($P < 0.001$). Hand-to-mouth ($P < 0.001$) and hand-to-head ($P < 0.001$) manoeuvres exhibited significant enhancement. The hand-to-spine manoeuvre did not show a substantial alteration. A significant correlation was found between the injury severity and the enhancement of the Mallet score post-surgery ($P = 0.009$). **Conclusion:** Open anterior subscapularis release yielded significant mid-term functional enhancements in shoulder motion, with no modification in medial rotation. Improvements were observed even in children beyond 4 years of age, with those having more severe injuries showing greater functional recovery.

Keywords: Neonatal brachial plexus palsy, shoulder contracture, subscapularis, tenotomy

Introduction

Neonatal brachial plexus palsy (NBPP) is induced by undue traction on the brachial plexus during challenging childbirth.[1] It remains a prevalent condition, with the incidence estimated to be between 0.2 and 1.5 cases per 1000 live births.[2] Various risk factors have been suggested as indicative of NBPP, yet multiple studies have identified macrosomia and shoulder dystocia as particularly significant contributors.[2] The upper NBPP typically presents as a classic Erb–Duchenne palsy (C5-6), characterised by compromised abduction and lateral rotation of the shoulder, a deficit in elbow flexion and forearm supination, whereas hand function is maintained. In extended Erb–Duchenne palsy (C5-7/8), there is an additional impairment in wrist extension. Total NBPP constitutes a comprehensive palsy (C5-T1) with entire paralysis and loss of sensation in the affected upper limb, occasionally accompanied by a Claude Bernard-Horner sign. Lower NBPP is less common, denoting Dejerine-Klumpke palsy (C8-T1), which presents with isolated hand and wrist paralysis, as well as the Claude Bernard-Horner sign. While most patients spontaneously recuperate in their initial months of life, shoulder contracture remains a frequent long-term manifestation.[3] Shoulder contracture has been observed in over half of the children who do not achieve

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complete neurological recovery by the age of 3 weeks.[4] The most typical complications in this group of patients are the early-life development of adduction and medial rotation shoulder contracture.[5] This limitation in shoulder movement is predominantly due to subscapularis muscle shortening and atrophy.[6] In these patients, the shoulder abductors and lateral rotators, being relatively more affected, fail to exert sufficient resistance against the comparatively preserved adductors and medial rotators of the shoulder, predominantly the subscapularis.[7] In patients with protracted contracture, glenohumeral incongruence and posterior subluxation are likely to ensue.[8] Various surgical alternatives are at hand for addressing shoulder contracture and the advancing deformity associated with NBPP. Among soft-tissue procedures, open anterior subscapularis release is a straightforward and secure intervention in children with shoulder adduction and medial rotation contracture resultant from unresolved NBPP.[8] This study aimed to evaluate the clinical outcomes following open subscapularis release without the necessity of tendon transfer (e.g. *latissimus dorsi* or *teres major*) in children presenting with shoulder adduction and medial rotation contracture due to persistent NBPP.

Materials and Methods

Study design and settings

We conducted a cross-sectional, observational study from 1st January 2014 to 31st December 2021 within our department.

Study population

Our study focused on a cohort of patients aged 12 months or older with unresolved upper or global NBPP who underwent open anterior subscapularis release at our institution and had a minimum of 5-year follow-up. This procedure was proposed for toddlers if passive shoulder lateral rotation at adduction was 0° or less despite an adequate physiotherapy programme or for older patients with active shoulder abduction of < 90° and lateral rotation at adduction of < 10°. The exclusion criteria included children with lower NBPP, a history of previous surgery on the same shoulder, concurrent health conditions such as cerebral palsy, and those unavailable for post-surgery follow-up.

