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Current Methods of Treatment of Traumatic Brachial Plexus Palsy

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Abstract:

Background: Traumatic brachial plexus palsy is a severe peripheral nerve injury that may result in substantial motor, sensory, and functional impairment of the upper limb. Management depends on the mechanism, anatomical level, severity, and timing of injury, as well as the potential for spontaneous neurological recovery. Early clinical assessment, electrodiagnostic studies, and imaging are essential for selecting the appropriate treatment strategy. Current surgical options include neurolysis, direct nerve repair, nerve grafting, and nerve transfers, with priority given to restoring shoulder stability and movement, elbow flexion, forearm supination, and protective hand sensation. Distal nerve transfers, including double fascicular, medial pectoral, intercostal, and phrenic nerve transfers, have expanded the reconstructive possibilities and may permit earlier reinnervation of target muscles. Appropriate patient selection and timely intervention remain the main determinants of functional outcome. This review summarizes the current principles, timing, indications, and surgical techniques used in the treatment of traumatic brachial plexus palsy.

Keywords: Traumatic brachial plexus palsy; Nerve transfer; Nerve grafting; Neurolysis; Direct nerve repair; Neurotization; Upper limb reconstruction.

Introduction:

Both Homer's Iliad (8th century BC) and Thucydides' History of the Peloponnesian War (5th century BC) described brachial plexus injuries brought on by shoulder trauma. Galen gave the first description of identifying and treating a brachial plexus injury in the first century BC in Rome, describing a patient who recovered hand sensation through conservative treatment (1).

During the European Renaissance, artists and anatomists such as Leonardo da Vinci began to represent the brachial plexus in detail (2).

In 1900, William Thorburn published the first description of the primary healing of a brachial plexus injury, describing a 16-year-old patient's arm damage caused by a milling machine (3).

In order to reinnervate target muscles after brachial plexus root avulsions, Harris and Low pioneered the practice of neurotization, or nerve transfer, in 1903 (4).

It was concluded at the 1966 International Society for Orthopaedic Surgery and Traumatology meeting in Paris that surgical treatment of the defects was almost impossible and, even when done, did not guarantee a positive result (5).

Microneurosurgical techniques were being developed concurrently. a few of case series showing rather encouraging recovery (6).

Gilbert reproduced a sequence of 110 children that Tassin described in 1983. By 1984, Gilbert had accumulated over 180 cases (7).

Distal nerve transfers have been widely used in brachial plexus surgery in the modern era, with the goal of enhancing proximal reconstruction results and providing an alternative to anatomical repair with nerve grafts.

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Neurolysis, nerve repair, nerve transfers, and nerve grafting are examples of modern brachial plexus surgery techniques that are developing and producing progressively better results (8).

Yeoman and Seddon first described the use of nerve transfers for intercostal nerves in the 1960s, but it has only recently spread to target muscles to speed up reinnervation. described the fascicular transfer that reinnervates the biceps by internal neurolysis of the ulnar nerve. For the repair of entire brachial plexus palsy, novel nerve transfers have been reported, providing new donor nerve options and aiding in the recovery of additional target muscle groups, including those involved in hand function (9).

PRIMARY PROCEDURES

Goals and priorities

Recovering shoulder abduction, external rotation, elbow flexion, and forearm supination are the main achievable goals in the treatment of severe brachial plexus injuries. This combination of activities allows the patient to move objects with the unaffected arm while holding a feeding tray, raising his hand to his lips, and pushing doors open (10).

Additionally, some specialists advise pursuing the restoration of shoulder adduction and wrist extension. Restoring feeling is a secondary goal, with particular attention to the dispersion of the median nerve. Unfortunately, restoring intrinsic hand function is more difficult and usually has negative outcomes (11).

Timing of surgery

A thorough assessment of the patient's ability to withstand and adjust to a severe, life-altering damage, as well as to manage several surgeries and a protracted recuperation, must be included in the evaluation of the patient as a surgical candidate (12).

There are various ways to classify injuries that cause brachial plexus palsies. They could be clean or dirty, open or closed, jagged or sharp. A plan for the timing of nerve restoration is suggested, taking into consideration the pathophysiology of various lesion types (Fig. 1) (13).

