Plastic Surgery - Cyber Lectures

Brachial Plexus Injuries
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Projecting for a useful rehabilitation following Brachial Plexus Injury is one of the most demanding surgical designs. Advent of microsurgical techniques has made Brachial Plexus more accessible surgically, than it used to be a couple of decades ago. Microneural co-aptation of damaged Nerve Fascicles at Trunk, Division or Cord levels, have its limitations of time gap between the injury and repair and ultimate usefulness of the limb. Secondary Microsurgical Reconstruction in pre-ganglionic or Global Brachial Plexus Lesions, utilizing Adjoining or Distant Motor Nerves and Free Functioning Muscle Transfer (FFMT) have added a number of possibilities for a useful rehabilitation program. The person will never be able to achieve precision and original technical skills, after these secondary procedures; however, the limb can be turned into a useful supporting limb. Time interval between injury and secondary surgical repair do not influence the outcome significantly, however it is recommended to perform the neural re-distribution of the injured / damaged Brachial Plexus, utilizing available adjoining / distant donor motor nerves as early as possible.

Secondary Microsurgical Reconstructions - In Global Root Avulsion Injuries: Brachial Plexus

Over the decades, the therapeutic approach and the strategy of the management of Global Root Avulsion Injuries in Brachial Plexus lesions have changed dramatically. Secondary Neuro-muscular Microsurgical Reconstruction has replaced steps like Limb Amputations. Primary micro-neural reconstitution of Brachial Plexus Roots / Cords / Trunks is limited by factors like level of the injury, extent of the Neural / Muscular involvement and the time gap between the Surgery and the Injury. Results are greatly influenced by other factors and the Age and the Occupation of the patient.

Secondary Microsurgical Reconstruction offered plenty of options in the strategies of management of Brachial Plexus Injuries. Use of Adjoining and Sparable Motor Nerves like Accessory Spinal Nerve, Dorsal (Motor) Root of C-4, Inter-Costal Nerves (T3, T8) and Contralateral Lateral Pectoral Nerve, has been in clinical practice over 15 years. Uses of Contralateral Root of Contralateral C-7 have added a new leaf in the management of Brachial Plexus Injuries.

Ability to transfer a Live, Functioning and a Dynamic Muscle (FFMT) by Micro-neurovascular Techniques has changed the overall picture of rehabilitation in these cases. Muscles like Gracilis, Latissimus Dorsi and / or Serratus Anterior are effectively being transferred to achieve important and useful functions such as:

- Flexion at Elbow,
- Extension at Elbow,
- Flexion at wrist,
- Flexion of Fingers and Thumb and
- Extension at wrist.

I would like to share my experiences of Primary and Secondary Microsurgical Reconstructive procedure in over 105 Global Brachial Plexus Lesions.

Possible Nerve Donors:

- Accessory Spinal Nerve
- Dorsal Root of C-4 (IPSI-Lateral)

- Inter-Costal: T-4 TO 9
- Dorsal Root of C-4 (Contra-Lateral)
- Contra-Lateral Lateral Pectoral Nerve
- Contra Lateral Accessory Spinal Nerve.

Possible Donor Muscles: (free)

- Gracillis For Elbow Movements.
- Gracillis + Adductor Longus for Shoulder.
- Lattissimus Dorsi For Shoulder.
- Gracillis for Finger Flexors.

Possible Muscle Transfer: (Island)

- Trapezes for Shoulder Abduction.
- Lattissimus Dorsi for Flexion of Elbow.
- Lattissimus Dorsi for Extension of Elbow.
- Serratus Anterior/ Pectoralis Major for Flexion of Elbow.
- Teres Major + Lattissimus dorsi for External Rotation of Arm.
- Zanoli Procedure for Pronation of Arm.
- Brachio-Radialis Transfer for Extension of Fingers.
- Extensor Indices for Opponence of thunb.
- Flexor Carpi Ulnaris to extensor Carpi radialis.
- Other Tendon/Muscle Transfer Based on it's Recovery.

