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Management of Missile Injuries of the Brachial Plexus

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Abstract: Missile injuries of the brachial plexus are a challenging group of peripheral nerve injuries. A total of 22 soldiers with penetrating missile injuries were treated at Army Hospital (Research & Referral) from jun 2002 to Apr 2005. 17 patients underwent surgery at a mean of 2 months to 2 years after the injury. The indications were no return of function in the paralysed limb and severe and intractable pain. No operations were performed in 5 patients showing neurological recovery.

Neural elements were grafted in 10 patients at three levels : root and trunk level (3); cord level (5) and branch level (2). Microneurolysis was done in 4 patients in whom the proximal root stumps were severely fibrotic and not suitable for grafting. One patient with previous failed repairs was treated by free functioning muschle transfer, two years after the injury. All patients were followed upto 2 years after surgery. Good or useful results (return of power, sensations and relief from neuralgic pain) were obtained in 70% of cases. Poor results were observed after repairs of the medial cord and ulnar nerve.

The overall results results achieved after repairs of C5, C6 and C7 roots, and the lateral and posterior cords highly justify a timely surgical intervention in brachial plexus palsy following missile injuries.

Keywords: missile injuries; brachial plexus

INTRODUCTION

Injuries to the brachial plexus are devastating and strike a predominantly young and active population. The treatment of injuries to the brachial plexus is demanding and difficult. The surgical exploration demands a clear and concise understanding of the normal anatomy and its variations, including the pathoanatomy. Recovery takes a long time and results are often unpredictable. Return of function is far from satisfactory; however, for the patient it means a significant improvement to resume a somewhat normal social life[1].

Many times the diagnosis of brachial plexus lesions is not only delayed but patients are often referred too late to the specialized centers dealing with such injuries. This is partly due to the lack of awareness amongst the clinicians about the recent developments in the field of brachial plexus surgery.

Penetrating missile injuries of the brachial plexus are a challenging group of peripheral nerve lesions. These injuries are infrequent in civilian practice. In recent military conflicts they have constituted approximately 2.6% to 14% of all peripheral nerve injuries[2]. Missile injuries of the plexus were generally considered to have a poor, almost hopeless prognosis and a conservative approach of waiting for spontaneous recovery was advocated[3,4]. In the last two decades with improvements in radioimaging, electrophysiological testing and application of microsurgical techniques, significant advances have been made in the management of these injuries.

This paper will highlight the critical aspects of missile injuries of the brachial plexus and present the experiences gained during the management of 22 cases.

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MATERIALS AND METHODS

From June 2002 to April 2005, a total of 22 soldiers with missile injuries of the brachial plexus were treated at Army Hospital (Research and Referral) Delhi Cantt. All of them were males with a mean age of 26 years (21 to 32 years). In 13 patients, injuries were caused by bullets and in 9 by shell, mortar or grenade fragments. All patients were referred from the field hospitals located in the operational areas or from the field firing ranges. Associated vascular, skeletal and lung injuries were present in 10 cases. One patient had a complete disruption of the axillary artery which was treated in the field hospital by emergency ligation. Later it was revised with an autogenous vein graft. Another patient had a tear in the subclavian vein which was repaired by simple suture. Associated skeletal injuries to the clavicle

(2), scapula (1), ribs (3) and humeral head (1) occurred singly or in combination in 7 cases. Clavicular fractures were treated by open reduction & plate fixation. One patient had contusions in the lungs.

A total of 17 patients underwent exploration of injured plexus at a mean of 4 months (2 months to 2 years) after the injury (Table 1). The indications were continuing paralysis and severe and intractable pain. No operations were performed in 5 patients showing neurological recovery.

Table 1. Denervation time

S No	Denervation time	No of patients
1	2 months – 4 months	3
2	4 months – 6 months	8
3	6 months – 8 months	3
4	8 months – 10 months	1
5	10 months – 12 months	1
6	12 months – 2 years	1

All patients were operated under general anaesthesia, in the supine position with the affected upper extremity abducted on an arm board. Access to the chest and legs were also made available as needed for the harvest of donor nerves for transfer or grafting. Paralytics were withheld until all nerves were completely evaluated by electrical stimulation. Brachial plexus was explored through an incision around the posterior border of the sternocleidomastoid muscle, curving posterolaterally over the superior border of the clavicle, and then extending to the arm through the deltopectoral groove (Fig 1).

