Survey to Study Variations in Surgical Techniques in Upper Brachial Plexus Injuries

Rohini Prasad[1] Arun Kumar Rajeswaran[2] Purvashree Prasad[3]

[1] Department of Plastic Surgery, Avinash Hospitals, Apollo Hospitals, Chennai, Tamil Nadu, India
[2] Department of Plastic Surgery, MV Hospital, Chennai, Tamil Nadu, India
[3] Velammal Medical College Hospital and Research Institute, Chennai, Tamil Nadu, India

Address for correspondence Rohini Prasad, MBBS, MS, MCh, Avinash Hospitals Chennai, Apollo Hospitals, Chennai, Tamil Nadu, India (e-mail: rohinibph@yahoo.com).

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Abstract

Nerve transfers for upper brachial plexus injuries are now the standard of care and produce consistent and favorable results. Despite unanimity in the treatment of upper brachial plexus injuries by triple transfer, viz., spinal accessory to suprascapular nerve, triceps branch of radial to axillary nerve, and double fascicular transfer for elbow flexion, there are plenty of differences in the surgical approaches and techniques. A case scenario and related survey was sent to 10 senior brachial plexus surgeons and their responses were analyzed and compared with surgical techniques described in literature.

Keywords

- nerve transfer
- spinal accessory to suprascapular nerve transfer
- triple nerve transfer
- upper brachial plexus injuries

Introduction

Nerve transfers for restoration of upper extremity function in traumatic upper brachial plexus injuries is now the standard of care and has shown consistent postoperative outcomes.[1] The most common nerve transfers for upper plexus (c5, c6) injuries are spinal accessory nerve (SAN) to suprascapular nerve (SSN), nerve to triceps branch of radial to axillary nerve, and double fascicular nerve transfer for elbow flexion. However, the surgical approach, precise technique, and timing of surgery may vary from one surgeon to another. This article analyzes the results of a survey sent to 10 senior brachial plexus surgeons (more than 10 years surgical experience in brachial plexus injuries) across the country and compares it with international techniques and outcomes.

Materials and Methods

A questionnaire based on a specific case was sent to 10 senior brachial plexus surgeons by mail and WhatsApp and they were asked to provide answers with explanation for how and why they do it. All the surgeons were from India but from different institutions and parts of the country.

Survey on Nerve Transfer for Upper Brachial Plexus Injuries

Case scenario: A 30-year-old nondiabetic with a history of 3-month-old injury to the upper trunk with 0/5 power elicited in supraspinatus, deltoid, and biceps muscles. Triceps and hand function were normal.

1. Would you explore the plexus? Why/why not?

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2. For SAN to SSN transfer do you prefer anterior or posterior approach and Why?
3. For posterior approach do you prefer prone position or lateral position? If lateral how do you place the limb?
4. For a patient who has clinically no shoulder abduction you find that SSN is stimulable intraoperatively. What would you do?
5. Which approach to axillary nerve transfer would you prefer?
6. For transfer to axillary nerve which branch of triceps would you use? Why?
7. For transfer to axillary nerve would you divide axillary nerve proximal to branch to teres or distal?
8. Do you selectively transfer to anterior division of axillary nerve anytime? When do you so?
9. Do you routinely do a double fascicular nerve transfer for restoration of elbow flexion?
10. Between median and ulnar nerve fascicle which one would you give to biceps and which nerve fascicle to brachialis branch of musculocutaneous nerve (MCN)?