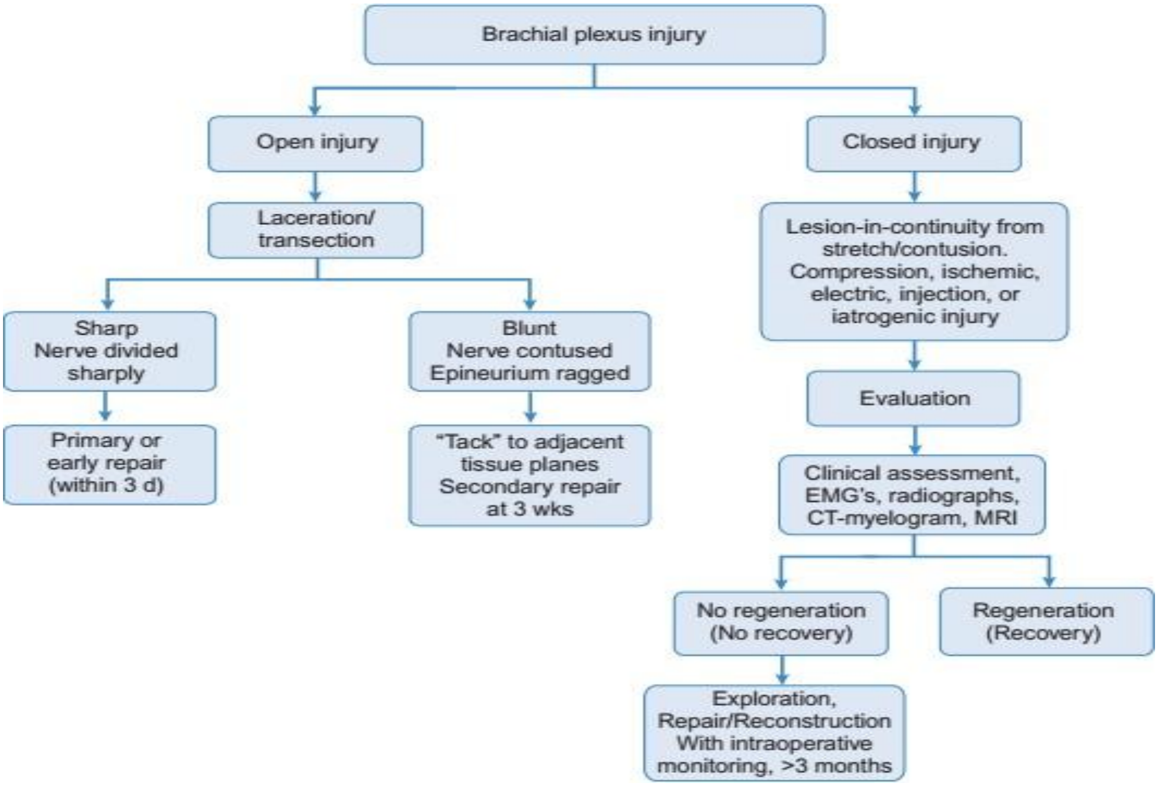

Figure 1: Algorithm for the timing of nerve surgery. (14)

Open Injuries

Only sharp transection injuries should be considered for primary nerve repair. The injury zone, which cannot be precisely determined during the initial examination, will extend in the event of an avulsion or crush damage. If found, the proximal and distal nerve stumps can be approximated to lessen nerve end contraction or tagged with sutures to help identify them during definitive reconstruction. Three weeks later, the development of scar tissue has advanced sufficiently to accurately define the injury zone, remove the injured nerve segments, and fill in the resulting gap as needed (15).

A significant frequency of spontaneous nerve regeneration and muscle reinnervation is caused by gunshot injuries, which usually result in varied degrees of nerve damage, including neurapraxia and axonotmesis. Only concurrent injuries to vascular or other vital structures require a wound assessment at the time of damage. In contrast to 3 to 4 months for closed injuries, management for these patients is conservative for 4 to 5 months because a higher percentage will show spontaneous functional recovery (Fig.1) (16).