Fig 1: Incision for exposure of supraclavicular Brachial plexus

The roots of plexus were searched between the scalenicus anterior and medius muscles. To expose the cord and terminal branches, the incision was extended along the deltopectoral groove from the clavicle to the upper medial arm (Fig 2). The humeral insertion of pectoralis major and the origin of pectoralis minor were divided. The supraclavicular and infraclavicular plexuses were connected by means of retroclavicular dissection. In two patients clavicular fractures were reduced and fixed with plate and screws. The level and extent of injury was determined by gross examination and electrical stimulation with a DC stimulator at 0.5, 1.0 and 2.0 mA. This was particularly helpful in lesions in continuity in which a decision had to be made whether to proceed with neurolysis, resection of neuroma and nerve grafting or neurotization. If stimulation of the nerve produced muscle contraction neurolysis of the scarred portion was done. If no muscle activity was seen, the neuroma was resected and the gap reconstructed with sural nerve grafts. Neural elements were grafted at three levels; root and trunk level (3), cord level (5) and at branch level (2) (Table 2). One patient with previous failed repairs was treated by free functioning muscle transfer, 2 years after the injury. External neurolysis was done in four cases when injured nerve felt hard on palpation or found constricted in scar tissue, giving rise to persistent pain and paralysis (Table 3).

Table 2. Level of brachial plexus injuries

S No	Level	No of cases
1	Root	1
2	Trunk lesions	2
3	Cord lesions	5
4	Terminal branches	2
5	Multiple levels	7

Table 3. Type of reconstruction

S No	Reconstruction	No of patients
1	Microneurolysis	4
2	Nerve grafts	10
3	Neurotization	02
4	Free functioning muscle transfer	01

Neurotization of a peripheral nerve closer to the target muscle was done in two patients when the proximal root stumps of C5, C6 & C7 were severely fibrotic and unavailable for grafting. The donor nerves that were used for neurotization included spinal accessory nerve, part of ulnar nerve (Oberlin transfer) and radial nerve branch to long head of triceps. In both the cases spinal accessory nerve was coapted with suprascapular nerve to achieve initial 20 to 30 degrees of shoulder abduction. For further improvement of shoulder abduction, deltoid was reinnervated by coapting the radial nerve branch to long head of triceps to the axillary nerve. Elbow flexion was restored by direct coaption of one or two ulnar fascicles with nerve to biceps. Postoperatively the extremity was immobilized for 4 weeks. After this time the patients were instructed to begin physical therapy, gradually increasing the range of motion, along with electrical stimulation, to keep the joints and the denervated muscles in good condition until reinnervation.

RESULTS

The clinical results of repairs were categorized in three grades:

Good The motor contractile force greater than M3 of Medical Research Council scoring and good tactile sensation, with ability to distinguish, warmth, cold and pain.

Acceptable The motor contractile force greater than M3 and presence of protective sensation.

Failure Inability to use the extremity purposefully and effectively.

Nerve grafting One or more elements of the plexus was repaired in 10 patients. There were two good results (Fig 1 to 6), five useful and three poor results. Repair of upper trunk, lateral and posterior cords produced most of good and useful results. Repairs of the medial cord or ulnar nerve yielded poor results.

