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ORIGINAL ARTICLE

An Experience with Missile Injuries of the Brachial Plexus: Points to Ponder

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Abstract

Specific Aims and Objectives: The management of missile injury of the brachial plexus is challenging and functional outcomes differ considerably from high-speed motor vehicle accidents. This study aims to present the functional outcomes following surgical treatment of different grades of missile induced brachial plexus injuries.

Methods: Forty-eight cases of brachial plexus injuries were managed in a tertiary care centre in the period between March 1998 and November 2012. The intra-operative nerve lesions consisted of neuroma- in-continuity, diffuse adhesions, fibrosis, and partial or total disruptions of various elements of the brachial plexus. Nerve grafting, neurolysis and nerve transfer were the most commonly performed procedures. Patients were followed up for a minimum of 3 years after surgery.

Observations: Best functional outcomes were obtained following reconstruction of lateral cord, musculocutaneous and radial nerves. Repairs of upper and middle trunks, posterior cord and median nerve produced satisfactory outcomes. Results were highly unsatisfactory following repair of lower trunk and medial cord lesions.

Conclusion: In the absence of satisfactory neurological recovery, surgical intervention should not be delayed. A timely executed microsurgical reconstruction results in satisfactory to good functional outcomes in missile injuries of the brachial plexus.

Introduction

Missile injury caused by bullets, mortar, tank, cannon shells and grenade particles is the second leading cause of brachial plexus injury after high-speed motor vehicle accidents. In war scenario the incidence of missile injury of the brachial plexus ranges between 2.6% and 14%.[1] The extent of neurological dysfunction largely depends on the size and type of missile, its velocity and the path traversed. While a low velocity missile inflicts trauma by a direct impact, high velocity missiles generate shock waves and cavitations, resulting in considerable compression and stretching of the nerve elements. In addition missile induced soft tissue, skeletal and vascular injuries complicate the treatment and functional outcomes of the nerve repairs[2].

Attempted nerve repairs during world wars I and II were discouraged by their poor clinical results and a predominantly “wait and see” policy was adopted[3]. The advances in surgical techniques in 1960’s and 1970’s with incorporation of nerve grafts in bridging nerve gaps resulted in favorable clinical outcomes which witnessed newer horizons in the years immediately thereafter[2].

The present study is an attempt to define the surgical indications and functional outcomes following repair of missile injuries of the brachial plexus.

Patients and Methods

Patients

This report is an experience in the surgical management of 48 cases of missile injuries of the brachial plexus treated in a tertiary care centre in the period between March 1998 and November 2012. All patients were males with the mean age of 23 years (range between 20 and 29 years). Sixteen patients (33%) had sustained splinter injury from bombs and grenades, while 32 (67%) had high velocity bullet injury. Associated injuries (Table 1) were present in 31patients (vascular injury in 5, hemo-pneumothorax in 7, and compound-comminuted fractures of ribs, humerus, clavicle, and scapula in 19).

Table 1: Associate injuries

Type of injury	Location of injury
Vascular injury	5 (SV-3, AA-2)*
Hemo-pneumothorax	7
Skeletal injuries	19 (Rbs-7, Hm-5, Cl-4,Sp-3)**

* SV- Subclavian Vein, AA- Axillary Artery
** Rbs- Ribs, Hm- Humerus, Cl- Clavicle, Sp- Scapula

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Immediate surgical intervention was indicated for the vascular injury, chest trauma, untidy wounds and unstable fractures. In majority of the cases the wounds were debrided and no attempts were made to explore the injured nerves. On healing of wounds patients were observed for recovery in neurological functions for a minimum period of 3 months. Those with persistent sensori-motor deficits and pain syndromes were treated surgically.

Pre-operative Assessment

Each patient was subjected to a detailed clinical examination. Plain x-ray films of the cervical spine, clavicle, humerus and chest were obtained. Magnetic resonance imaging (MRI) of the supra-and infra-clavicular brachial plexus and electrophysiological studies were used as main diagnostic tools.