Closed Injuries

For at least three months following the injury, management is non-operative in order to evaluate any spontaneous functional recovery. The patient needs a clinical reevaluation and additional electrodiagnostic testing three months after the accident. Non-operative therapy must continue if there is evidence of muscle reinnervation, and the patient must be reevaluated on a regular basis. Different levels of injury are indicated by the healing shown in a non-anatomical sequence, which calls for surgery (Fig. 1) (17).

Indication and contraindications

The selection of patients, together with indications and related contraindications, is encapsulated in the subsequent (table.1):

Table 1: Patient Selection In Cases Of Traumatic Brachial Plexus Injury (18)

	Who		When
Indications Who to operate; When to operate	No hope for spontaneous or further recovery	Sharp nerve transection	Acutely (as early as possible)
		Blunt or ragged nerve transection	Acutely or subacutely (within 3–4 weeks)
		Stretch injury without clinical or electrographic signs of recovery	Subacutely (between 3 to 6 months; earlier if root avulsions are suspected or demonstrated)
	Potential for functional improvement with secondary procedures	Late presentation (>12 months) Incomplete recovery after spontaneous recovery or repair	Any time
Contraindications Who not to operate	Late presentation (>12 months) for primary nerve reconstruction		
	Ongoing spontaneous recovery		
	Unrealistic expectations		
	Unwillingness to undergo procedure given the risk–benefit ratio		
	Relative factors to take into consideration: Age Medical comorbidities Stiffness and contractures Associated traumatic brain injury Associated spinal cord injury		
Functions to prioritize	1. Elbow flexion 2. Shoulder stability 3. Hand sensibility 4. Wrist and finger flexion 5. Wrist and finger extension 6. Intrinsic hand muscle function		

SURGICAL STRATEGIES

LEVEL 1 INJURY: PREGANGLIONIC ROOT INJURY

Nerve transfer

In a surgical process known as "nerve transfer," a physiologically functional nerve is purposefully sectioned (with little donor morbidity) and reallocated to a distal, more critical, but irreversibly paralyzed nerve. The surgery works best when it is done within the crucial five-month period following the accident(**19**).

Nerve transfer can be broadly classified into four categories:

1. **Extraplexus nerve transfer**

Transplanting a neighboring nerve from the brachial plexus either from the ipsilateral or contralateral neck to the avulsed brachial plexus for neurotization is known as extraplexus nerve transfer. The primary goal of the frequently used donor nerves is motor reinnervation. The phrenic nerve, spinal accessory (XI) nerve (reached through the anterior neck), hypoglossal nerve (XII), medial pectoral nerve, and contralateral C7 (CC7) spinal nerve are the donor nerves. **(20).**

2. **Intraplexus nerve transfer**

In cases of nontotal root avulsion, where at least one spinal nerve is severed but can be transferred to other, more important nerves instead of its original course, intraplexus nerve transfer is pertinent. When the C5 stump shows better health than the C6 stump in a case of C5 and C6 rupture injury (level 2), the C5 fibers are purposefully transferred to C6 (or the anterior division of the upper trunk) to allow for elbow flexion. **(21).**

3. **Closed-target nerve transfer**

By facilitating direct coaptation at a more distal position, closer to the neuromuscular junction, closed-target nerve transfer allows for a quicker recovery of motor functions. A procedure carried out outside of the supra- and infraclavicular fossae is known as closed-target nerve transfer. Examples include the musculocutaneous nerve, intercostal nerve transfer to the biceps nerve, partial ulnar nerve transfer to the biceps nerve, and partial median nerve transfer to the brachialis nerve **(22).**

4. **End-to-side neurorrhaphy nerve transfer**

End-to-side neurorrhaphy (terminolateral neurorrhaphy) is a method for connecting the distal end of a paralyzed and irreparable nerve to the side of an intact nerve through an epineurotomy or perineurotomy window, primarily aimed at restoring sensory function. For instance, end-to-side radial sensory to median nerve transfer aims to restore sensation and alleviate pain in cases of C5 and C6 nerve root avulsion **(23).**