Data collection and variables

Departmental records were examined to identify the patients with NBPP who had undergone open anterior subscapularis release within the specified study time frame. Patients with isolated shoulder involvement and normal hand and wrist function were classified as having Erb–Duchenne palsy; those with added wrist extensors deficiency were categorised as having extended Erb–Duchenne palsy; and those with weak hand function were designated as having global palsy. All patients were subject to standardised preoperative and postoperative evaluations. The Mallet score (unmodified) was utilised to appraise deficits in shoulder function.[9] Active and passive ranges of motion were gauged using a goniometer with the patients standing.

Operative technique

The same standardised surgical procedure was carried out by the senior surgeon, the last author of this paper, on all patients. Under general anaesthesia, the patient was positioned supine with modest support beneath the ipsilateral scapula. The range of motion of the shoulder was evaluated post-anaesthesia to ascertain the extent of subscapularis release required. The entire upper limb, along with the ipsilateral chest and neck area, was prepared to facilitate repositioning during the operation. A short longitudinal incision was made in the deltopectoral groove, starting proximally from the tip of the coracoid process. Cautery and blunt dissection established adequate separation between the pectoralis major and the deltoid. The cephalic vein, once identified, was carefully retracted. Tenotomy of the pectoralis major was carried out at its proximal third, and the coracohumeral ligament was liberated. The coracoid process, often found to be elongated and deformed, was systematically excised at its base. The insertions of the conjoint tendon anteriorly and the coracohumeral ligament superiorly were conserved. The conjoint tendon and the short head of the biceps brachii were retracted medially to facilitate access to the subscapularis tendon. A step cut Z-lengthening of the subscapularis tendon was executed if the muscle displayed normal morphology. In instances where the subscapularis was severely atrophic with a loss of elasticity, tenotomy was performed. During the release, utmost care was taken to identify and protect the axillary nerve inferiorly. Anterosuperior glenohumeral capsulotomy, which extends from the rotator interval tissue superiorly to the medial glenohumeral ligament inferiorly, was fashioned in cases of posterior glenohumeral subluxation to align the glenohumeral joint using a lever-arm manoeuvre without causing damage to the long head tendon of the biceps brachii. The shoulder's passive movement was then verified, and should full passive lateral rotation has been achieved, the operation was deemed complete. No tendon transfer, such as that of the latissimus dorsi or teres major, was conducted at the same operative time. When suturing the subscapularis tendon, the upper limb was positioned in abduction and lateral rotation. This position was kept until the cast was applied. The wound was sutured in layers without the use of any drain. In the operating theatre, a thoracobrachial cast was applied with the shoulder at 30° of abduction and 60° of lateral rotation, being cautious not to overlengthen the subscapularis [Figure 1].

Postoperative care and rehabilitation

Postoperatively, the patient was usually discharged the day following surgery. The cast was removed 6 weeks thereafter. Postoperative physiotherapy sessions commenced forthwith and were conducted on a regular basis to preserve the passive range of movement and to fortify the shoulder abductors and lateral rotators. Parents were additionally directed to perform stretching exercises for the shoulder muscles for 30 min daily.

Statistical analysis

Data were analysed utilising IBM SPSS Statistics version 28 for Microsoft Windows (IBM Corporation, Armonk, NY,

