DOI: 10.7860/IJARS/2026/82294.3087

Original Article

Surgery Section

Evaluation of Functional Outcome of Trapezius, Gracilis and Modified Quad Procedures in Brachial Plexus Injury: A Prospective Observational Study

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ABSTRACT

Introduction: In the early 19th century, well before the advent of microsurgical tools, surgeons reported encouraging results in brachial plexus reconstruction. By the late 1990s, aggressive reconstructions using extraplexal sources and vascularised muscle transfers were being reported. Some studies suggest that in late presentations, primary nerve transfer offers limited benefit; in such cases, muscle or tendon transfer (pedicled or free) is preferred. In low- and middle-income settings, delayed presentation (>12 months) is common, and prospective outcome data for muscle and tendon transfers in this cohort remain sparse.

Aim: To evaluate the functional outcomes of muscle and tendon transfers in late-presenting Brachial Plexus Injury (BPI) (>12 months), stratified by injury level (pre vs post-ganglionic) and aetiology {adult traumatic BPI vs Obstetric Brachial Plexus Palsy (OBPP)}.

Materials and Methods: A prospective observational study was conducted in the Department of Burns and Plastic Surgery, Civil Hospital Ahmedabad, Gujarat, India and the Department of General Surgery, Dr. MK Shah Medical College and Research Centre, Ahmedabad, Gujarat, India, from June 2022 to February 2024. A total of 40 consecutive patients presenting more than one year after injury were included. Variables assessed included age, gender, side involved, mechanism of trauma, injury level, procedures performed, and duration of follow-up. Primary outcomes were the Medical Research Council (MRC) grade for elbow flexion and shoulder abduction range measured in degrees. Secondary outcomes included external rotation, ability to perform activities of daily living, complications and donor-site morbidity, and the need for reoperation.

Results: The mean age of the cohort was 25.8 years; the mean age of males was 27.4 years and of females was 21.1 years. Among the 40 patients with BPI, the mechanism of injury was road traffic trauma in 32 patients (80%) and OBPP in 8 (20%) patients. Lesions were pre-ganglionic in 24 patients (60%) and post-ganglionic in 16 patients (40%). The right upper limb was involved in 28 patients (70%). Anatomically, 14 patients (35%) had upper-trunk injuries, while 26 patients (65%) had pan-plexus involvement. Among those who underwent Free Functioning Muscle Transfer (FFMT) for elbow flexion (n=8), six patients achieved ≥M3 strength at the 18-month follow-up (75%), and two patients achieved M2 strength (25%). In the upper trapezius transfer group (n=24), all patients demonstrated atleast a 40° improvement in shoulder abduction. A gain of 40-50° was observed in 12 patients (50%), 50-60° in 8 (33.3%) patients and 30-40° in 4 (16.7%) patients. Overall, eight out of 24 patients (33.3%) achieved an abduction gain of ≥50°.

Conclusion: In developing countries such as India, early referral is critical. Primary nerve reconstruction remains the preferred option within approximately six months of injury, whereas muscle and tendon transfers provide reliable functional gains in late presenters and as salvage procedures after failed primary reconstruction.

Keywords: Elbow flexion, Grafting, Musculocutaneous nerve

INTRODUCTION

Surgical reconstruction of BPI has evolved over more than a century. Early pre-microsurgical attempts yielded variable results, and the field has progressed to the modern era of nerve grafting, nerve transfer, and FFMT [1]. As reconstructive goals became more focused, particularly on restoration of elbow flexion and shoulder stability, surgeons increasingly utilised targeted nerve transfers such as the Oberlin transfer (ulnar nerve fascicle to the biceps branch of the musculocutaneous nerve) to reanimate priority functions with shorter reinnervation distances and more reliable outcomes in upper-plexus palsy [2]. In parallel, tendon and muscle transfers, including latissimus dorsi and teres major transfers for external rotation and abduction, expanded the reconstructive armamentarium, particularly for patients with residual deficits following nerve surgery [3].