LEVEL 2: POSTGANGLIONIC SPINAL NERVE INJURY

Neurolysis

When the nerve lesion is still intact (neuroma-in-continuity), this means thorough inquiry and external (circumferential) release without further intervention. Neurolysis was once used to treat obstetric brachial plexus palsy, however it is now generally considered to be ineffective. Some claim that when intraoperative nerve testing shows more than 50% conduction across a neuroma, patients may benefit clinically **(24).**

Direct(end-to-end) repair

When nerve endings may be reapposed without strain, this is ideal in cases of localized injury. The goal is to evaluate sharp penetrating injuries as soon as possible—within 72 hours. The techniques for direct coaptation without tension include (1) sufficiently mobilizing the two nerve ends and (2) performing traction sutures in the supraclavicular brachial plexus injury using 8-0 nylon for the internal fascicular sutures and 6-0 nylon for the epineurium (Fig.2) **(25).**

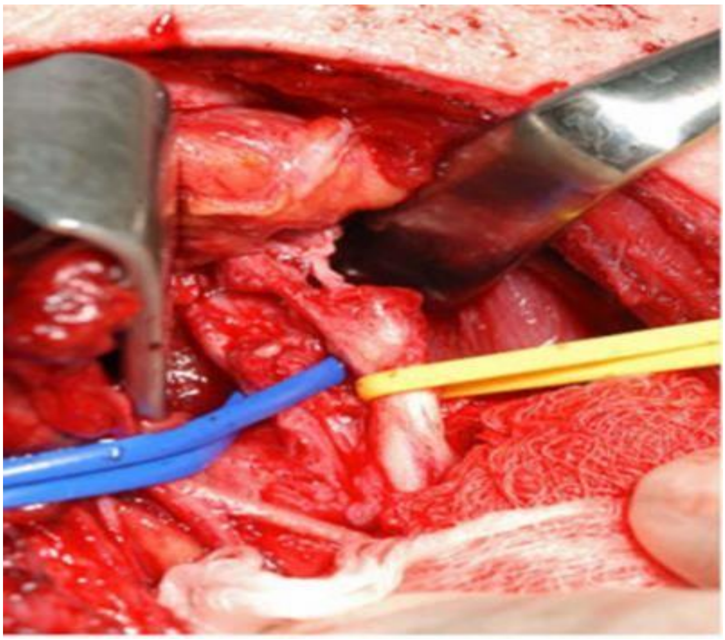

Figure 2: A direct epineural repair of both C5 and C6 in acute stab wound in the neck. (26)

NERVE GRAFTS

Reconstructing gaps caused by direct nerve injury and transection, neuroma excision, or nerve transfers using donor nerves that are too far away for direct transfer are all recommended uses for nerve grafts. In order to ensure that the proximal and distal nerve ends are composed entirely of healthy, uninjured nerve fascicles, it is imperative that any damaged nerve tissue be removed. The sural nerve and the vascularized ulnar nerve are the most often used nerves for grafting in brachial plexus repair (27).

The length of the nerve graft, the presence of scar tissue at the wound site, the number of grafts used, and the availability of a healthy proximal stump for grafting all have an impact on the outcome. For gaps smaller than 3 cm, synthetic tubular conduits can be used (Fig. 3) **(28)**

