Review Article

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Current trends in the management of brachial plexus injuries

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Abstract : In the last decade several advances have been added in the reconstruction of devastating brachial plexus injuries. This includes better understanding of the anatomy, advances in the imaging techniques, use of newer materials for nerve coaptation (e.g., fibrin glue), introduction of nerve conduits, incorporation of new immunosuppressive agents such as FK-506 and addition of new nerve transfers which selectively neurotize the target muscles close to the motor end plates. These new techniques have considerably improved the results of brachial plexus reconstruction, in particular, the upper plexal lesions.

Keywords: brachial plexus injuries, nerve repair, selective neurotization, nerve conduits, fibrin glue.

INTRODUCTION

Traumatic brachial plexus injury is devastating primarily affecting young individuals during the most productive years of their life. Last decade has witnessed significant developments in the management of these injuries. The advent of microsurgical techniques with use of magnification, microsuture and microinstruments has considerably improved the results in nerve reconstruction. Many advances have been made in the areas of neurobiology of nerve injury and regeneration, and increasing attempts are being made in the use of nerve allografts and nerve conduits for bridging the gaps. Recently introduced new nerve transfers selectively neutrotize target muscles close to motor end plates and produce early and consistently good results in the management of upper truncal injuries. Primary failures and those who present late, can suitably be rehabilitated with free functioning muscle transfers. The main advantage of the CT myelography is the visualization of pseudo meningoceles, which are usually the result of meningeal tears.

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DIAGNOSTIC MODALITIES CT MYELOGRAPHY

Myelography, in the evaluation of brachial plexus injuries, was first introduced by Murphey et al. in 1947[1]. The addition of CT scan has increased its positive predictive value to more than 95 percent[2.] Immediately after the injury, presence of blood clots may impede the pooling of dye and produce artifact, or if the tear has not yet completely sealed, there will be free flow of contrast dye to surrounding spaces. Therefore, the CT myelogram is best performed at least 1 month after the injury to allow the pseudomeningocele to fully seal and develop. The presence of a pseudomeningocele is suggestive of root avulsion, but is not diagnostic. Root avulsion may occur while the dural sheath remains intact, and the dura may tear without a root avulsion[3].

MAGNETIC RESONANCE IMAGING

MRI has the advantage of visualizing all portions of the brachial plexus, whereas CT myelography evaluates mainly the roots. MRI delineates mainly the distal plexal lesions[4]. In the last few years, a new MRI technique utilizing three dimensional fast spin-echo volume acquisition with maximum intensity projection has been developed[5]. Fast spin echo (FSE-MR) may prove useful in infants with obstetric palsy because it is noninvasive and can be performed under sedation.

TIMING OF REPAIR

The current trend is for an early repair. Patient should

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be observed up to 8-10 weeks for spontaneous recovery. After 4 weeks a baseline electromyography and CTM/ MR myelography should be performed. Patients with avulsion injury (completely flail and anaesthetic limb, severe deafferentation pain, Horner's syndrome and pseudomeningoceles on imaging) can be operated at this time. Other patients should be followed for another 6-8 weeks for spontaneous recovery. If there is no recovery, surgery should not be delayed further as results of repair deteriorate with passage of time. If some regeneration is evident but not in an anatomically consistent fashion (proximal to distal), exploration and reconstruction of the peripheral nerves that are not recovering is indicated.

REPAIR OF BRACHIAL PLEXUS

A correct diagnosis of the amount of damage to the plexus can be established only by exploration[6]. Functional assessment of the nerve is made by intra-operative nerve stimulation. A non-conducting neuroma is resected and the gap is reconstructed with nerve grafts.

NERVE GRAFTS

A direct nerve repair without nerve grafts is possible in only sharply transected injuries. In brachial plexus reconstruction this situation is rarely encountered. Therefore nerve grafting is the predominant technique employed in brachial plexus repair. In nerve grafting, certain points need elaboration. A tension free nerve graft is better than a primary repair under tension. Thin, cutaneous grafts (e.g. sural nerve) are prepared as they are easily vascularized. If the nerve graft is too thick (e.g. full thickness segments of a major nerve), the central part of the nerve graft will not become vascularized, and the graft will be a failure. Most surgeons are in the agreement that short nerve grafts are more successful than long nerve graft (i.e. more than 10 cm[7]). The nerve graft should be 20% longer than the length of the nerve defect. Vascularized nerve grafts may be suitable in a scarred bed and to reconstruct large nerve defects. Vascularized nerve grafts were introduced by Taylor & Ham in 1976[8]. Though the initial results were encouraging[9], but the technique continues to be controversial. A vascular complication might result in the complete loss of the graft. However, for bridging the long defects (30 cm or more), such as in the contra-lateral transfer, vascularized nerve grafts might prove to be more useful [10, 11]. In global brachial plexus with C8 and T1 root avulsions, pedicled vascularized ulnar nerve has been used for a contralateral C7 root transfer to the median nerve[12].