Results

1. All the surgeons preferred exploring the plexus before the transfer; however, one surgeon felt that if high-quality magnetic resonance neurogram is available and shows root avulsion they would plan direct nerve transfers to save operative time.
2. Five surgeons prefer the anterior approach for SAN-SSN transfer, 3 prefer the posterior approach while 2 are comfortable with both the approaches (►**Fig. 1**).3. Five surgeons prefer the lateral position for posterior approach (SAN-SSN), 1 prefers prone position, 1 prefers semilateral/semiprone, and 3 surgeons declared that they would not attempt posterior approach at all (►**Fig. 2**).
3. If clinically there was no shoulder abduction but intraoperatively SSN is stimulable: 6 surgeons said they would abandon the procedure, 1 would try stimulation at 1 mA and if still stimulable would abandon, 1 would do an end-to-side anastomosis, and 2 surgeons have said they would check the musculotendinous unit and if intact would go ahead with the transfer (►**Fig. 3**).
4. Four surgeons have preferred anterior approach for triceps branch to axillary transfer, 2 each have preferred posterior and lateral approach, respectively, and 1 has preferred posterolateral approach for the same (►**Fig. 4**).
5. Seven surgeons prefer the nerve to long head of triceps (NTLHOT) for transfer to axillary nerve, 2 have said that they would decide based on proximity to the recipient and size of the recipient nerve, and 1 surgeon prefers medial branch of triceps (►**Fig. 5**).
6. Six surgeons said that they would transfer triceps branch to axillary nerve proximal to origin of teres branch, 2 said they would transfer distal to teres branch, and 2 said that they would decide depending on the size match between donor and recipient (►**Fig. 6**).
7. One surgeon would prefer transfer of triceps branch to anterior division of axillary nerve, 7 surgeons preferred transfer to the main trunk, and 2 preferred deciding after seeing the size of the donor nerve (►**Fig. 7**).
8. Nine out of 10 surgeons opted for double fascicular nerve transfer for elbow flexion (►**Fig. 8**).

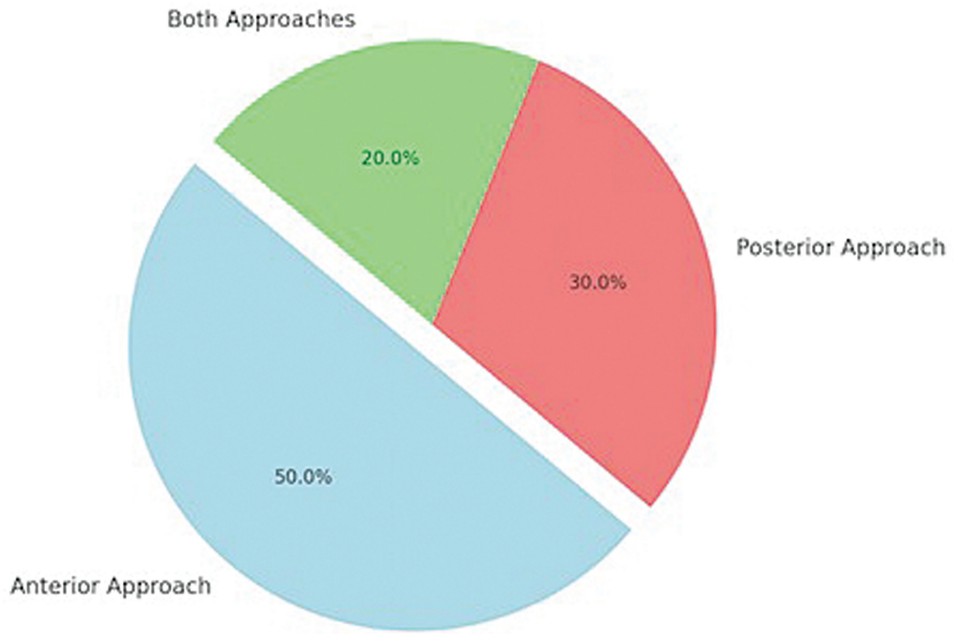

Fig. 1 Surgeons' preference for SAN-SSN transfer approach.