Timing of Repair

Immediate surgical intervention for neurological deficit was avoided and patients were generally observed for 3 months. Thereafter all patients were subjected to a complete clinical, radiological and electrophysiological examination. Nerve explorations were performed for lesions with incomplete recovery and no progression and those with disabling pain syndromes. Thirty three (68.7%) patients were treated 3 to 6 months after the injury. Fifteen (31.2%) patients underwent reconstruction as late as 10 months after the injury. These patients were either referred late or had been managed elsewhere for orthopedic trauma or wound infections.

Exploration of the Plexus and Intraoperative Findings

All patients were operated under general anesthesia with neck turned towards opposite side. The affected arm was abducted and rested on an arm board. A reverse C shaped incision was made with its horizontal limb about 1 cm above and parallel to the clavicle and the vertical extension along the posterior border of the sternocleidomastoid muscle. This incision frequently required modifications due to preexisting scars from healed wounds. At the beginning anaesthesia was maintained with short acting muscle relaxants to facilitate intraoperative nerve stimulation. Skin-platysma flap was raised and the external jugular vein was ligated. Thereafter the supraclavicular pad of fat was reflected downwards and laterally from the posterior border of sternocleidomastoid muscle. The inferior belly of omohyoid muscle was divided and plexal elements were identified in the space between the anterior and middle scalene muscles. Infraclavicular plexus was explored through an incision in the deltopectoral groove with its distal extension along the inner aspect of arm. Exposure of the cords and their terminal branches usually required division of pectoralis major and minor muscles. At this stage the site of injury to the plexus and its elements was recorded. Eleven (23%) patients had sustained injury in the supraclavicular region, whereas 37 (77%) patients in the infraclavicular region (Table 2).

Table 2: Location of injury

Location	Number of nerve elements injured
C5,C6 to upper trunk or upper trunk	13
C7 to middle trunk or middle trunk	4
C8,T1 to lower trunk or lower trunk	2
Divisions to lateral cord or lateral cord	14
Divisions to medial cord or medial cord	12
Divisions to posterior cord or posterior cord	15
Lateral cord to musculocutaneous nerve	11
Lateral cord to median nerve	9
Medial cord to median nerve	10
Medial cord to ulnar nerve	12
Posterior cord to radial nerve	13
Posterior cord to axillary nerve	8

On further exploration intact nerve elements encased in thick fibrous tissue were encountered in 72 (58.5%) lesions. A complete rupture of plexus with neuroma-in- continuity was observed in 14 (11.3%) lesions. Thirteen (10.5%) lesions were ruptured (Fig 1 to 4), whereas in remaining 24 (19.5%), intact peripheral nerves were surrounded by fibrous tissue.

Fig. 1 Missile injury neck (wound of entry)