A consistent theme across the literature is the critical role of timing. Early exploration and reconstruction (approximately 3-6 months) are repeatedly associated with superior motor recovery, whereas delays beyond 6-12 months increase the risk of irreversible motor endplate degeneration and diminish the effectiveness of primary nerve procedures [4,5]. Consequently, late presenters and patients with complete pan-plexus avulsions often require strategies that bypass denervated native musculature, most notably FFMT using the gracilis muscle, commonly innervated by intercostal or spinal accessory nerve donors [6]. Contemporary series and reviews report that FFMT can achieve ≥M3 elbow flexion in a majority of appropriately selected patients, even after prolonged denervation, with predictable donor anatomy and acceptable complication profiles [7,8].

Despite these advances, significant practice gaps persist in Low- and Middle-income Country (LMIC) settings, where delayed referral, polytrauma, logistical barriers, and health system constraints are common [9]. Many patients present well beyond the biologically favourable window for primary nerve reconstruction, and a substantial

proportion require salvage or primary muscle and tendon transfer procedures [10]. However, prospective, context-specific outcome data stratified by injury level (pre- vs post-ganglionic), aetiology (adult traumatic BPI vs OBPP), and procedure type (FFMT vs tendon transfer) remain limited in public-sector hospitals of LMICs [11,12].

Furthermore, although meta-analyses and clinical guidelines consistently identify timing as a major determinant of outcome, granular prospective evidence in late presenters-particularly quantifying functional gains such as MRC elbow flexion, shoulder abduction and external rotation, as well as complication and reoperation rates-remains heterogeneous and sparse [13-15].

Against this backdrop, the present study aimed to evaluate the functional outcomes of muscle and tendon transfers in late-presenting brachial plexus injury (>12 months), stratified by injury level and aetiology.

MATERIALS AND METHODS

A prospective observational study was conducted in the Departments of Burns and Plastic Surgery at BJ Medical College and Civil Hospital, Ahmedabad, Gujarat, India and in the Department of General Surgery at Dr. MK Shah Medical College and Research Centre, Ahmedabad, Gujarat, India, from June 2022 to February 2024. Prior approval was obtained from the Institutional Ethics Committees of all participating centres (IEC certificate numbers: BJMC/PS/IEC/2022/; MKSMC/GENSURG/IEC/2022/95).

Consecutive patients presenting at least 12 months after BPI who underwent muscle and/or tendon transfer for functional reconstruction were enrolled.

Sample size calculation: The final sample comprised 40 patients {adult traumatic BPI, n=32; Obstetric Brachial Plexus Palsy (OBPP), n=8}.

Inclusion criteria: Patients of 16-50 years of age traumatic BPI and children with persistent shoulder dysfunction for OBPP, interval from injury to presentation ≥12 months (late presenters) or failure of prior primary reconstruction, ability to comply with rehabilitation and follow-up and provision of informed consent were included in the study.