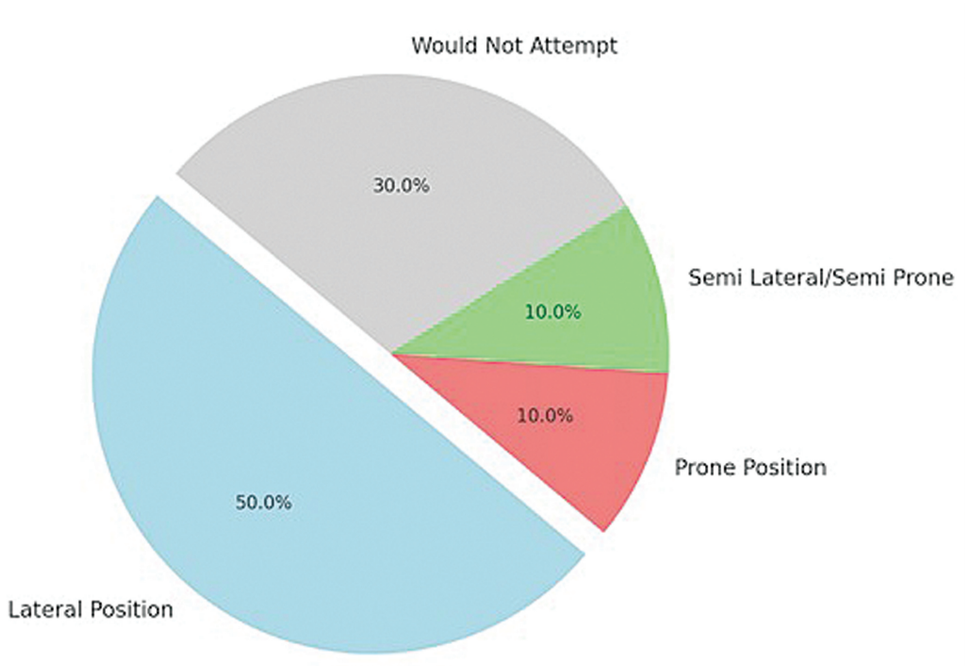

Fig. 2 Surgeons' preference for positioning in posterior approach (SAN-SSN).

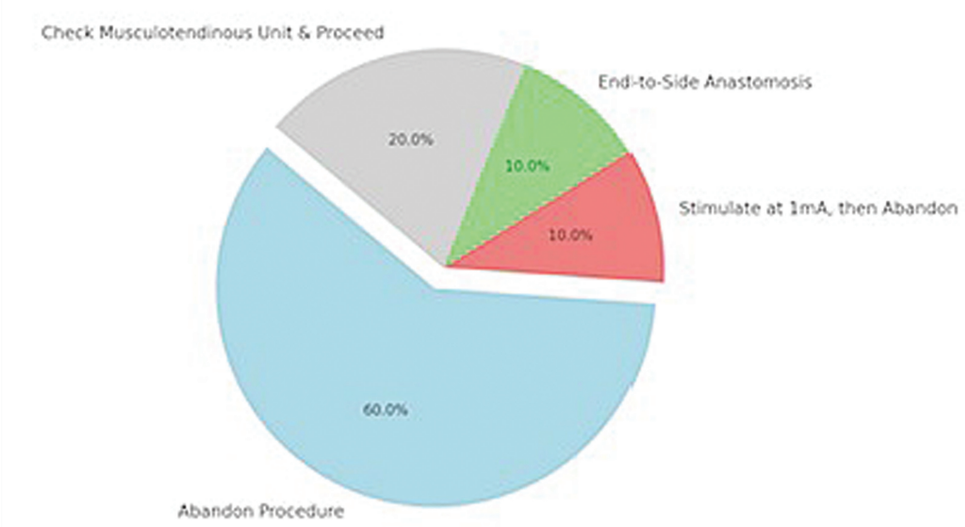

Fig. 3 Surgeons' decision if SSN is stimulate but no shoulder abduction clinically.

9. Eight surgeons would transfer fascicle from ulnar nerve to biceps branch of MCN, 1 surgeon prefers to transfer the better fascicle to biceps, and 1 surgeon prefers to transfer the fascicle depending on the proximity to the musculotendinous unit (►**Fig. 9**).

Discussion

Over the past 25 years nerve transfers have systematically replaced other techniques of brachial plexus reconstruction because of better and consistent functional outcomes.[1] The reason for the success of nerve transfers can be attributed to the fact that donor to recipient coaptation is done closer to the end organ and usually out of the zone of injury.