Fig. 2 Lack of active abduction at shoulder

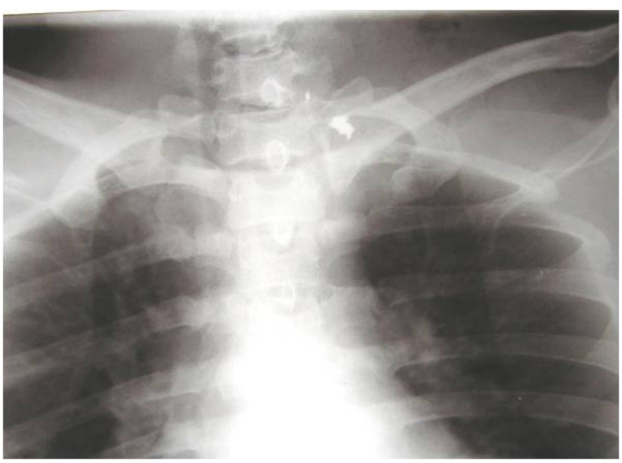

Fig. 3 Retained splinter in the neck which injured upper trunk

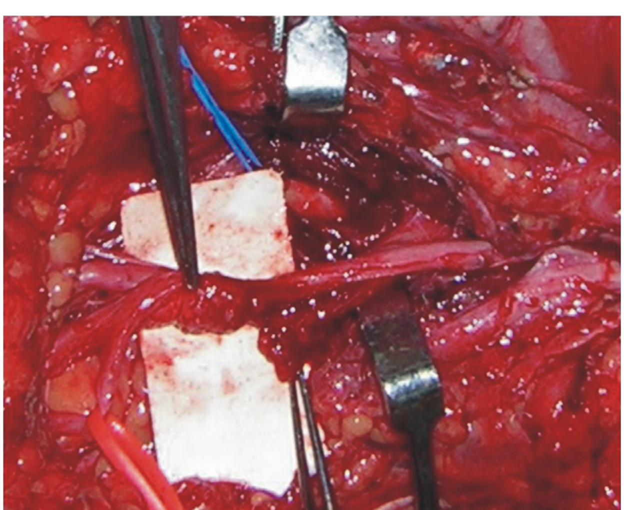

Fig. 4 A complete disruption of upper trunk

Microsurgical Procedures

All the nerve elements were examined in high power magnification under an operative microscope. A DC nerve stimulator at 1.0 mA was used to test the integrity of the lesions in continuity. If stimulation produced contractions in distally innervated muscles, an external neurolysis of scarred segment performed. A total of 25 patients (52%) were treated by neurolysis alone. If no muscle activity was observed, the neuroma was resected and sural nerve grafts were placed across the nerve defect. Incomplete ruptures were treated by partial neuroma excision and end-to-end sural nerve grafting. The fascicles maintaining continuity were neurolysed. Sixteen patients (33%) were treated by neuroma excision and nerve grafting (Fig 5). In 7 patients (15%) nerve grafting was combined with limited nerve transfers (spinal accessory nerve to suprascapular nerve and ulnar fascicle to biceps motor nerve transfer).

Table 3: Microsurgical procedures

Procedure	Number of Lesions	Number of Patients
Neurolysis	72 (T,C) * 24 (P) *	25
Neurolysis with nerve grafting	13	16
Nerve grafting with nerve transfers	14	7

* T - Truncal lesions, C- Cord lesions)
* P- Peripheral nerve lesion

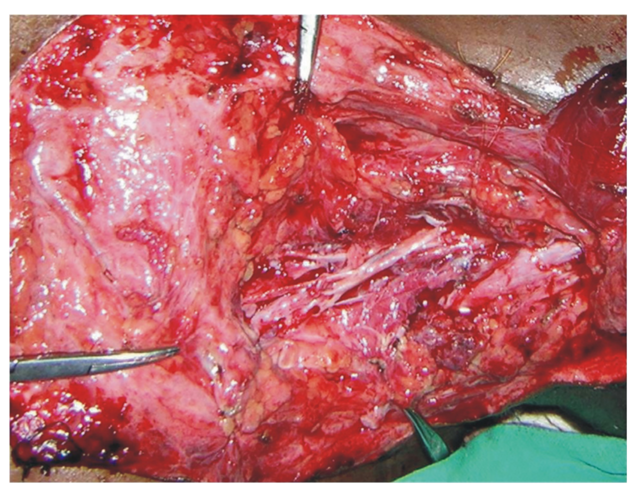

Fig. 5 Upper trunk nerve grafting with spinal accessory to suprascapular nerve transfer

Postoperative Assessment

Patients were followed up for a period of 3 years or more. At that time motor and sensory functions were assessed according to Muscle Research Council (MRC) Grading System (Table 4 and 5).