Endoscopic harvesting of the sural nerve graft has been devised[13] to overcome the potential drawbacks of the open technique. It is associated with less morbidity, more aesthetic advantages, and greater patient satisfaction.

NERVE ALLOGRAFTS

The use of allografts has been experimented in nonhuman primates and later practiced by Mackinnon et al in the humans[14] and the groups involved in hand transplantation[15]. Nerve allografts act as a temporary scaffold across which axons regenerate. Ultimately, the allograft tissue is completely replaced with host material. A new immunosuppressant FK 506, also known as tacrolimus, has greater potential and fewer side effects than other immunosuppressants. It has been established that FK-506 has neuroregenerative and neuroprotective effects[16].

FIBRIN GLUE IN NERVE REPAIR

Conventionally, nerve grafts have been sutured with a synthetic microsuture, which may induce considerable fibrotic and inflammatory reactions at the coaptation site which could seriously hamper regeneration of nerve fibres[17]. In 1988, Naraka[18] revived the use of fibrin glue in nerve repair. Since then its use has steadily gained popularity amongst the peripheral nerve surgeon. A recent study [19] has compared the use of fibrin glue and microsutures in the repair of rat median nerve and found that nerve repairs performed with fibrin sealants produced less inflammatory response and fibrosis, better axonal regeneration, and better fiber alignment than the nerve repairs performed with microsutures alone. In addition, the fibrin sealant techniques were quicker and easier to use.

NERVE CONDUITS

Although autologous nerve graft transplantation has been considered the "gold standard" for the treatment of patients with peripheral nerve gaps, their major disadvantage is the limited number of donor nerves available. This problem has led to the development of nerve guidance channels. These nerve conduits help in directing axonal sprouts from the proximal stump to the distal nerve stump. They also provide a channel for diffusion of neurotropic and neutotrophic factors and minimize infiltration of fibrous tissue [20]. Tubes made of biological materials such as collagen have been used with

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more success for distances of less than 3 cm.[21].

NERVE TRANSFERS

Neurotizations (or nerve transfers) are performed for repair of severe brachial plexus injury, in which the proximal spinal nerve roots have been avulsed from the spinal cord. A proximal healthy nerve is coapted to the distal denervated nerve to reinnervate the latter by the donated axons. The concept is to sacrifice the function of a lesser valued donor muscle to revive the function in the recipient nerve and muscle that will undergo reinnervation. The use of nerve transfers has been a major advance in the field of brachial plexus reconstruction with many different donor nerves being used to restore the desired function. Ideally nerve transfers should be performed before 6 months post injury but may be better suited than grafting in situation after the preferred 6 months time frame. A variety of donor nerves exist as a source for neurotization. Some of the more common neurotization sources include the spinal accessory nerve, phrenic nerve, medial pectoral nerve and the intercostal nerves. More recently, the use of a fascicle of a functioning ulnar or median nerve (Oberlin transfer) in patients with intact C8 and T1 has allowed a rapid and powerful return of elbow flexion[22].

Neurotization sacrifices the donor nerve, at least partially to restore the recipient nerve or muscle function. The net gain in function must be more important to the affected limb than the function that is lost. Theoretically, transferring a pure motor donor nerve to a motor recipient nerve gives the best result of motor neurotization, for example, spinal accessory-suprascapular neurotization. However not all of the available donor nerves are pure motor nerves.

Intercostal nerves contain a significant amount of sensory fibers. In this instance, its motor rami should be identified before it is connected to the motor recipient. The method of identification includes intraoperative electrical stimulation, direction of nerve fibers and histochemical staining. Ideally there should be a matching in the number of fascicles in the donor and recipient nerves, but this is rarely possible. A commonly used donor nerve such as intercostal nerve contains approximately 1300 myelinated fibers, and the spinal accessory nerve, 1700 fibers[23,24]. Concerning the recipient side, the suprascapular nerve contains approximately 3500 fibers, the musculocutaneous nerve contains 6000 fibers, the axillary nerve, 6500 fibers, the median nerve, 18000 fibers; the ulnar nerve, 16000 fibers; and the radial nerve, 19000 fibers[25]. An ideal motor neurotization of the musculocutaneous nerve that has 60% motor fiber would require two spinal accessory nerves,[26,27] or five intercostal nerves[28]. However, in clinical situations only one spinal accessory nerve or two to three intercostal nerves can reinnervate biceps to a functional levels (grade 3 or more) in 70% of patients [21,29].

