Functional Evaluation of Levator Scapulae Tendon to Supraspinatus in Adult Brachial Plexus Injuries

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Abstract

Introduction Brachial plexus injuries are severe life-altering injuries. The surgical method to restore shoulder abduction in adult upper brachial plexus injuries involves the usage of nerve grafts and nerve transfers targeting the suprascapular and/or the axillary nerve. When the primary nerve surgery has been unsuccessful or recovery has been incomplete or with a late presentation, muscle transfer procedures are needed to provide or improve shoulder abduction. Levator scapulae to supraspinatus is a transfer to improve shoulder abduction in posttraumatic brachial plexus injuries.

Material and Methods The study included 13 patients with the age ranging from 17 to 47 years with a mean age of 30 years. All these patients had preop shoulder abduction of Medical Research Council (MRC) grade ≤ 3 . All had a minimum of MRC grade 4 of active elbow flexion. Eleven patients had primary surgery. Only patients with a minimum of 1 year postoperative follow-up were included. All 13 patients underwent levator scapulae transfer only.

Results All patients had a stable shoulder postoperatively. The average increase in active shoulder abduction was from 6.15° (median: 0°) preoperatively to 61.92° (median: 60°), with an average gain in shoulder abduction of 49.61° (median: 50°).

Conclusions Transfer of levator scapulae tendon to the supraspinatus is an option to improve shoulder abduction in posttraumatic brachial plexus. In conditions where supraspinatus alone is not functioning, levator scapulae is the best available transfer, considering its strength and maintaining the form of the shoulder unlike trapezius transfer. In patients with previous surgery where supraspinatus has recovered partially but not functionally significant, this tendon transfer can be considered for the augmentation of the existing shoulder abduction.

Keywords

- brachial plexus injuries
- levator scapulae
- supraspinatus

Introduction

Brachial plexus injuries are severe life-altering injuries. The surgical method to restore shoulder abduction in patients with injuries of the upper plexus in adults involves the usage of nerve grafts and nerve transfers targeting the

suprascapular and or the axillary nerve. Shoulder abduction being affected by multiple muscle groups and selective neurotization may not give normal shoulder function. So, even when the elbow function has been restored, poor shoulder function may need further procedures to optimize shoulder abduction. Nonfunctioning shoulders can

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also be surgically fused or a trapezius transfer done to provide some movement or, at least, stability to prevent inferior subluxation; this can also improve elbow function by providing the innervated elbow flexor a stable fulcrum to exert its action.¹⁻⁴ Obstetric plexus injuries (OBPI) following birth injury is a special subset where the transfer of the latissimus dorsi has been done with good return of shoulder abduction.⁵

Since a previous use of the spinal accessory nerve (SAN) denervates the lower and possible middle part of the trapezius muscle, its use may not be prudent in muscle transfer, and the common attempt to improve joint function by an isolated trapezius transfer alone leads to an obligatory proximal migration of the humeral head.⁶ The decreased distance between the humeral head and acromion results in mechanical impingement as well as decreased trapezius lever arm. The consequence is ineffective shoulder abduction and flexion. Shoulder fusion prevents lying down at night on the same side, and on account of the unstable nature of the fusion, it may give considerable morbidity in young adults.

Narakas has described levator scapulae tendon transfer in the palsy of spinati, elongated with a periosteal strip in children, fascia lata or artificial tendon/ligament in adults, passing under the acromion. This modification of Saha's method is quite efficient in the presence of a strong deltoid.⁷

The aim of the study is to evaluate the functional improvement of shoulder abduction after transfer of levator scapulae tendon to supraspinatus in patients with traumatic brachial plexus injuries either when the primary nerve surgery has been unsuccessful or recovery has been incomplete

Subjects and Methods

The study included 13 patients with the age ranging from 17 to 47 years with a mean age of 30 years from February 2017 to February 2020 (►Tables 1 and 2). All these patients had preop shoulder abduction of Medical Research Council (MRC) grade ≤3. All had a minimum of MRC grade 4 of active elbow flexion. Eleven patients underwent primary surgery, seven were neurotization to supraspinatus nerve, using SAN in five patients and phrenic nerve in two patients (►Table 3). In these patients, either shoulder abduction is absent or with minimal abduction, which is functionally not significant. Only patients with a minimum of 12 months postoperative follow-up were included. All 13 patients underwent only a transfer of the levator scapulae tendon to the supraspinatus.