Exploration of the Plexus

Most surgeons routinely explore the supraclavicular brachial plexus in the upper trunk and pan plexus injuries, for obtaining a root-level diagnosis and possibility of availability of a root for grafting and potential for neurolysis.[2] In the presence of refined nerve transfer techniques with consistently superior outcomes for upper trunk injuries and advancements in neuroimaging, we question the necessity

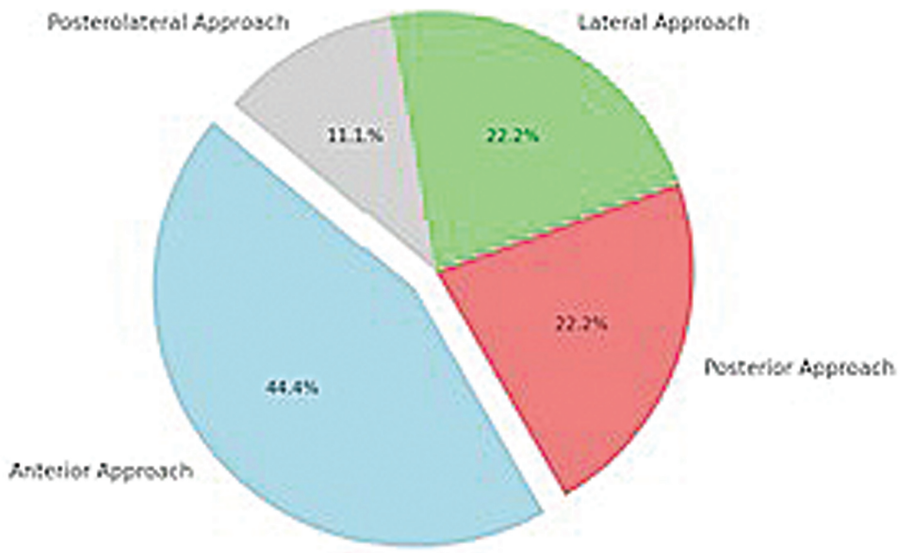

Fig. 4 Surgeons' preference for triceps branch to axillary transfer approach.

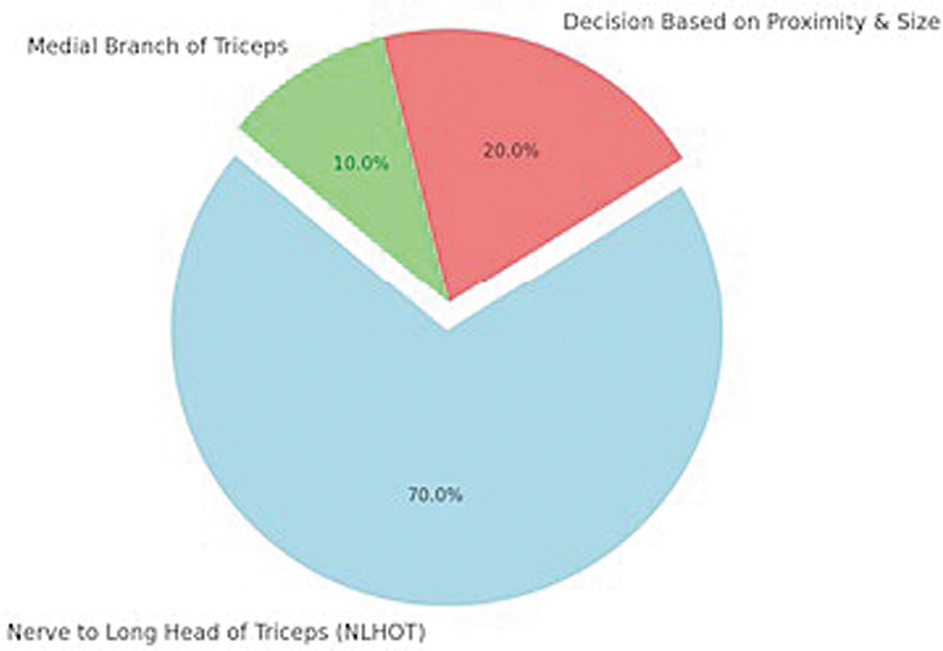

Fig. 5 Surgeons' preference for triceps to axillary nerve transfer.