Neurotization to a recipient site at the peripheral part of the plexus such as the musculocutaneous nerve, the suprascapular nerve, or the axillary nerve is more effective than a recipient in the central part such as the posterior cord or the lower trunk. In the latter situation, the donor fibers are dispersed through branches to several nerves. Scattering of donor fibers over a large area not only makes neurotization insufficient but also causes simultaneous contraction of antagonistic muscles.

Nerve reconstruction is almost always superior to palliative muscle or tendon transfer in adult brachial plexus injury. Nerve transfer or neurotization includes three major categories, extraplexal neurotization, intraplexal neurotization, and end-to-side neurorraphy.

Extraplexal neurotization is the transfer of a non brachial plexus component nerve to the brachial plexus for neurotization of an avulsed nerve. Sources commonly used include spinal accessory nerve, intercostal nerves, phrenic nerve, deep cervical motor branches, and contralateral C7 transfer.

Intraplexal neurotization is the transfer of a spinal nerve or more distal plexus component with intact spinal cord connections to a more important denervated nerve. In most cases, a ruptured proximal nerve is used. Examples include connecting the proximal stump of C5 or C6 to the distal aspect of C8, lower trunk, or median nerve, or the use of a portion of a functional ulnar nerve to the musculocutaneous nerve. Neuromuscular neurotization (direct implantation of motor nerve fascicles in to denervated muscle) may also be used from intraplexal sources.

In end-to-side neurorrhaphy, the distal stump of an irreparably injured nerve is implanted into a healthy nerve without injuring the function of the healthy nerve. The method is mostly used for sensory neurotization but, at present is seldom practiced.

In neurotization, direct suture without tension is

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always superior to indirect suture with a nerve graft. This is especially true for the weak donor nerves such as intercostal nerves and the distal spinal accessory nerve.

Ipsilateral nerve transfer is always superior to the contralateral nerve transfer. For example, an ipsilateral C5 to median nerve transfer will be better than a contralateral C7 to median nerve transfer from the functional point of view.

In neurotization, attempt is made to reinnervate the recipient nerve as close to the target muscle as possible. An out standing example of the latter is the transfer of an ulnar nerve fascicle directly to the biceps branch of the musculocutaneous nerve in close proximity to its entry into the muscle.

The patient must be motivated and able to cooperate with surgical pre-and postoperative care recommendations. All patients undergoing neurotization need induction exercises. For example, after intercostal or phrenic nerve transfer patients will be directed to run, walk or perform hill climbing to obtain deep breathing. As recovery progresses, frequent exercise of the reinnervated muscles provides an internal nerve impulse that is always superior to the external electrical stimulation.

In general, spinal accessory nerve transfers are most appropriate for the shoulder, intercostal nerve transfer for the elbow flexion and phrenic nerve transfers for shoulder function or arm extensors. When available, partial ulnar nerve transfer is best used for elbow flexion. The contralateral C7 transfer is preferred for hand flexors and sensation in global plexopathies.

REIMPLANTATION OF AVULSED SPINAL ROOTS INTO THE SPINAL CORD

On the basis of animal experiments, Carlstedt etal[30] surgically treated 10 patients with brachial plexus lesions and obtained useful muscle function in the proximal arm muscles after root replantation. Direct root replantation is not always possible. Connection of target nerves of the brachial plexus to nerve grafts implanted into the spinal cord represents an alternative.

CONCLUSIONS

Brachial plexus injuries represent devastating injuries with a poor prognosis. The results of brachial plexus repair have considerably improved with the introduction of microsurgical techniques and magnification. Shorter defects (as in obstetric palsy) are being bridged with nerve conduits. Use of fibrin glue in nerve coaptation has considerably reduced the operating time. Nerve allografts with new immunosuppressant (FK-506) are being used where there is paucity of autografts. Direct replantation of avulsed spinal roots into the spinal cord is a new area of research in brachial plexus reconstruction.

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