Indications and Advances:

Free Functioning Muscle Transfer Upper Extremity
Exhaustive laboratory and clinical trials and precise understanding of intramuscular microcirculation and the process of motor re-innervation, have provided a new dimension to the skeletal muscle being transferred as Free Functioning muscle transfers (FFMT). FFMT have provided an unlimited option in restoration of function in some of the difficult Reconstructive Problems of Upper Extremity; like Brachial Plexus Injuries, Post-Polio Paralysis, Proximal and Extensive Soft Tissue Tumor Resection compromising the functional status of the Extremity seriously, Post-Traumatic / Post-Infective loss or Ischaemic Contracture of Muscles.

For being able to perform a successful Free Functioning muscle transfers (FFMT), it is mandatory to provide the transplanted muscle a suitable and adequate source for motor innervation. The transplanted muscle should provide adequate strength of contraction and adequate range of motion to be able to achieve the desired function. In order to replace the long flexors of the finger, a range of motion of 6.0 -7.0 cm's must be obtained following Free Functioning muscle transfer. As the total amount of muscle contraction is proportional to the length of the individual muscle fiber, a strap muscle will contract more than a pinnate muscle. Following Free Functioning muscle transfer, if the muscle is positioned at a tension that is slightly too tight or too loose, a portion of the useful range of contraction may be out of the Range of Motion of the particular joint. Hence, for Free Functioning muscle transfer, a muscle has to be chosen, which has a greater range of motion at its pre-transfer normal site than what will be desired at the transplanted site.

Anatomical Considerations:

- Teres Major + Lattissimus dorsi for External Rotation of Arm.
- Zanoli Procedure for Pronation of Arm.
- Brachio-Radialis Transfer for Extension of Fingers.
- Extensor Indices for Opponence of thunb.
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The Gracillis muscle has a single nerve composed of two to six fascicles. The distance of the nerve anastomosis from the neuromuscular junction should be minimized and preferably should be kept to 2.0 cm or less. Two-team approach is advocated, one each for the recipient and donor site respectively. At the recipient site the distal end of Sural nerve graft is identified and prepared and so are the recipient vessels, while the other team prepares the donor muscle on its neuro-vascular pedicle. The donor muscle neuro-vascular pedicle should be divided only when recipient site is ready, as the warm ischaemia time of muscle is short. Transfixing stitches to be used for insertion of donor muscle at the recipient site is kept ready in place.

Secondary Microsurgical Reconstruction Brachial Plexus Injuries:

Secondary microsurgical reconstructions in pre-ganglionic or global Brachial Plexus lesions, utilizing adjoining or distant motor nerves and functioning muscle transfers have added a number of possibilities for a useful rehabilitation program. Time interval between injury and secondary surgical repair do not influence the outcome significantly. These procedures aimed at providing:

- Motor re-innervations to important paralyzed muscles, performing flexion / extension at elbow.
- Motor re-innervation to the latissimus dorsi muscle for secondary re-enforcement of flexion / extension at elbow.
- Motor axonal outlet for a dynamic neurovascular free functional muscle transfer.

Possible Donor Motor Nerve:

Dorsal Root of C-4	:	Nerve Graft	:	Nerve to Lat. Dorsi
Accessory Spinal Nerve	:	Nerve Graft	:	Nerve to Triceps.
Intercostal nerves T3 - T6	:	Nerve Graft	:	Nerve to Biceps Brachii.
Intercostal nerve T7 - T9	:	Nerve Graft	:	Banked in Arm for II FFMT.

Contralateral C7 root	:	Nerve Graft	:	Cross-Chest banking for FFMT
Phrenic Nerve	:	Nerve Graft	:	Banked in Arm for II FFMT

Depending upon extent of the lesion and residual muscle power, a planned secondary neural reconstitution of the plexus with subsequent Free Functioning muscle transfer in mind is undertaken. Author prefers following combination:

Dorsal Root of C-4 to Nerve to Lat. Dorsi:

The Dorsal Root (Motor) of C-4 can be identified by following Sensory Cervical branches proximally and using an Intra-operative nerve stimulation to differentiate between the Sensory and the Motor Branches. Microneural co-optation is performed with the Nerve to Latissimus Dorsi Muscle using a Sural Nerve Graft.