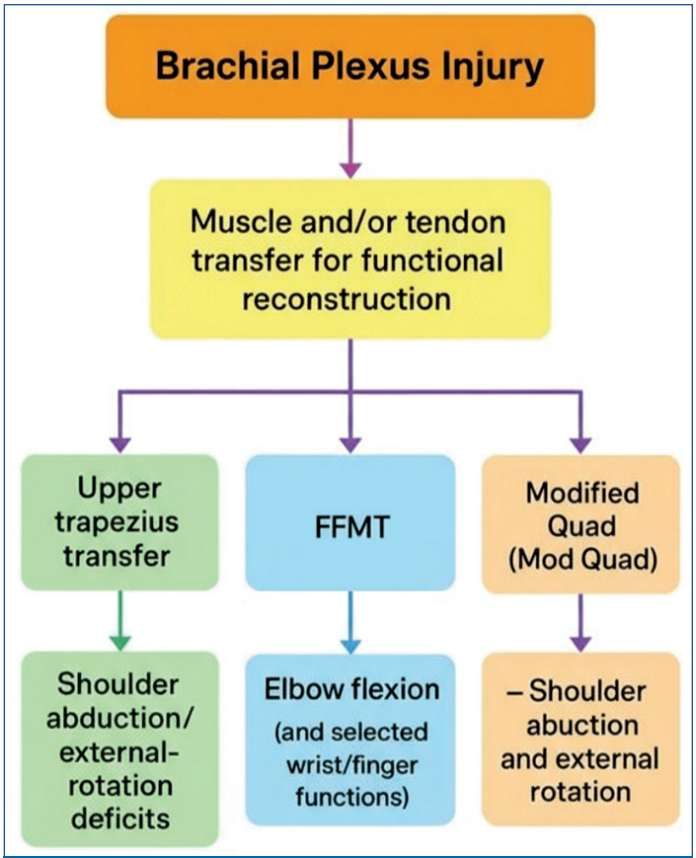
Exclusion criteria: Non traumatic adult BPI (tumour, radiation injury, medical contraindications to surgery or rehabilitation, fixed joint ankylosis or severe contracture precluding transfer and refusal or withdrawal of consent were excluded from the study.

Study Procedure

All patients underwent thorough clinical examination and, where indicated, imaging {Magnetic Resonance Imaging (MRI) or Computed Tomography (CT) myelography} and electrodiagnostic studies to classify injuries as pre- or post-ganglionic. Surgical procedures were individualised based on functional deficits and included upper trapezius transfer for shoulder abduction and external rotation deficits; FFMT for elbow flexion and selected wrist or finger functions in cases of long-standing denervation; and the Modified Quad (Mod Quad) procedure for OBPP with adduction and internal rotation contracture [Table/Fig-1]. Standardised postoperative physiotherapy protocols were implemented across centres.

Parameters and outcomes: Primary outcomes included: (a) Elbow flexion strength assessed using the British Medical Research Council (BMRC/MRC) grading scale, with ≥M3 considered functional [16]; (b) Shoulder abduction range measured in degrees using a goniometer in the scapular plane [17].

Secondary outcomes comprised shoulder external rotation measured by goniometer, Modified Mallet score for OBPP [18], assessment of activities of daily living using the Disabilities of the Arm, Shoulder and Hand (DASH) short form for adults where applicable [19], complications (infection, donor-site morbidity, reoperation), and time to first clinical reinnervation following FFMT.



[Table/Fig-1]: Overview of muscle and tendon transfer techniques for functional reconstruction in BPI and OBPP.

Data were recorded using a pretested proforma, including demographics (age, gender, side involved), mechanism of injury (road traffic accident or OBPP), injury level (pre or post-ganglionic), operative details, and follow-up findings at 18 months.

STATISTICAL ANALYSIS

Data were analysed using descriptive statistics. Continuous variables were summarised as means, standard deviations, medians, and ranges, while categorical variables were presented as frequencies and percentages.

RESULTS

A total of 40 patients were studied, including 32 (80.0%) with adult traumatic BPI following road traffic accidents and 8 (20.0%) with OBPP [Table/Fig-2].

Variables	Category	n (%)
Aetiology	Road traffic accident (adult BPI)	32 (80)
	OBPP	8 (20)
Injury level	Pre-ganglionic	24 (60)
	Post-ganglionic	16 (40)
Side	Right	28 (70)
	Left	12 (30)
Global vs upper trunk	Global (pan-plexus)	26 (65)
	Upper trunk (C5-C6/±C7)	14 (35)
Age range (years)	21-30	22 (55)
	31-40	4 (10)
	41-50	6 (15)
	<10 (OBPP)	8 (20)
Time to presentation	Modal at ~1 yr and ~2 yrs; additional clusters at ~1.5 yrs and ~3 yrs; all OBPP after ~3 yrs	-

[Table/Fig-2]: Baseline characteristics of the BPI cohort.