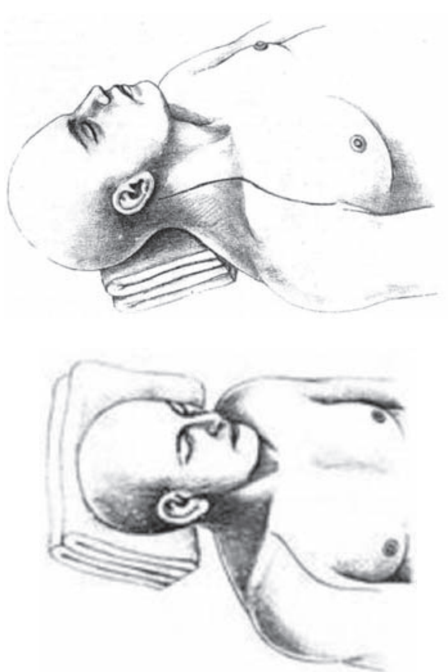

Fig 2: Incision for exposure of infraclavicular Brachial Plesxus

Fig 3: Gunshot wounds chest and axilla

Fig 4: Good range of elbow flexion after repair of lateral cord

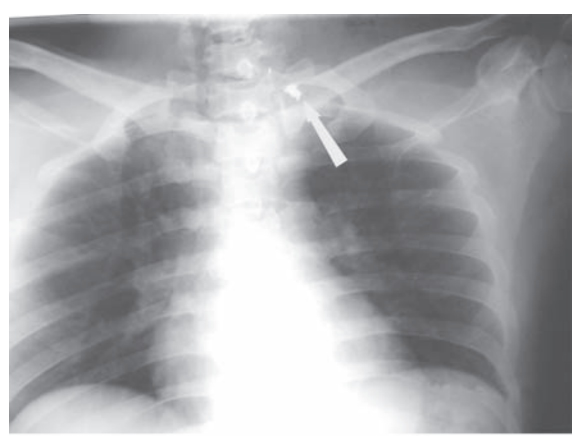

Fig 5: Good range of shoulder abduction following axillary nerve repair

Fig 6: Splinter wound Left side neck

Neurolysis Three patients achieved good results and one useful results.

Nerve transfers

Both patients achieved good results.

Free functioning muscle transfer

The single patient operated two years after the injury achieved M3 elbow flexion in 8 months following free gracillis muscle transfer (Fig 7 to 10).

Fig 7: Splinter lodged in deeper neck

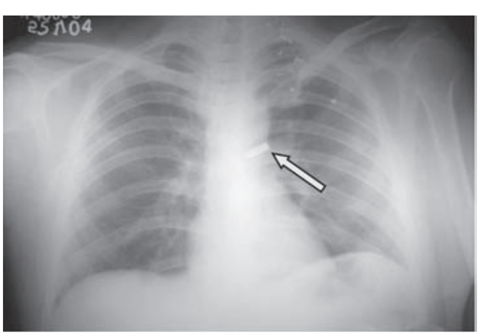

Fig 8: Good range of elbow flexion following upper Trunk repair

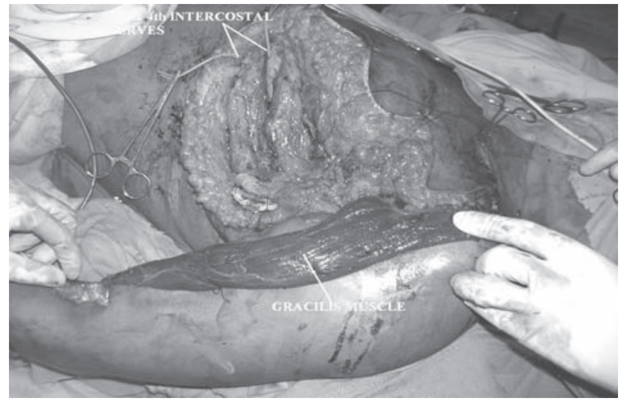

Fig 9: Global palsy following missile injuries in the neck

Fig 10: Bullet and its fragments in the neck & chest

DISCUSSION

Armed conflict has always provided the surgeon with an opportunity to advance the science of trauma surgery. In the words of Hippocrates, "let him who wishes to be a surgeon go to war". Ambrose Pare[5] further added, "in the pursuit of his profession, a surgeon can wish no more welcome test of fire than battlefield".

In modern day warfare weapons have become increasingly more powerful and the injuries they cause are more extensive [6]. A proper treatment of missile injuries of the brachial plexus requires a sound knowledge of wound ballistics. Missile wounding can be understood in terms of physical interactions between the missile and the tissues through which it passes. The primary destructive effects of a missile are caused by the crushing action of the missile itself. Besides this when a missile strikes animal tissues, a high pressure shock wave is formed which moves spherically away from the point of impact[7]. The kinetic energy of high velocity missile, when it passes through the tissues, is transferred to adjacent tissue elements, which are propelled radially, creating a large subatmospheric temporary cavity directly behind the missile. When the elastic limit of this outwardly displaced tissue is reached, it falls inward whence it was displaced. This cycle may be repeated several times resulting into extensive damage to the tissues[8,9]. Bullet or its fragments may impart sufficient kinetic energy to dense tissues such as bone. The shattered bone fragments become secondary projectiles and travel in almost all directions, causing extra damage to surrounding tissue[10].