for exploration of the plexus to establish presence of intact root. In addition, plexus exploration can be avoided if the timing from injury is more than 8 months as nerve grafting will have a significantly poorer result compared with nerve transfers. Surgeons prefer neurolysis as it is known to decrease neuropathic pain. A prospective study by Armas-Salazar et al[3] in August 2022 over 10 patients who underwent proximal exploration and neurolysis only, showed significant improvement in Visual Analog Scale (VAS). Of these 10 patients only 3 had root-level injuries. They has also compared four other publications in which neurolysis was done in addition to nerve grafting and nerve transfers and the mean improvement in VAS was around 39%. Neurolysis essentially helps in neuropathic pain due to compression or entrapment when there is nerve continuity.[3] The advantages in neurolysis in preganglionic root avulsion injuries are yet to

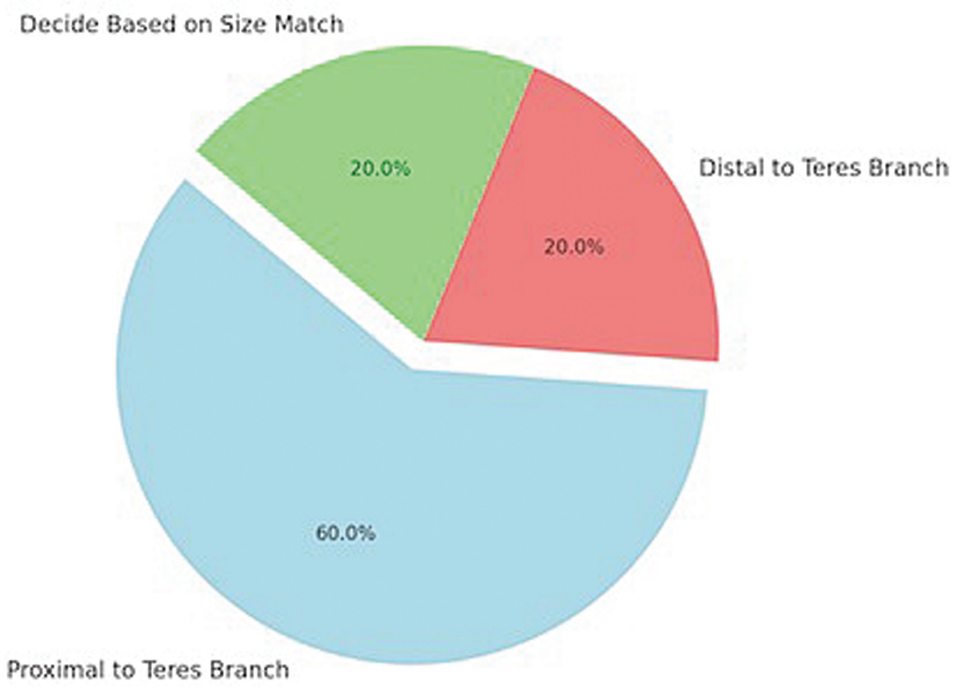

Fig. 6 Surgeons' preference for triceps to axillary nerve transfer location.