Operative Technique

Since levator scapulae is a deep-seated muscle, preoperative testing is difficult. Clinically, levator scapulae muscle function is elicited by squaring of scapula/shoulders (►Fig. 1). Intraoperative nerve stimulation is used to confirm the activity of the muscle before transfer.

The surgery was done under general anesthesia with the patient in a lateral decubitus position, so that the involved shoulder is well accessible (►Fig. 2). The ipsilateral upper

extremity was prepared and draped accordingly to allow shoulder positioning during surgery; a protective bean bag was placed between the thighs. No muscle relaxation was permitted till complete harvest of the levator scapulae muscle. A bipolar nerve stimulator was used during surgery to confirm the strength of innervation of the levator scapulae muscle.

Infiltration of all skin incisions was done using 1 in 2,00,000 adrenaline saline solution. The first incision was made along the paraspinal line of upper back, 1 inch from the midline. This facilitates exposure of the lower and middle fibers of the trapezius muscle. This was retracted medially in the middle part to expose the levator scapulae muscle. The insertion of this muscle was followed down along the medial border of the scapula to enable a periosteal extension to be harvested, as this would give sufficient length to reach the rotator cuff (►Fig. 3). Care was taken to resuture the detached rhomboideus muscle after sectioning and elevating the levator muscle tendon complex. A subtrapezius tunnel was created from the upper end of scapulae toward acromion process all along the supraspinous fossa (►Fig. 4).

The second incision, curved, was given over deltoid region. Origin of the middle portion of the deltoid was disinserted to reach subacromial bursa and identification of the supraspinatus tendon. Through the subtrapezius tunnel, levator scapulae tendon was directed to supraspinatus tendon and sutured with 2-0 polypropylene/nylon sutures, keeping the upper limb in a minimum of 90 degrees of abduction (►Fig. 5). Sectioned deltoid muscle fibers were reanchored to acromion process. Closure of the skin incisions was done in two layers using 3-0 poliglecaprone and skin clips for the skin.

The limb was splinted with the shoulder between 90 and 120 degrees of abduction, using a preoperatively prepared removable splint for a period of 6 weeks (►Fig. 6). Thereafter, the splint was removed for three sessions (15 minutes each) of shoulder abduction, eliminating gravity for 2 weeks; from 8 to 10 weeks, the sessions were increased to six times a day. From 10 weeks, intermittent abduction against gravity was encouraged. Only night splint was advised after 3 months for a further period of 3 months.

Results

Results of the surgery have been assessed according to the scale of assessment as shown in (►Table 4).

Active ROM for Shoulder Abduction after Levator Scapulae Transfer (►Tables 5 and 6)

Median preop shoulder abduction: 0°
Median postop shoulder abduction: 60°
Median gain in shoulder abduction: 50°

Complications

One patient had a postoperative hematoma on the first postoperative day (POD), for which evacuation of hematoma was done. One patient showed no result due to poor

Table 1 Patient details, preop delay, type of injury, primary surgery, shoulder abduction