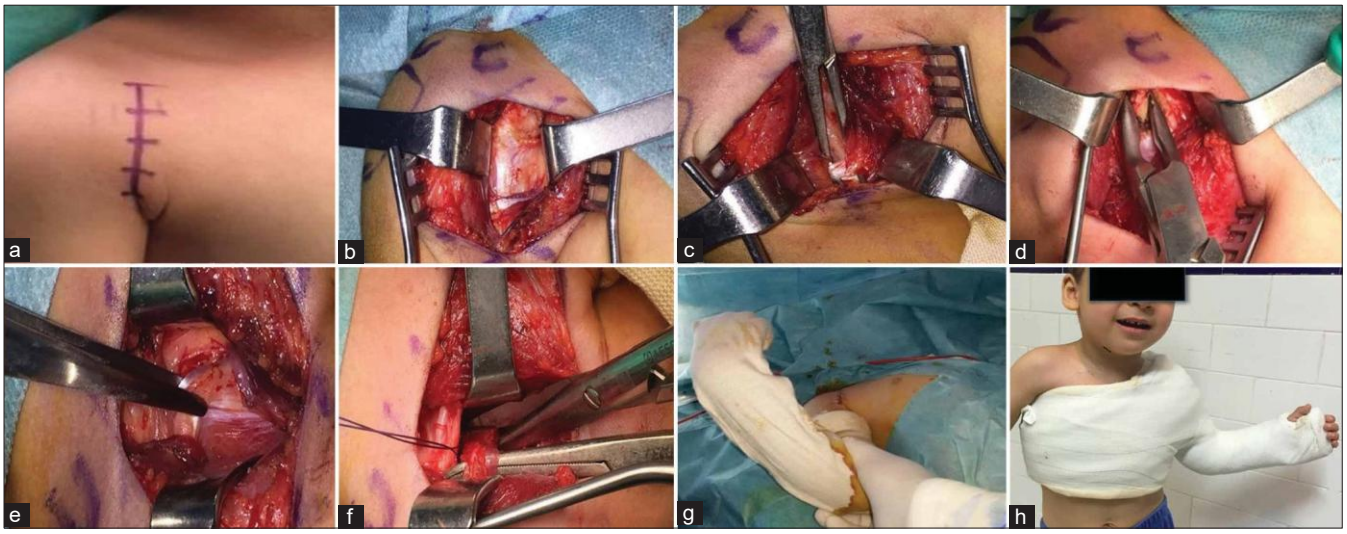


Figure 1: Initiating the open subscapularis release through the deltopectoral approach (a), manoeuvring betwixt the deltoid and pectoralis major (b), conducting a proximal third tenotomy of the pectoralis major (c), excising the coracoid process at its base (d), retracting medially the short head of the biceps brachii (e), performing a step-cut Z-lengthening on the subscapularis tendon (f), ensuring the shoulder's positioning in a reduced posture concluding the procedure (g), applying a thoracobrachial cast (h)

USA). The normal distribution of variables was ascertained using the Shapiro–Wilk test. Descriptive statistics were computed as number and percentage, median and interquartile range, mean and standard deviation or minimum and maximum value. Children younger than 4 years at the time of surgery were differentiated from their older counterparts, and patients with Erb–Duchenne were distinguished from those with more extensive injuries. A Pearson's Chi-square test or Fisher's exact test was employed to compare categorical variables. The postoperative values were contrasted with preoperative values utilising Student's paired *t*-test for continuous normally distributed variables and the Wilcoxon signed–rank test for skewed variables. $P < 0.05$ was deemed statistically significant. Univariate and multivariate regression analyses were performed to identify the factors associated with the postoperative Mallet score. Variables with $P < 0.25$ in the univariate linear regression analysis were entered into the multiple linear regression model for analysis. $P < 0.05$ was ultimately considered statistically significant with a 95% confidence interval.

Ethical considerations

Ethical clearance was secured from our institution's ethics committee (identifier N°7/2022). The requirement for informed consent was waived due to the observational and retrospective nature of this study. The collection of data was conducted anonymously, with information that could identify patients or physicians not being recorded or stored.

Results

Characteristics of the series

Within the cohort of 75 patients with NBPP who were treated with open anterior subscapularis release during the relevant timeframe at our institution, 43 (57%) were not included due to insufficient follow-up. Consequently, the remaining 32 (43%) patients participated in the study. The group consisted of 14 boys and 18 girls, yielding a sex ratio of 0.78. The age at which patients underwent surgery ranged from 18 months to 15.5 years, with a median age of 36 months (25; 56). The right side was affected in 24 (75%) cases, the left in 8 (25%), and bilateral involvement was seen in 1 (3.1%) case, where there was adequate spontaneous recovery of the right side by the time of the first surgery. The classification of the patients was as follows: Erb–Duchenne palsy in 22 (69%) instances, extended Erb–Duchenne palsy in 7 (22%) and global palsy in 4 (13%). The demographics and injury characteristics of our patients are detailed in Table 1.