Accessory Spinal Nerve to Nerve to Triceps:

The Accessory spinal nerve provides innervation to Trapezius and the Sternomastoid muscles in neck. The nerve is identified using an intra-operative nerve stimulation and nerve co-aptation is performed with the nerve to Triceps, using a long Sural nerve graft.

Intercostal Nerves:

The Motor Segments of Intercostal Nerves T3 to T9 are identified using an intra-operative nerve stimulation. Upper three nerves are co-opted directly to the nerve to Biceps Brachii. A long Sural nerve graft is used to lengthen lower four nerves and distal ends are passed subcutaneously to flexor aspect of the elbow and Banked for providing motor axonal outlet for subsequent Free Functional Muscle Transfer.

A functional muscle transfer is designed, when Tinnel signs confirm the growth of axons up to distal end of nerve grafts, which may also be confirmed intra-operatively by frozen section study of the Neuroma, prior to dissection of the muscle. The recipient site is prepared and recipient artery, the vein and the distal end of nerve grafts are identified and tagged for subsequent use. The designated muscle for free transfer is dissected, keeping its neurovascular supply intact. As functional motor power of the transferred muscle is greatly influenced by muscle ischaemia, care is taken to complete all requisite steps at recipient site before actually dividing the vascular pedicle. The transferred muscle is sutured using previously passed transfixation sutures. The muscle should be sutured under sufficient tension so as to cause slight over correction. Neuro-vascular anastomosis is completed promptly with minimum muscle ischaemia time.

For a dynamic re-animation of upper Extremity a functional microneurovascular muscle transfer is the most recent and viable alternative. Tamai was first to report microneurovascular transfer of Gracilis muscle. Usefulness of this procedure was endorsed by reports from Manketlow and O'Brien. The Gracilis muscle has an advantage of predictable and adequate neurovascular pedicle with possibility of incorporating the Skin Island. Latissimus dorsi, Serratus anterior and Rectus abdominis are a few other donor muscles used as free functioning muscle transfer.

Physiotherapy program begins with passive external exercise / splints and a long period of active exercise. Postoperatively, electrical stimulation of the transferred muscle is started after three weeks to maintain physiological tone and nutrition of the transferred muscle, till it recovers good nerve supply via the cross face grafts. The onset of muscle function / contraction varied from 2 - 4 months following transplantation. A full range of muscle contraction was obtained within 6 - 9 months of transplantation. Grip strength gradually increased over a period of 2 years and then slowly increased for an additional year or more.

Most workers have reported good results with free functioning muscle transfer re-innervated either by muscular neurotization, nerve implantation or nerve suture. However, final functional results were dependent on spontaneous vascularization and sufficient re-innervation .

Neuro - muscular neurotization implies direct implantation of Motor Nerve in to the denervated muscle. This method developed by Stiendler, Atiken, Sorble and Porter is being used by Narakas and Hentz, when nerves such as Supra-scapular, Axillary, Radial or Median are avulsed from their muscles.

Histologic Findings:

Nerve implantation gap resulted in less complete re-innervation. Numerous gaps of small atrophic fibers were absent among obviously re-innervated fiber. However the gross distinction between a central "red" zone containing more NADH reactive fibers, and a peripheral white zone was still possible. In a NADH stained sections of the central zone, higher and uniform intensity of staining was characteristic. In the peripheral white zone, large profiles of hypertrophic muscle fiber were typical. In more than half the muscle fibers, the myonuclei were seen in the central position.

Muscular neurotization has taken place in all seven cases but this kind of re-innervation was less successful than the other two. Single bundles of re-innervated type grouped muscle fibers were found. In addition to these normal looking fibers, small atrophic as well as hypertrophic fibers were absent. Central position of the myonuclei was similar to the other gap. The volume of the operated muscles of this gap was usually reduced to approximately half that of the control muscles.