S. no.	Age/sex	Preop delay		Type of injury	Any primary surgery done	Shoulder abduction	
		Time since injury	Time since first surgery.			Preop against gravity	Postop against gravity
1	21/M	2 years	–	Trauma–C5 lesion	Nil–late presentation	30	110
2	37/M	–	3	Trauma–pan plexus lesion	Late presentation–FFMT for elbow flexion and wrist extension	0	15
3	25/M	9 months	–	Ipsilateral compound clavicle & fracture scapula	Nil	0	155
4	23/M	–		Trauma–pan plexus lesion	Neurotisation (SAN-MCN cable grafts), tendon repair, CMCJ, PIPJ arthrodesis	0	40
5	31/M	–	3 years	Trauma–T1 hand	Neurotization (phrenic nerve to SSN, SAN to MCN), Steindler's procedure, tendon transfers for wrist extension.	0	50
6	20/M	–	5 years	Trauma–pan plexus lesion	FFMT for elbow flexion and wrist extension.	0	60
7	17/M	–	20 months	Trauma–C5, C6, C7 lesion	Neurotisation SAN to SSN Oberlin 1.	10	45
8	30/M	–	2 years	Trauma–C5, C6, C7 lesion	Neurotization SAN to SSN.	0	60
9	32/M	–	3 years	Trauma–C5, C6, C7 lesion	FFMT for elbow flexion.	0	60
10	47/M	–	2 years	Trauma–pan plexus lesion	SAN to SSN; 3, 4 ICN to MCN.	0	60
11	37/M	–	6 years	Trauma–C5, C6, C7 lesion	Neurotization (phrenic nerve to SSN, SAN-MCN).	30	80
12	41/M	–	15months	Trauma–C5, C6 lesion	Neurotization (SAN to SSN, Somsak, Oberlin).	0	30
13	29/M	–	13 months	Trauma–C5, C6 lesion	Neurotization SAN to SSN, Oberlin 1 & 2.	10	40

Abbreviations: BPI, brachial plexus injury; CMCP, carpometacarpal joint; FFMT, free functional muscle transfer; ICN, intercostal nerves; PIPJ, proximal interphalangeal joint; SAN, spinal accessory nerve; SSN, suprascapular nerve.

Table 2 Type of lesion

Type of lesion	Isolated C5 lesions	Upper plexus (C5-6) lesions	Extended upper plexus (C5-7) lesions	Pan plexus
No. of patients	2	2	5	4

Table 3 Previous surgery where SAN has been used for extraplexus neurotization

Type of lesion	Isolated C5 lesion	Upper plexus (C5-6) lesions	Extended upper plexus (C5-7) lesions	Pan plexus lesions
Previous surgery	2	2	5	4
Type of previous surgery	–	1 patient: underwent SAN-SSN neurotisation. 1 patient: SAN-SSN neurotisation & triceps motor branch transfer to axillary nerve (Somsak transfer)	2 patients: underwent SAN-SSN neurotisation. 2 Patients: phrenic nerve-SSN neurotisation. in whom SAN-MCN neurotization done with cable grafts. 1 patient: FFMT for elbow flexion.	1 patient: SAN-SSN neurotization & 3,4 ICN-MCN neurotisations. 1 patient: SAN-MCN neurotisation with cable grafts 2 patients: FFMT for elbow flexion and wrist extension with SAN

Abbreviations: ICN-MCN neurotization: intercostal nerve coaptation with musculocutaneous nerve; SAN-SSN neurotization: spinal accessory nerve coaptation with nerve to suprascapular; SAN-MCN neurotization: spinal accessory nerve coaptation with musculocutaneous nerve.

Fig. 1 Picture demonstrating squaring of scapula/shoulder.

Fig. 2 Preoperative anatomical depiction of levator scapulae muscle.

Fig. 3 Intraoperative picture demonstrating harvested levator scapulae muscle.

Fig. 4 Intraoperative picture demonstrating levator scapulae muscle directed toward the supraspinatus tendon through the subtrapezius tunnel.

Fig. 5 Intraoperative picture demonstrating levator scapulae muscle sutured to supraspinatus tendon.

Fig. 6 Postoperative picture showing shoulder splinted in 90° abduction.

compliance postoperatively in view of head injury. There were no infections, no wound dehiscence, and no seroma formation.