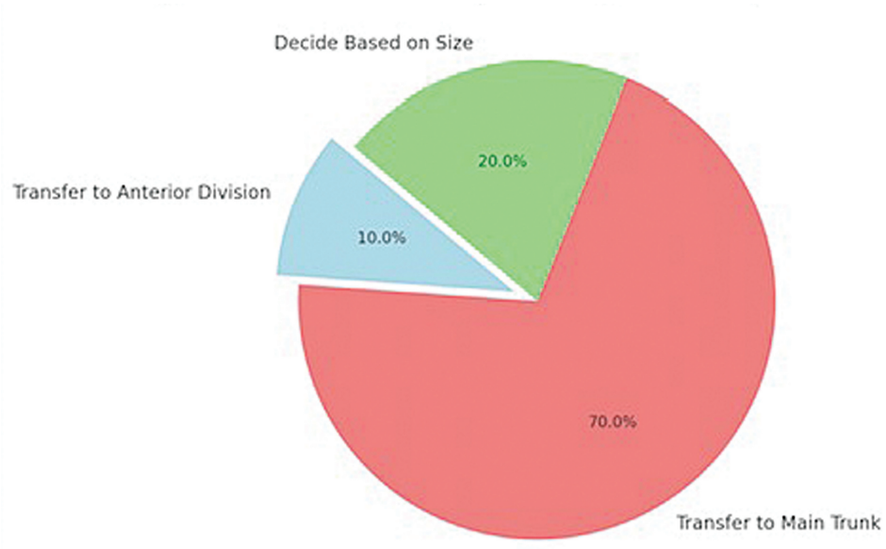

Fig. 7 Surgeons' preference for target in triceps to axillary nerve transfer.

be proven. Only a large series comparing (1) exploration neurolysis and nerve transfer versus and (2) nerve transfers only can prove the efficacy of this procedure. Surgeons who do all the nerve transfers by the anterior approach claim that the incision for exploration can be extended for the triple transfer without any change in the position of the patient. Hence, they would always explore the plexus before the transfers.

Anterior versus Posterior Approach for Spinal Accessory to Suprascapular Nerve Transfer

- While 50% of the surgeons in our survey prefer the anterior approach, worldwide there is a shift toward posterior approach for SAN to SSN. The proponents of the anterior approach claim that the patients' position need not be changed after exploration of plexus, the

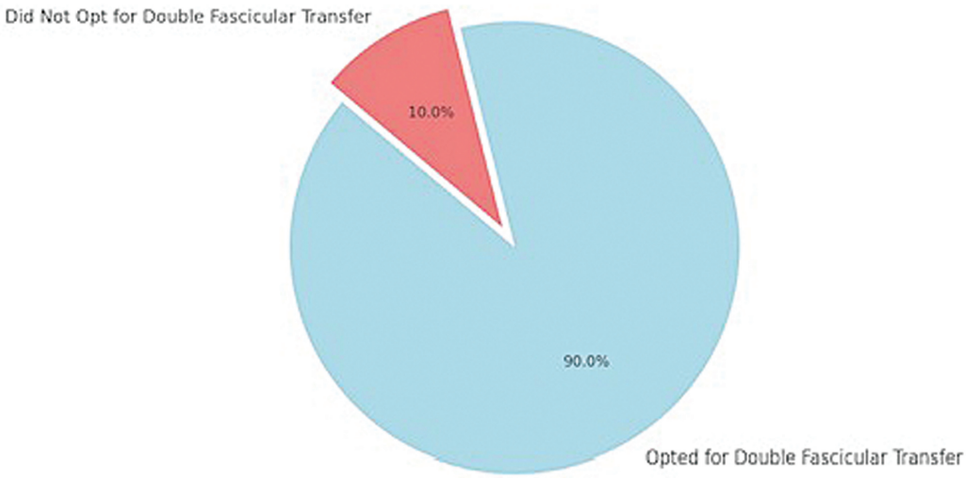

Fig. 8 Surgeons' preference for double fascicular nerve transfer for elbow flexion.