Surgical outcomes

The median Mallet score improvement after open anterior subscapularis release was 4 (2; 6). The increase in postoperative Mallet score was statically significant ($P < 0.001$) with a median follow-up of 78 months (72; 82). Abduction ($P = 0.002$), lateral rotation ($P < 0.001$), hand-to-mouth manoeuvre ($P < 0.001$) and hand-to-head manoeuvre ($P < 0.001$) were significantly improved. The hand-to-spine manoeuvre was not considerably changed ($P = 0.523$). Pre-operative and post-operative shoulder ranges of motion are detailed in Table 2.

The Mallet score improvement after surgery showed no significant difference when comparing children younger than 4 years versus older ones at the time of surgery ($P = 0.663$). In univariate analysis, only injury extension was significantly associated with Mallet score improvement after surgery (odds ratio [OR] = −2.035 [−3.351; −0.718], $P = 0.004$). In multivariate analysis, and adjusting for all other factors close to significance in univariate analysis, which explained 34% of Mallet score improvement after surgery, the extent

Table 1: Patient's characteristics*

Characteristics	Patients (*n*=32)
Sex	
Male	14 (44)
Female	18 (56)
Age at surgery	
12 months to 4 years	22 (69)
Over 4 years	10 (31)
Side involved	
Right	24 (75)
Left	8 (25)
Bilateral (spontaneous recovery on one side)	1 (3.1)
Extend of injury	
Erb–Duchenne palsy (C5–6)	21 (66)
Extended Erb–Duchenne palsy (C5–7/8)	7 (22)
Global palsy (C5–T1)	4 (13)
Post-operative follow-up (months)	
6	24 (75)
12	8 (25)

*Values are given as a *n* (%)

Table 2: Pre- and post-operative shoulder ranges of motion*

Shoulder movement	Pre-operative range of motion (*n*=32)	Post-operative range of motion (*n*=32)	*P*
Abduction (°)	97±43	109±48	0.002
Lateral rotation (°)	−11±12	37±22	<0.001
Hand-to-mouth manoeuvre (grade)	2 (2–2)	4 (3–4)	<0.001
Hand-to-spine manoeuvre (grade)	2 (2–3)	3 (2–3)	0.523
Hand-to-head manoeuvre (grade)	2 (2–2)	4 (3–4)	<0.001
Mallet score	12 (11–14)	17 (15–19)	<0.001

*Values are given median (IQR) and mean±SD. IQR: Interquartile range, SD: Standard deviation

of injury remained the only factor significantly associated with Mallet score improvement after surgery (OR = −1.807 [−3.128; −0.485], *P* = 0.009) as shown in Table 3.

Discussion

In this series, patients exhibited significant improvement in shoulder mobility following open anterior subscapularis release, with Mallet scores rising post-surgery without medial rotation deterioration [Figure 2]. Greater injury extent correlated with enhanced Mallet scores postoperatively, as those with more severe afflictions (extended Erb–Duchenne or global palsy) saw more functional gains after surgery. Age at surgery, below or above 4 years, did not significantly impact Mallet score enhancements, indicating no additional functional benefits from earlier surgical intervention in this study.

In children with NBPP, early spontaneous biceps function recovery within 3–6 months suggests progressive reinnervation, predicting good outcomes.[3] However, waters found that despite biceps recovery, over half still had inadequate shoulder abduction, and 85% had restricted lateral rotation.[10] Recovery varies among muscles, leading to imbalance and persistent paresis. Furthermore, axonal misdirection causes agonist and antagonist co-contraction, restricting shoulder movement and precision.[11] Fairbank initiated anterior shoulder release for NBPP in 1913, with Sever's later endorsement in 1918.[12,13] Anterior shoulder release entailed the still-in-use release of the pectoralis major and subscapularis tendons at their humeral insertions. We modified this technique, offering a one-stage soft-tissue reconstruction through a deltopectoral approach, primarily using *Z*-lengthening of the subscapularis, adding a partial tenotomy of the pectoralis major. In addition, we executed systematic coracohumeral ligament release and coracoid osteotomy, addressing the often deformed coracoid process as Burnier *et al.* noted, and correlating with glenohumeral incongruity as Nath *et al.* found.[14,15] However,