Discussion

The standard muscle transfer for shoulder abduction has been the transfer of the trapezius to the deltoid insertion, usually with a segment of the acromion to enable a secure fixation. The common attempt to improve joint function by an isolated trapezius transfer alone leads to an obligatory

proximal migration of the humeral head. The decreased distance between the humeral head and acromion results in mechanical impingement as well as decreased trapezius lever arm. The consequence is ineffective shoulder abduction and flexion. This is also relatively contraindicated in patients who had undergone an unsuccessful SAN to SSN transfer in the past.

Due to its very proximal innervation (cervical plexus C4, C5), levator scapulae muscle is likely to be functioning even in severe upper plexus lesions. This fact allows us to utilize this transfer as a glenohumeral intrinsic stabilizer even when no latissimus dorsi is available. This has also proven useful in obstetric palsy to improve shoulder abduction. Permanent deficiency in abduction of the arm seen after brachial plexus injury may be corrected by a levator scapulae transposition onto the supraspinatus.⁷

The levator scapulae muscle is innervated by nerves exiting from the C4 and C5 roots (sometimes C3 also) as the dorsal scapular nerve; this also supplies the rhomboideus muscles, thus making this a potential donor for tendon transfer even in avulsion upper brachial plexus injuries.

Table 4 Scale for assessment of results following levator scapulae transfer

	MRC grade	ROM (in degrees)	Gravity
Good	M4	75	Against gravity
Fair	M3	30–75	Eliminating gravity
Poor	< M2	< 30	Eliminating gravity

Abbreviation: ROM, range of motion.

Table 5 Results

S. no:	Age/sex	Nature of injury	Shoulder abduction in degrees		MRC Grade		Postoperative improvement in range of shoulder abduction in degrees.
			Preop against gravity	Postop against gravity	Preop	Postop	
1	21/M	C5 lesion	30	110	M2	M4	80
2	37/M	Pan plexus lesion	0	15	M0	M1	15
3	25/M	C5 lesion	0	155	M3	M4	155
4	23/M	Pan plexus lesion	0	40	M2	M3	40
5	31/M	Trauma-C5, C6, C7 Lesion	0	50	M1	M3	50
6	20/M	Pan plexus lesion	0	60	M1	M3	60
7	17/M	C5, C6, C7 lesion	10	45	M1	M3	35
8	30/M	C5, C6, C7 lesion	0	60	M0	M3	60
9	32/M	C5, C6, C7 lesion	0	60	M2	M3	60
10	47/M	Pan plexus lesion	0	60	M0	M2	60
11	37/M	C5, C6, C7 lesion	30	80	M2	M4	50
12	41/M	C5, C6 lesion	0	30	M2	M3	30
13	29/M	C5, C6 lesion	10	40	M1	M3	30

Abbreviation: MRC, Medical Research Council.

Table 6 Outcome according to the evaluation scale described above

	Isolated C5 lesion	Upper plexus (C5-6) lesions	Extended upper plexus (C5-7) lesions	Pan plexus
Good	2	–	–	–
Fair	–	2	5	3
Poor	–	–	–	1

Levator scapulae is a type 1 muscle with a broad muscle belly after arising as four tendinous slips from the cervical vertebra (►Fig. 7). Through its insertion onto the medial upper corner of the scapula, it elevates the scapulae and rotates the inferior angle of scapula medially. The vector of pull of levator scapulae muscle transfer is from above, contrary to latissimus dorsi which is from below.

Study of the excursion of the potential muscles around the shoulder reveals the levator scapulae has 15.3 cm of excursion, far above that for the trapezius muscle, although its relative tension is 1.7%, lower than other shoulder muscles.⁸ Due its excursion and vector of pull being similar to supraspinatus and it being spared in majority of the plexus injuries, this muscle can be considered as a potential donor.