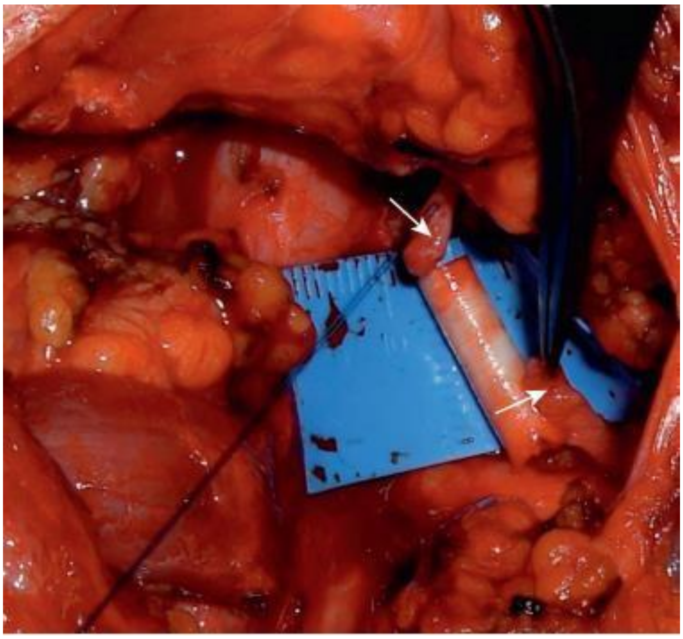

Figure 3: A nerve tube is sized to fit the short gap between the 2 nerve ends (indicated by the white arrows) (29).

LEVEL 3: PRECLAVICULAR AND RETROCLAVICULAR

It is common to see nerve rupture followed by the development of neuromas and significant scarring. Restoring the connection between the supraclavicular and infraclavicular brachial plexus requires bypass nerve transplantation. In order to facilitate grafting or neurolysis, a clavicle osteotomy is often required, especially for lower trunk injuries **(30).**

LEVEL 4: INFRACLAVICULAR

Nerve ruptures are often associated with this injury. However, distal nerve avulsion can happen at the muscle or bone attachment, like when the MCN is avulsed from the surface of the biceps muscle. Nerve grafts are frequently used, improving the prognosis and reducing aberrant reinnervation. Nerve grafting of the proximal nerve stump and direct implantation into the muscle (nerve to muscle neurotization) may be beneficial for nerve avulsion from the muscle, possibly restoring some function **(31).**

Preferred Nerve Transfers for Restoration of Elbow flexion

Documented donor nerves for elbow flexion comprise the partial ulnar nerve, partial median nerve, pectoral nerve, thoracodorsal nerve (in C5, C6 ± C7 avulsions), intercostal nerve, XI nerve with a nerve graft, phrenic nerve with or without nerve graft, and CC7 (in pan-plexus avulsions). The recipient nerve is the mixed nerve (MCN), biceps nerve, or brachialis nerve **(32).**

DOUBLE FASCICULAR TRANSFER (DFT)

First described how the motor branch of the biceps receives information from the motor ulnar fascicle of the ulnar nerve (FCU) (33).

While the biceps muscle primarily acts as a forearm supinator and also contributes to elbow flexion, the brachialis muscle is the primary elbow flexor. Elbow flexion strength is therefore greatly increased by reinnervating the brachialis and biceps muscles (34).

The primary option, when feasible, for C5, C6 avulsion is the double fascicular transfer (DFT), which involves transferring a predominantly FCU fascicle from the ulnar nerve to the biceps or brachialis branch of the MCN, alongside a predominantly FCR, FDS, or palmaris longus fascicle from the median nerve to the brachialis or biceps branch. Because of improved motor reeducation synergy, the median nerve transmits to the brachialis branch more efficiently (25).

The surgical strategy changes from a DFT to a single fascicular transfer (FCU to biceps) if C7 is involved. Injury to C7 leads to the potential use of FCR (C6, C7) as a donor, allowing FCU to be transferred to the biceps brachii to restore elbow flexion through median to radial nerve transfers or tendon transfers. Additionally, the pronator teres is linked to these injuries, and the pronation function may be impaired (28).

MEDIAL PECTORAL TRANSFER

If the ulnar and median nerves are not functioning, the thoracodorsal nerve and the branches of the medial pectoral nerve (MPN) are good substitutes. The medial pectoral direct repair to the medial cutaneous nerve was published (35).