Missile injuries of the brachial plexus may also injure the neighboring vessels (axillary artery and vein, subclavian artery and vein), bones (clavicle, ribs, scapula, humerus) and visceras (lungs, pharynx, oesophagus etc). In an emergency situation when a brachial plexus lesion is associated with injury to major vessels, the question arises, whether in the same stage the brachial plexus repair should be performed to deal with the whole injury immediately. If not only a vascular surgeon, but also a surgeon experienced in brachial plexus surgery is available, and if the patient's state is well enough that he can sustain approximately an 8 hour surgery, then an attempt to repair the brachial plexus may be undertaken. However, in most of the times, it is much better to concentrate at this stage on the vascular repair, and leave the brachial plexus for an early secondary repair. Contrary to the experiences gained from World War II[3], it is now well appreciated that many missile injuries to the brachial plexus do not recover spontaneously and produce severe functional disability and persistent pain from the strangulating effect of dense scar tissue on plexus elements. Missile injuries manifest as partial and / or complete disruption of one or more neural elements at the level of root, trunk, cord and terminal branches. A direct 'hit' to the clavicle is associated with a particularly high incidence of total disruption of the plexus.

At exploration lesions in continuity are commonly found. This must be checked carefully to exclude 'blunt' injuries[11]. Intraoperative recording of compound nerve action potentials (NAP) are important in this regard. When nerve action potentials are found to traverse the lesion, a microneurolysis will produce good or useful results. On the other hand if no nerve action potentials are detected, the lesion is resected and grafted. The grafts are done using 10-0 nylon suture. Autogenous sural nerve is used as the graft material of choice.

Neurotization is offered to the patients with root avulsions. A variety of donor nerves both intraplexal and extraplexal are used for this purpose e.g. spinal accessory nerve, phrenic nerve, cervical motor branches, intercostals nerves, contralateral C7, etc. Patients presenting more than one year after injury will require muscle transfers. Double free functioning muscle transfers (gracilis muscles from both thighs) provide satisfactory restoration of elbow and hand functions.

One of the most disturbing factor in missile injuries of brachial plexus is the presence of severe pain syndrome in many of the cases. There are many theories of this neuralgic pain. It may be related to partial transection of lower roots, lower trunk or medial cord of the plexus and manifests as intense burning pain and hyperpathia[12]. Some of these cases may temporarily respond to sympathetic blockade. Another type of pain is caused by compression of neural elements in the scar tissue, and responds well to excision of scar tissue and microneurolysis. The most disabling pain is of central origin resulting from avulsion of the dorsal sensory rootlets from posterior horn. This area in spinal cord is called dorsal root entry zone (DREZ). The most likely cause of this kind of pain is spontaneous hyperactivity of deafferentation pain transmitting neurons in the dorsal horn. The DREZ lesioning procedure, which destroys the hyperactive pain transmitting neurons in the dorsal horn, is sometimes helpful[13].

CONCLUSION

Missile injuries of the brachial plexus often comprise a spectrum of neurological lesions from neuropraxia to axontomesis and neurotmesis. Most commonly, on exploration, one finds nerve lesions in continuity. It becomes difficult to differentiate neuropraxia, which is likely to recover, from the most severe neurotmesis, which will require excision of neuroma and nerve grafting. Many low velocity missile injuries (muzzle velocity less than 2000 feet /sec) inflicted by hand guns or revolvers are associated with neuropraxic lesions and recover on expectant approach in weeks to months unless the missile has directly damaged the neural elements. Contrary to this high velocity missiles (AK-47 assault rifles, sten guns, machine guns, etc), with muzzle velocity averaging 3000 feet/sec produce extensive damage to soft tissues, blood vessels, bones and may divide all or part of the brachial plexus. Extent of nerve injury may extend far beyond the site of injury. At the same times injuries at multiple levels of the plexus are common. Such lesions will never recover on expectant approach. Hence after waiting for a period of 4-6 weeks the patient should undergo radiological and electrophysiological studies. The presence of pseudomeningoceles on CT Myelography is highly suggestive of root avulsions. MRI studies give more information about the distal part of the brachial plexus. Many times the diagnosis is made only at exploration. Hence a thorough clinical evaluation plays an important role in the overall management. Surgery of the patients who are not recovering should not be delayed more than 2 to 2 ½ months after the injury. Till that time the nutrition of paralyzed muscles must be maintained by electrical stimulation. Joints should also be moved passively to prevent contractures. Results are poor in those who are operated late because with passage of time the motor end plates undergo degeneration.

The operative repair of missile injuries of the brachial plexus can give good results. The severity of trauma and the extent of damage to neural and vascular structures will determine the final outcome, closely followed by the delay between the injury and repair. Timely repairs of C5, C6 and C7 roots, and the lateral and posterior cords produce the most gratifying results.

Most of the cases of brachial plexus injury following missiles occur in young adults during the most productive periods of their lives. With modern microsurgical techniques these patients can be rehabilitated to lead a near normal life.

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