Nerve Banking

Concept popularized by Terzis, implies carrying of a distant Motor Axonal Output to an Accessible site, that is (the shoulder or proximal arm) with or without the help of a Interposition Nerve Graft, for subsequent free functioning muscle transfer. In neglected or delayed cases of Brachial Plexus Injury wherein, the time since injury is so long (>1-2 years) that it would preclude successful neurotization or re-innervation of previously denervated muscles. Usually the spinal accessory or intercostal nerves are directed to the vicinity of shoulder or Proximal Arm with the help of a Interposition Nerve Graft. The distal end of graft is left un-sutured and is allowed time for axonal regeneration, following which a healthy muscle like the Latissimus dorsi, Gracillis are transferred to the Shoulder and Arm by microvascular free tissue transfer. The nerve of the transferred muscle is then joined to the previously placed nerve graft.

Friedman et. al. reported 50% success following a co-aptation between the transposed intercostal nerves and Free Vascularized Gracillis Muscle, transferred to the position of Biceps. Akasaka et. al. have reported Free Functioning Muscle Transfer combined with Inter-costal Nerve for reconstruction of Elbow Flexion and Wrist Extension. Chuang et. al. used contra lateral C7 as donor motor nerve with a cross-chest nerve graft , which was subsequently co-opted to nerve in free muscle transplantations. Doi et. al. reported double Free Functioning Muscle Transfer to restore pre-hension following complete avulsion.

Contiguous Musculo Tendinous Unit Transfer in Brachial Plexus Injury
Muscle Tendon Reconstructions

The timing of secondary reconstructions depends on determining that the neurologic recovery for a particular muscle, either the recovery has plateaued sub-optimally, or is unlikely or impossible. It is also based on direct knowledge of the status of nerves or generally a post injury time of more than 18 months without any evidences of recovery. Secondary reconstructions are carried out on the shoulder, elbow, wrist and hand.

Shoulder Joint:

The mobility of the shoulder should be preserved with any or all possibilities of providing muscular control by means of multiple muscle/tendon transfers. According to Haas, it was Hildebrandtin 1906, who laid the foundation for tendon and muscle transfers about the shoulder joint for paralysis of the Deltoid Muscle. He transferred the entire origin of the pectoralis major muscle to the Clavicle and Acromion Process. Slomann in 1916< reported transferring of the origin of the long head of Triceps Muscle to Acromion Process. Ober transferred the long head of Triceps muscle along with short head of Biceps muscle to the Acromion Process.

The Mayer's Transfer of the insertion of the Trapezius Muscle has been described by Haas as the most satisfactory transfer for complete paralysis of the Deltoid Muscle. Bateman modified the Mayers Trapezius Muscle Transfer by osteotomizing the Acromion and transferring it laterally along with the Trapezius muscle and anchoring the Acromion directly to the Humerus. Saha also modified Mayer's Trapezius Muscle Transfer, by completely mobilizing the superior and middle Trapezius muscle laterally from its origin. This makes the transfer two inches longer without endangering its nerve or blood supply and thus the additional length provided, increases the leverage of transfer on the humerus.

Karev reported good results following Mayer's Trapezius Muscle Transfer. Aziz reported successful treatment in 27 patients with Brachial Plexus Injury by transfer of Trapezius muscle to proximal humerus.

Itoh used latissimus dorsi muscle to replace paralyzed Anterior Deltoid Muscle and stated that in patients, who have suffered partial lesions, it may be possible to use multiple adjacent muscles to augment shoulder control.

Leffert states that for patients with total loss of shoulder control and in whom transfers are not possible, Arthrodesis of the gleno-humeral joint is a potential salvage procedure. In order to have maximal control of the shoulder arm complex the patient must have at least functioning Serratus anterior and Trapezius muscles. Shoulder fusion should generally be done as the last of staged Reconstructive Procedures.

Elbow Joint:

Although neural reconstruction can restore good elbow flexion, Leffert states that in patients, who have a partial lesion with maintained hand sensibility, tendon transfer may be preferable due to better predictability.

Stiendler in 1918 recommended use of the Flexor/Pronator Muscle group arising from the medial Epicondyle, to be used and their origin to be transposed proximally to humerus so that the Elbow Flexion increases with Acute Contraction of these muscles. Mayer and Green modified the original Flexoroplasty in 1954 by attaching the Medial Epicondyle to the bone (humerus) and more laterally to decrease the pronator effect. Though most patients can flex through a useful range against gravity, it is rare to be able to lift more than 5 pounds following such transfer.