In a modified operation, the medial pectoral nerve is transferred to the brachialis branch via an interposition nerve graft, and the fascicle of the flexor carpi ulnaris (FCU) is transferred to the biceps branch of the musculocutaneous nerve (MCN) (Fig. 4).**(18).**

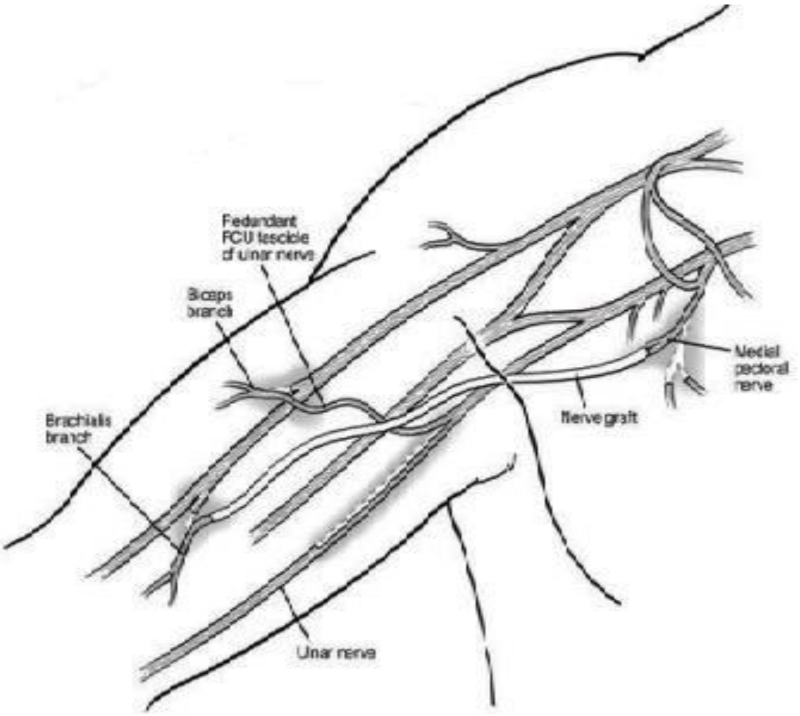

Figure 4: Medial pectoral transfer to musculocutenous using nerve graft (36)

INTERCOSTAL NERVE (ICN) TRANSFER

The initial attempt to transfer the ICN to the MCN was conducted by Seddon in 1963, aimed at reinnervating the elbow flexor in a patient with total root avulsion **(32).**

Reports from the 1960s and 1970s by Asian surgeons facilitated its popularization, with additional targets subsequently introduced for which the intercostal nerves were utilized as donors, in addition to the MCN and its branches **(33).**

<u>PHRENIC NERVE TRANSFER</u>

Gu et al. (1989) documented a series of phrenic nerve transfers to either the musculocutaneous or median nerves, resulting in an 84% recovery rate of M3 or better among patients (Fig.5)**(19).**

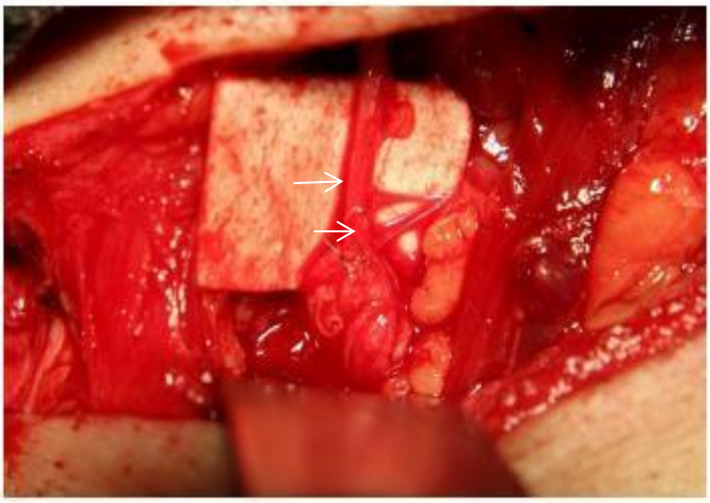

Figure 5: The phrenic nerve is sutured to the anterolateral bundles of the anterior division of the upper trunk end to end using 8/0 nylon. (21)

Contraindications to the use of the phrenic nerve exist and should be respected, such as patients less than 3 years of age, patients with severe thoracic trauma or cardiorespiratory morbidity and those who are obese **(21).**

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