Following trapezius transfer (n=24), shoulder abduction improved by 40-50° in 12 patients, 50-60° in eight patients, and 30-40° in

four patients. Among patients who underwent FFMT for restoration of elbow flexion (n=8), most demonstrated meaningful functional improvement. At the final 18-month follow-up, 6 (75.0%) patients achieved functional elbow flexion of at least M3 strength on the MRC scale, while the remaining two patients (25.0%) attained M2 strength [Table/Fig-3].

Procedure/Analysis	Outcome metric	Results
Trapezius transfer (n=24)	Shoulder abduction gain	40-50° in 12/24; 50-60° in 8/24; 30-40° in 4/24.
FFMT for elbow flexion (n=8)	MRC elbow flexion at last follow-up	≥M3 in 6/8=75.0%, M2 in 2/8=25.0%.
Mod Quad (OBPP) (n=8)	Shoulder abduction (absolute)	140° in 4; 130° in 2; 120° in 2.
	Shoulder external rotation (absolute)	70° in 4; 60° in 2; 50° in 2.

[Table/Fig-3]: Procedure-specific functional outcomes and analytic summaries.

DISCUSSION

In the present cohort, road traffic accidents represented the predominant mechanism of BPI, with most lesions demonstrating a pre-ganglionic pattern. The right upper limb was more commonly affected, and patients typically presented one to two years after the inciting event. Delayed referral remains prevalent due to systemic barriers to specialised care. Such delays substantially reduce the therapeutic window for primary nerve reconstruction, "which yields optimal outcomes when performed within six to twelve months of injury" [20].

Both experimental and clinical evidence indicate that prolonged denervation leads to degeneration of the motor endplate and diminished responsiveness to nerve repair, whereas tendon and muscle transfer procedures continue to provide dependable functional improvement in late presenters [21].

With respect to shoulder reconstruction, the functional gains observed following upper trapezius transfer in present study are consistent with previous reports [22]. Elhassan B et al., demonstrated that both upper and lower trapezius transfers can restore meaningful elevation and external rotation in chronic brachial plexus palsy. Subsequent refinements, including augmentation with Achilles tendon grafts, have further enhanced postoperative stability and range of motion [23].

Elbow flexion outcomes following FFMT in present study showed that 75% of patients achieved functional strength (≥M3), aligning with contemporary literature. Systematic reviews report that 80–90% of patients undergoing gracilis FFMT attain at least antigravity elbow flexion [24]. Comparative studies by Maldonado AA et al., further demonstrated superior strength outcomes with FFMT compared to intercostal nerve transfer to the musculocutaneous nerve in pan-plexus injuries, particularly when native musculature is non functional [25]. Recent meta-analyses also emphasise the importance of donor nerve selection, intraoperative tensioning, and rehabilitation adherence in determining outcomes [26].

Within the OBPP sub-group, the Modified Quad procedure produced significant improvements in shoulder abduction and external rotation, consistent with prior reports [27]. Overall, the present study adds prospective evidence from a public-sector LMIC setting, where outcome data remain limited.

Limitation(s)

The sample size was modest, which limits the strength of sub-group comparisons and reduces the ability to detect smaller differences in outcomes. In addition, the study did not include a randomised or matched comparator group, making it difficult to directly contrast the effectiveness of different reconstructive options. As a descriptive observational study, causal inferences cannot be drawn, and the findings should be interpreted accordingly.

CONCLUSION(S)

In patients presenting more than one year after brachial plexus injury, muscle transfers such as trapezius transfer for shoulder function and free functioning gracilis muscle transfer for elbow and hand reconstruction provide reliable and meaningful functional recovery. While muscle transfer techniques are highly effective in delayed presentations, early primary nerve reconstruction-ideally within six months of injury-remains essential for achieving optimal outcomes.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Aug 28, 2025
- Manual Googling: Dec 11, 2025
- iThenticate Software: Dec 17, 2025 (7%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Jul 25, 2025**
Date of Peer Review: **Oct 18, 2025**
Date of Acceptance: **Dec 18, 2025**
Date of Publishing: **Mar 01, 2026**