Table 4: MRC Grading System (Motor recovery)

Motor recovery	Description
M0	No contraction
M1	Return of perceptible contraction in proximal muscles
M2	Return of perceptible contraction in both proximal and distal muscles
M3	Return of perceptible contraction in both proximal and distal muscles of such degree that all important muscles are sufficiently powerful to act against resistance
M4	Return of function as in M3 with the addition that all synergic and independent movements are possible
M5	Complete recovery

Table 5: MRC Grading System (Sensory recovery)

Sensory recovery	Description
S0	Absence of sensibility in the autonomous area
S1	Recovery of deep cutaneous pain sensibility within the autonomous area of the nerve
S2	Return of some degree of superficial cutaneous pain and tactile sensibility within the autonomous area with disappearance of any previous over-reaction
S3+	Return of sensibility as in S3 with some recovery of 2-point discrimination within the autonomous area
S4	Complete recovery

The return of motor and sensory functions were categorized as good, fair, and poor. Good recovery was defined as at least M4 power in the proximal muscles, M3 in the distal muscles, and S3 recovery in sensory function. Fair recovery was defined as at least M3 function in proximal muscles and S2 sensory recovery, regardless of the motor function of distal muscles. Recovery of M2 or less motor, and less than S2 sensory functions were regarded as poor results. For supraclavicular injuries (spinal nerves and trunks) good recovery was considered if active shoulder abduction (suprscapular and axillary nerves) and active elbow flexion (musculocutaneous nerve) were M4 or more. M3 power in shoulder and elbow was considered as fair result. For C8, T1 or lower trunk injuries, good recovery was considered with finger flexion recovered to M4, hand muscles recovered to M3, and sensory function recovered to S3. Recovery in peripheral nerves was also assessed. Both motor and sensory functions were assessed for the median and ulnar nerves. However only motor recovery was evaluated for the musculocutaneous, radial and axillary nerves.

Results

The surgical outcomes are shown in Table 6 to 9.

Table 6: Functional outcomes of neurolysis in intact nerve elements encased in thick fibrous tissue (72 lesions)

Final outcome	No of lesions	(%)
Good	64	(90%)
Fair	5	(6%)
Poor	3	(4%)

Table 7: Functional outcomes of nerve grafting and limited nerve transfers in complete rupture of plexus with terminal neuroma (14 lesions).

Final outcome	No of lesions	(%)
Good	11	(79%)
Fair	2	(14%)
Poor	1	(7%)

Table 8: Functional outcomes of nerve grafting and neurolysis in partial ruptures (13 lesions)

Final outcome	No of lesions	(%)
Good	11	(84%)
Fair	2	(16%)
Poor	0	(0%)

Table 9: Functional outcomes of neurolysis in intact peripheral nerves surrounded by fibrous tissue (24 lesions)

Final outcome	No of lesions	(%)
Good	22	(92%)
Fair	2	(8%)
Poor	0	(0%)

Table 10: Functional results as per the location of injury

Location	Good (%)	Fair (%)	Poor (%)
C5,C6 to upper trunk or upper trunk	66	29	5
C7 to middle trunk or middle trunk	43	51	6
C8,T1 to lower trunk or lower trunk	8	41	51
Divisions to lateral cord or lateral cord	45	34	21
Divisions to medial cord or medial cord	18	21	61
Divisions to posterior cord or posterior cord	24	32	44
Lateral cord to musculocutaneous nerve	66	22	12
Lateral cord to median nerve	14	30	66
Medial cord to median nerve	16	34	50
Medial cord to ulnar nerve	Nil	12	88
Posterior cord to radial nerve	32	44	24
Posterior cord to axillary nerve	34	48	18

Neurolysis alone was very effective in peripheral nerves surrounded by a layer of fibrous tissue. It was not equally effective when nerve elements were surrounded in dense fibrous tissue, as was noticed in the truncal and cord lesions. In upper truncal lesions with complete rupture, anatomical reconstruction using sural nerve grafts combined with spinal accessory to suprascapular and ulnar fascicle to biceps branch, produced good functional outcomes in 79% of the lesions. Treatment of partial ruptures with neurolysis of intact fascicles and nerve grafting of damaged segment produced good functional outcomes in 84% of lesions.

Best results were obtained following repair of upper trunk (Fig 6 and 7), lateral cord, musculocutaneous and radial nerves. In selected cases limited nerve transfers provided good return of shoulder and elbow functions. Repairs of middle trunk neuroma, posterior cord and median nerve also yielded in satisfactory outcomes. Results were highly unsatisfactory following repair of lower trunk, medial cord and ulnar nerve lesions.