Table 3: Univariate and multivariate linear regressions of independent predictors of Mallet score improvement following surgery

Characteristics	Univariate analysis			Multivariate analysis		
	OR	CI 95%	*P*	OR	CI 95%	*P*
Sex						
Male	−1.286	−2.659–0.088	0.066	−1.076	−2.311–0.159	0.085
Female	1					
Age at surgery						
12 months–4 years	1					
>4 years	−0.964	−2.479–0.551	0.204	−0.494	−1.842–0.853	0.459
Side involved						
Right	0.583	−1.069–2.236	0.477			
Left	1					
Extent of injury						
Erb–Duchenne palsy	1					
Extended Erb–Duchenne or global palsy	−2.035	−3.351–−0.718	0.004	−1.807	−3.128–−0.485	0.009
Pre-operative Mallet score	−0.166	−0.599–0.266	0.437			

OR: Odds ratio, CI 95%: 95% confidence interval



Figure 2: Shoulder range of motion in one of our patients. Preoperative (left) and postoperative (right) photographs. Abduction (upper) and lateral rotation (lower) photographs

some recommend cautious lengthening and immobilization to avoid muscle weakness, whereas van der Sluijs *et al.* caution against complete tenotomy due to the risk of rotation loss.[16,17] Burnier *et al*. reported no such loss after partial subscapularis tenotomy without lengthening.[14] Others suggest limiting intervention to coracohumeral ligament release to avoid capsulotomy-induced scarring and instability.[16,18] Carlioz and Brahimi chose to release the subscapularis at its scapular origin, a method later supported by Gilbert *et al.*[19,20] Tendon transfers began with L'Episcopo in 1934, combining anterior release with teres major transfer, and later included the latissimus dorsi.[21,22] Hoffer *et al.* advanced this by transferring both to the rotator cuff posteriorly.[23] Subsequently, Pagnotta *et al.* and Pearl explored these methods, with Pearl introducing an arthroscopic approach in 2003.[24,25] Kruit *et al.* reported that isolated subscapularis release showed diminished long-term efficacy, a trend also seen in tendon transfer cases.[24,26,27] For significant glenohumeral incongruity, Price *et al.* recommended rotational humeral osteotomy in older patients.[28] Hence, shoulder contracture release in NBPP patients could encompass a range of combinations: subscapularis release (step vs. fractional lengthening or origin release), pectoralis major release (step vs. intramuscular lengthening), additional release (coracohumeral ligament release), capsulotomy (open versus endoscopic), tendon transfer (latissimus dorsi, or teres major, or both to the humeral head superiorly or to the infraspinatus) and with or without osteotomy (coracoid process or humeral rotational osteotomy). Our results may therefore not be applicable to all reconstructive techniques, given the multitude of possible surgical approaches and rehabilitation variations.