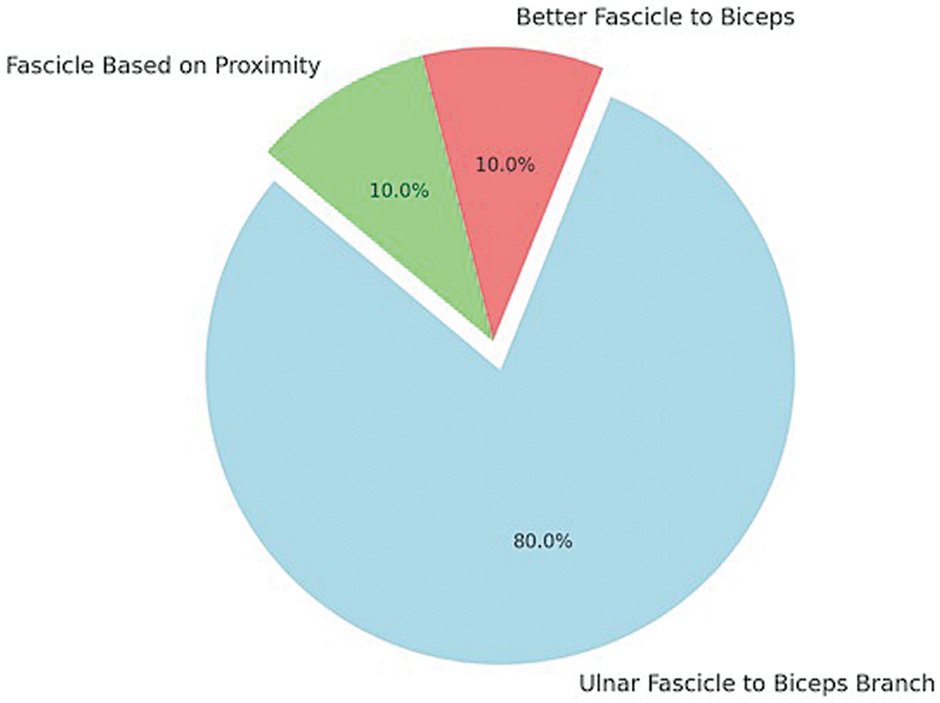

Fig. 9 Surgeons' preference for fascicle transfer to biceps branch.

technique is easy with good return of function. Further distal SAN can be reached by Bertelli's[4] maneuver in the anterior approach. The proponents of posterior approach claim that this approach involves neurotization closer to target and away from scarring, hence early recovery and any second injuries of SSN can be ruled out. Moreover, preservation of proximal nerve supply to trapezius can be done in the posterior approach. Tahir et al[5] in 2022 did a comparative study of outcomes of shoulder function with 23 patients. In 10 patients the transfer was done anteriorly and in 13 patients it was done posteriorly. Five out of 10 patients who had anterior transfer achieved a power of m4 or more while 11 out of 13 patients who underwent posterior approach achieved a power of m4 or more. The outcome measurement was done by measuring the angle of abduction of shoulder and range of movement.

A retrospective study ($n = 30$) by Singh et al[6] found that there was no statistical difference in the muscle strength in the two groups (anterior vs. posterior) but significant recovery in

external rotation; however, there was no significant difference in range of motion in abduction and external rotation.

Importance of Intraoperative Nerve Stimulation and SETS for Lesion in Continuity

Resection of such a lesion that is regenerating is as bad as doing exploration without repair or transfer with no potential for useful spontaneous recovery. The frequency of lesions in continuity as well as the difficulties in evaluating them in the early months by electromyography let alone by surgical inspection has led to the development of intraoperative nerve action potential (NAP) recording.[2]

Where neurolysis was based on a recordable NAP across a lesion in continuity, 93% recovered good function.[7] Where resection of the lesion was based on absence of a NAP, the injury was, without exception, neurotmetic and/or one with poor potential for useful recovery without repair. A recordable NAP in the absence of clinical function could mean partial injury or lesions in continuity with equivocal chance for recovery. While most surgeons in our study have opted for abandonment of nerve transfer if NAP was recordable, there is evidence that end-to-side supercharging nerve transfer has merit in improving function. Dunn et al[8] have studied results of supercharged end to side (SETS) in ulnar nerve lesions in continuity between 2000 and 2018 and among 78 patients. Note that 91.9% gained intrinsic function with no morbidity. The idea of SETS and RETS (reverse end to side) is to augment and increase the number of regenerating axons without sacrificing any native regenerated or regenerating axons. von Guionneau et al[9] have comprehensively reviewed the mechanisms of axonal regeneration and functional recovery after a SETS nerve transfer.