Fig. 6 Full restoration of shoulder abduction

Fig. 7 Restoration of elbow flexion

Discussion

A sound knowledge of wound ballistics is essential to understand the damage caused by different kinds of missiles[3,4]. Injury from low velocity missiles (muzzle velocity less than 2000 feet/second) are usually neuropraxic or axonotmetic with good potential for spontaneous recovery in 3 to 4 months of time. Most of the injuries caused by high velocity missiles (muzzle velocity averaging 3000 feet/second) are neurotmesis and will eventually need microsurgical reconstruction.

Missiles contuse and lacerate or severe the nerves partially or completely. Because of excessive contamination with retained foreign materials and an ischemic bed, there is considerable inflammatory response which manifests subsequently as diffuse fibrosis and scarring in and around the injured nerve elements.

There has been a paradigm shift in the management of missile injuries of the brachial plexus. The experience gained during World War I and II prevented surgeons from an aggressive surgical approach. The advances in microsurgery in late 1960's and 1970's with the pioneering work on peripheral nerves by Millesi[5] (who advocated a liberal use of nerve grafts in bridging nerve defects) and Narakas[6] (who popularized nerve transfers) brought newer horizons in the management of missile injuries of the brachial plexus.

In missile injury of brachial plexus an aggressive wound management and repair of an associated vascular or skeletal injury takes priority over the immediate nerve repair, which is undertaken as an early secondary or late secondary procedure[7]. A period of observation for 2 to 3 months allows a clear demarcation between low grade and high grade lesions. During this period neuropraxic injuries recover and tissue vascularity is reestablished. This permits re-entry through the healed area without compromising survival of skin margins. Also by this time epineurium gets thicker and stronger to hold the sutures. Formation of neuroma at the rupture site distinguishes healthy tissue from the scarred tissue.

In missile injuries of the brachial plexus lesions in continuity are common. Nerve root avulsions, frequently observed in motor bike accidents, are rarely encountered in missile induced brachial plexus injuries. Inraoperative nerve stimulation and recording of Compound Nerve Action Potentials (CNAP) have been used to assess the neuronal integrity. When CNAP was found to traverse the lesion, neurolysis provides good functional results. However when no CNAP was found to traverse the lesions, neuroma resection and nerve grafting is performed. In present series neurolysis of the lesions in continuity resulted in better functional outcomes (good outcomes in 90% of cases) than nerve grafting (good outcomes in 79% of cases). We attribute this to a more severe grade of injury in the grafted group and inherent problems related to nerve grafting techniques.

In C5,C6 and upper truncal reconstruction we preferred nerve grafts (to bridge the nerve defects) supplemented with nerve transfers. A direct transfer of spinal accessory erve to the suprascapular nerve reduces loss of regenerating axons at the coaptation site which occurs at two places when a nerve graft is used. The addition of ulnar fascicular transfer to the biceps branch results in an early restoration of elbow flexion[8].

Severe disabling pain is experienced by a few patients with missile injuries. Stewart and Birch[9] have described four distinct patterns of pain syndrome: causalgia, neurostenalgia, posttraumatic neuralgia, and central pain. Causalgia presents with burning pain, allodynia, and hyperpathia and results from partial transection of C8,T1 roots, lower trunk, medial cord, or its branches. An entrapment of nerve in the fibrous tissue is the cause of neurostenalgia. A partial injury to the nerve results in posttraumatic neuralgia. Central pain is less common and caused by an injury to proximal roots or the spinal cord.

Conclusion

The neurologic lesions from a missile may vary from neuropraxia to axonotomesis and neurotmesis. A timely performed surgery results in good functional outcomes. Results are more favorable for lateral cord, musculocutaneous nerve and upper trunk, followed by the posterior cord, radial, axillary nerves. Results are highly unsatisfactory following repair of lower trunk, medial cord and ulnar nerve lesions.

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