Aziz, Singer, and Wolff reviewed 27 patients of brachial plexus injury treated by transfer of trapezius. They used a modification of the surgical technique described by Mayer (1927) and Bateman (1955) and amended by Saha (1967). The average gain in shoulder abduction was 45.4 degrees with a range of 20 to 120 degrees.⁹

Ruhmann et al included 31 patients with paralysis of the deltoid and supraspinatus. Trapezius transfer was performed according to the method of Saha. Average increase in active abduction was from 7.3°(0–45°) to 39°(25–80°) at the latest review¹⁰

Kotwal et al treated 27 patients with deltoid paralysis by trapezius transfer using Saha's technique in poliomyelitis and brachial plexus injury patients and found that the average gain in active abduction was 60 degrees in the brachial plexus group and 45 degrees in the poliomyelitis group.¹¹

Fig. 7 Anatomy of levator scapulae muscle.

Singh et al treated eight patients of posttraumatic brachial plexus injury with insufficient shoulder abduction by trapezius muscle transfer, in which the trapezius was dissected and detached from its insertion along with the periosteum and sutured to the insertion of the deltoid muscle. The average increase in active abduction of shoulder was from 13.7 degrees (0 to 35 degrees) preoperatively to 116 degrees (45 to 180 degrees) postoperatively and of shoulder flexion from 24.3 degrees (15 to 30 degrees) to 107 degrees (90 to 180 degrees).¹²

In our study, 11 out of 13 patients had undergone a previous surgery where SAN has been used for extraplexus neurotization, making the trapezius transfer a relative contraindication. Further levator scapulae do not distort shoulder form, contrary to trapezius transfer.

In a study by Covey et al, who performed modified the L' Episcopo procedure where latissimus dorsi tendon was rerouted anteriorly to humerus and then anastomosed to teres major tendon routed posteriorly, the average increase in abduction and external rotation were 26° and 29°, respectively.¹³ This procedure has commonly been used in obstetric brachial plexus injury sequelae; four of the patients in our study sustained pan plexus injuries and hence the latissimus dorsi muscle would not be available; further, in the five patients with a C5, 6, 7 lesion, the muscle would have been less than grade IV, making it a poor choice for tendon transfer.

Narakas has described levator scapulae as the best tendon transfer in the palsy of spinati, elongated with a periosteal strip in children, or fascia lata in adults, passing under the acromion. This modification of Saha's method is quite efficient in the presence of a strong deltoid.¹⁴ He achieved an increase of shoulder abduction of 36°(extremes 18° and 70°).

In our study, the results were better in upper plexus group (►Tables 5 and 6) on account of presence of deltoid muscle (►Figs. 8–13). The levator scapulae on account of its size, excursion, and tension is best suited to augment or replace the function of the supraspinatus muscle.

Conclusion

Transfer of levator scapulae tendon to the supraspinatus is an option to improve shoulder abduction in posttraumatic brachial plexus injuries; this is especially so in patients where the trapezius has been denervated consequent to an earlier SAN harvest for an unsuccessful neurotization.

This transfer can be considered in following clinical situations:

1. Where supraspinatus is denervated and deltoid is innervated, levator scapulae transfer can be considered as a best tendon transfer procedure.
2. In partially recovered patients, this transfer helps to augment the supraspinatus and improve range of motion (ROM) of shoulder abduction.
3. In pan plexus injuries, this transfer helps to correct the glenohumeral subluxation and improve ROM of shoulder abduction to some extent.

Fig. 8 Preoperative picture in front view demonstrating no shoulder abduction in a patient with isolated C5 lesion.

Fig. 10 Postoperative picture in back view demonstrating 155° of shoulder abduction in a patient with isolated C5 injury.

Fig. 9 Postoperative picture in front view demonstrating 155° of shoulder abduction in a patient with isolated C5 injury.

Fig. 11 Preoperative picture in anterior view demonstrating 30° of shoulder abduction in a patient with C5 injury

Fig. 12 Postoperative picture in anterior view demonstrating 110° of shoulder abduction in a patient with C5 injury

Fig. 13 Postoperative picture in posterior view demonstrating 110° of shoulder abduction in a patient with C5 injury.

Future Perspective

Levator scapulae to supraspinatus can be considered in obstetric brachial plexus injury patients and combined with other muscle transfers for the improvement of external rotation in both adult and pediatric groups.

Conflicts of Interest

None declared.

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