Triceps Branch of Radial to Axillary Nerve Transfer

- Approach
- Selection of donor branch of triceps
- Total or selective nerve transfer

The anterior approach for triceps to axillary nerve transfer offers the advantage of being compatible with other transfers and access to other donor nerves.[2] However, the axillary vessels are in close proximity and requires a large incision.

The posterior approach requires a separate incision in the posterior aspect of the arm and change in position if patient was supine. However, it provides easier and safe access to both axillary and radial nerves and helps in selective reinnervation close to the target muscles.

Wells et al[10] studied 80 cases of nerve to triceps to axillary transfer and found that NTLHOT was a more efficacious donor than medial branch or branch to anconeus. Desai et al[11] showed in a series of 27 patients that 81% had at least M3 after transfer and 62% had M4 strength. He found no difference in results relating to donor branch.

Kim et al[12] studied the anatomic patterns of axillary and radial nerves and concluded that nerve transfer to the anterior division of axillary nerve can restore function of the deltoid muscle in 86% of cases. They also noted that the medial head branch and long head branch are the best donor options. Khair et al[13] have described the number of axons in the donors and recipient of the triceps to axillary transfer NTLHOT 2,302, nerve to medial head 2,198, and nerve to lateral head 1,462. The axonal count of the main trunk is 7,887, the anterior trunk is 4,052, and the posterior division 1,242. This further helps us to use NTLHOT as the donor and the anterior division of axillary nerve as the recipient.

Double Fascicular versus Single Fascicular and which Fascicle to Biceps

For upper trunk injuries, the double fascicular nerve transfer for elbow flexion, which involves coapting expendable fascicles from median and ulnar nerves to musculocutaneous branches to biceps and brachialis, is now the standard of care. Most surgeons are able to achieve Medical Research Council (MRC) >3 with minimal donor morbidities consistently.

Oberlin et al transferred flexor carpi ulnaris fascicle to biceps branch of MCN[14] and according to results published in 1994, of the 32 patients, 22 achieved MRC >3 and 10 patients required additional Steindler's flexorplasty. Sungpet et al[15] in 2000 published results of 36 cases of transfer of a single fascicle from ulnar nerve to biceps and showed that 34 out of 36 achieved grade 3 or better. Mackinnon et al[16] in 2005 reported results of reinnervation of brachialis and biceps to restore elbow flexion in 6 patients. All achieved MRC 4+ with no motor or sensory deficits in median or ulnar (donor). The reason for these results was additional reinnervation of brachialis, which is the primary elbow flexor giving extra mechanical advantage as compared with single fascicle transfer by Oberlin et al.

While majority of surgeons in our study preferred using ulnar nerve fascicle for biceps, a study of 32 cases with median nerve fascicle to biceps and ulnar nerve fascicle to brachialis by Karuppiah Kumar et al[17] showed 22 patients with MRC 4 and 8 patients with MRC 3. The advantage according to them is that the nerve to biceps is closer to the median nerve and the length of the nerve to brachialis helps it reach the ulnar nerve which is farther posteriorly.

Conclusion

While exploration of plexus in early injury helps in identifying suitable donors and neurolysis helps in decreasing neuropathic pain, the role of routine exploration in delayed presentation of upper plexus injury is questionable as results of nerve transfers have been proved undoubtedly superior to nerve grafting. While studies show equal results with anterior and posterior approach to SAN-SSN nerve transfer, there is a shift toward posterior approach. For lesions in continuity, which show intraoperative stimulation despite no clinical motor improvement, the concept of end-to-side supercharging helps in functional recovery with minimal or no morbidity. In triceps to axillary transfer, both clinical and anatomical studies show that NTLHOT is a better donor and selective neurotization of anterior division has equivalent result to whole nerve. Posterior approach to triceps to axillary transfer is technically easier and safer than the anterior approach. Double fascicular transfer is standard of care for elbow function and surgeons prefer ulnar to biceps

and median to brachialis, although the reverse has shown equal recovery in studies.

Conflict of Interest
None declared.

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