Recent literature predominantly examines combined subscapularis release and tendon transfers for NBPP.[14,18,19,29,30] This shift reflects concerns over recurrence and limited gains from isolated subscapularis release, particularly in older children, prompting a preference for tendon transfers.[20,26,29,31] Nonetheless, newer research challenges this view. Newman *et al.* in 2006 reported effective shoulder contracture treatment and motion improvements with subscapularis release plus rehabilitation.[31] Immerman *et al.* in 2013 and Naoum *et al.* in 2015 found it offered significant motion benefits and joint remodelling, especially in cases with glenohumeral deformities, as observed by Burnier *et al.* in 2019.[14,18,32] Allard *et al.*, in 2021, noted that in patients with malleable soft tissues and bone, subscapularis release alone was adequate.[30] The study also indicated lasting shoulder motion improvements and minimal medial rotation loss without tendon transfers. Debate persists over the best time for NBPP surgery. Gilbert *et al.* noted superior outcomes in under-twos compared to over-fours, with Price *et al.* affirming diminished benefits in older children due to reduced joint remodelling capacity.[20,28] Conversely, Newman *et al.* observed no significant age-related outcome differences, although small samples might obscure such contrasts.[31] Cohen *et al.* suggested that early intervention could avert glenohumeral subluxation, supporting a consensus on the advantages of early surgery for shoulder contracture in NBPP.[26,30,33] Terzis *et al.* recommended operating between 18 months to 4 years, whereas Price *et al.* advocated for preoperative joint assessment in over-fours.[28,34] Subscapularis release may slightly reduce medial rotation but often increases motion elsewhere.[31] This study did not replicate the abduction or lateral rotation decreases reported by Pagnotta *et al.* and Kirkos *et al.*, potentially due to a shorter follow-up.[24,27] Greenhill *et al.* suggested that less radical surgery could minimise medial rotation loss.[35] Daily tasks involving medial rotation are rare, yet improved abduction and lateral rotation significantly benefit routine activities.[31] Oztürk *et al.* found medial rotation loss negligible against lateral rotation gains.[36] Excessive surgery, however, may hinder midline-reaching tasks.[16] Abzug and Kozin revised the Mallet score to assess medial rotation better.[37] Naoum *et al.* saw no long-term lateral rotation maintenance or medial rotation gains from intensive physiotherapy post-surgery.[32] Our study echoes Javid and Shahcheraghi's finding that lower preoperative scores correlate with functional improvements, contrasting with Sabapathy *et al.*, who observed better results with extensive release in specific palsy types.[38,39] Surgical success hinges on functional gains versus harms. Our study showed comparable improvements in postoperative shoulder motion to other research and enhanced hand workspace and overall ability.[14,30] However, our less aggressive approach might not yield the significant abduction and lateral rotation seen elsewhere.[16,23,24,33,35-39] Controversy surrounds the surgical correction of adduction and medial rotation in NBPP, with no agreed criteria for release and transfer. Comparing outcomes is challenging due to differences in assessment techniques, patient age at surgery, follow-up duration, rehabilitation practices, centre-specific practices, surgical indications, retrospective data and the potential for observer bias without blinded assessments. Moreover, there is a dearth of mid to long-term data and clarity on outcomes from combined surgeries, making it difficult to determine the most effective procedures and their precise indications conclusively. In addition, reconstructive surgeries carry a considerable risk of failure.[28]

This study had several constraints, including a mid-term follow-up insufficient to gauge long-term outcomes or the impact of growth on clinical results. We applied the traditional, not the modified, Mallet score, limiting medial rotation assessment. Without radiological or magnetic resonance imaging analysis due to logistical reasons, we could not consider preoperative glenohumeral deformity's predictive value. Observer bias is possible since the surgeon also conducted follow-ups. A small cohort size weakened our conclusions and precluded detailed patient group comparisons. The absence of a control group meant we could not confirm the superiority of the subscapularis release over other methods despite comparing favourably with existing literature. A more robust study without these drawbacks is recommended for conclusive recommendations.

Conclusion

Open anterior subscapularis release proved a viable first surgical step for NBPP-induced adduction and medial rotation shoulder contracture. Significant mid-term shoulder motion improvements were noted without medial rotation compromise. Nevertheless, its long-term efficacy awaits further study. Varied injury extents predict differing benefits, with more affected individuals showing more significant post-surgical functional gains. Notably, even older children attained considerable functional improvement, suggesting that surgery before age four is not crucial for enhanced outcomes. Consequently, we advocate this straightforward, beneficial technique as an initial treatment for selected patients across ages within the setting of countries with restricted resources. Substantial clinical progress and patient satisfaction are attainable, although some cases may necessitate additional surgery for sustained results or to address recurrent contracture.

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Conflicts of interest

There are no conflicts of interest.

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