Original Article

Surgical Management of Traumatic Radial Nerve Injury

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ABSTRACT

Background: Traumatic peripheral nerve injury (PNI) is a serious medical condition encountered in many of the injuries to the upper and lower extremities, and in 3–10% of patients. The average incidence of radial nerve lesions is approximately 11%. Wrist drop represents the most common presentation of radial nerve palsy. Radial nerve palsy after fracture of the humerus is the most common nerve lesion in long bone fractures. This palsy may occur acutely at the time of injury, secondary to fracture manipulation, or from healing callus. Radial nerve may be injured at axilla by direct pressure. The surgical treatment of PNIs is still a challenging and highly demanding procedure. An understanding of the pathophysiology of PNI and selection of a suitable time for surgery are necessary for proper treatment of this challenging disorder although some nerve injuries recover spontaneously, in some cases surgery is the only therapeutic option for the improvement of neurological deficits or control of neuropathic pain.

Objectives: To review the cases of radial nerve injury, to highlight the etiological factors leading to radial nerve injury resulting in wrist drop, evaluate the result of primary and delayed peripheral nerve repair after various types of injury and determine factors favoring good prognosis.

Patients and Methods: This is a retrospective study of twenty patients of traumatic radial nerve injury which were managed in our department. All their clinical data, electromyogram (EMG) and nerve conductive study (NCS), the indication of surgery, its timing and type of surgery and outcome were collected to assess the surgical role.

Results: Success was seen in seven out of eight patients who underwent primary repair and in six patients who underwent delayed repair. Excellent results were common in younger patients.

Conclusion: In addition to the clinical examination, the nerve conduction studies and electromyography is a useful investigation tool to assess the injury, and to monitor the recovery following the primary repair. In order to achieve good results, it is important to follow the rules required for proper surgical repair of peripheral nerves.

INTRODUCTION

Acute peripheral nerve injuries (PMI) are one of the serious sequelae which could result from trauma to extremities. These traumatic injuries comprise a major cause of physical disability that affects mainly young adults of working age. Radial nerve was found to be one of the most frequently injured of all nerves. Radial nerve palsy in arm most commonly is caused by fracture of humerus. The anatomical consideration of the radial nerve being in direct relation to the distal shaft of humerus is responsible for its added risk of injury.

In contrast to the central nervous system, peripheral nerves have the ability to regenerate. This ability has been utilized for a long time in the treatment of injuries of peripheral nerves. The traditional treatment for PNIs is repair using microsurgical techniques, either by primary nerve suture, secondary (delayed) repair, or nerve graft. The surgical treatment of PNIs is still a challenging and highly demanding procedure. The results have shown improvement, which could be explained by different advances in microsurgical techniques.

Classification of nerve injury is based on the damage sustained by the nerve components, nerve functionality, and the ability for spontaneous recovery. Key issue in defining surgical treatment for patients with peripheral nerve injury is to determine whether the injury results in an open or closed lesion. The severity of the injury is variable and can be classified according to Seddon’s classification in three types: neuropraxia, axonotmesis, and neurotmesis (Figure 1).
Neurapraxia represents the mildest form of nerve injury and is defined by a temporary blockage of nervous conduction caused by a segmental demyelination. The large fibers are more selectively and severely affected than the small fibers, leading to motor paralysis, and some proprioceptive and tactile sensitivity loss, but with maintenance of thermal and pain sensitivity in most cases. The prognosis is excellent since there is no distal axonal degeneration; the blockage resolves through remyelination and the nerve function is recovered in a matter of days or weeks.

Axonotmesis occurs when the injury is sufficient to determine the loss of axonal continuity, but most of the nerve connective tissue framework is preserved, including the tubular endoneural support that surrounds each axon. Despite the damage being more extensive in axonotmesis than in neurapraxia, spontaneous regeneration is still possible. Sunderland has further subdivided axonotmesis into three degrees.

In Neurotmesis, there is loss of axonal continuity and of the internal nerve connective tissue framework, a rupture occurs in the epineurium with macroscopic loss of nerve continuity or interposition of scar tissue between the interrupted fibers, which prevents spontaneous regeneration and requires surgical treatment.

Table 1: Showing the relation between Seddon and Sunderland classifications.

<table>
<thead>
<tr>
<th>Seddon Classification of nerve injury</th>
<th>Process</th>
<th>Sunderland</th>
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<tbody>
<tr>
<td>Neurapraxia</td>
<td>Segmental demyelination</td>
<td>First degree</td>
</tr>
<tr>
<td>Axonotmesis</td>
<td>Axon severed but endonemum intact (optimal circumstances for regeneration)</td>
<td>Second degree</td>
</tr>
<tr>
<td>Axonotmesis</td>
<td>Axon discontinuity, endo-neurial tube discontinuity, perineurium and fascicular arrangement preserved</td>
<td>Third degree</td>
</tr>
<tr>
<td>Axonotmesis</td>
<td>Loss of continuity of axons, endoneurial tubes, perineurium and fasciculi; epineurium intact (neuroma in continuity)</td>
<td>Fourth degree</td>
</tr>
<tr>
<td>Neurotmesis</td>
<td>Loss of continuity of entire nerve trunk</td>
<td>Fifth degree</td>
</tr>
</tbody>
</table>

Closed injuries are more frequently associated with nerve injuries in continuity, characterized by absence of nerve rupture and by occurrence of neuropraxis and axonotmesis as the predominant mechanisms of injury. Therefore, spontaneous recovery is possible and surgery is indicated only after 3 months if no recovery is identified. This period is arbitrated based on axonal growth rate (1–3 mm/day). Conversely, the occurrence of an open injury related to a nerve course has been more frequently related to neurotmetic injuries and must be treated with early surgery.

Sharp instruments are causative factors resulting in sharp stumps. The repair should be done promptly during the first 3 days after the injury. When blunt stumps are identified during surgery, the repair should not be performed immediately because the
inflammatory process that takes place extends for up to 3 weeks after the injury. If repair is performed within this period there is a risk to connect nerve stumps still involved in an ongoing inflammatory process that results in fibrosis and prevents progression of the regenerated axon. In summary, surgical timing in a traumatic peripheral nerve injury is defined by the “rule of three”: immediate surgery within 3 days for clean and sharp injuries; early surgery within 3 weeks for blunt/contusion injuries; and delayed surgery, performed 3 months after injury for closed injuries.

Special settings:
Nerve injuries due to gunshot wounds have been considered closed injuries since there is no tissue exposure. Most lesions are caused by indirect heat and by the shock wave from the bullet. Usually the projectile does not transect the nerve so continuity is preserved and there is potential for at least partial spontaneous recovery. Therefore, surgery for patients with nerve injuries due to gunshot wounds should be performed 3–4 months after the injury. Another condition that does not follow the “rule of three” occurs when an injured nerve is located in an area where non-related surgery had been performed for example an emergency vascular intervention nearby the nerve is an exposure. Most lesions are caused by indirect heat and due to brachial plexus injury (post. cord injury or injury to roots C6, 7, 8).

Surgical consideration:
Classically surgery for treatment of peripheral nerve injuries should be considered in patients demonstrating complete palsy after the traumatism. Persistent neuropathic pain uncontrolled with medical treatment is another indication, and in these cases, neurolysis, which consists in the removal of a fibrotic hypertrophic epineurium and adherent adjacent tissue to the nerve, should result in partial or total pain relief. The basic procedure in peripheral nerve surgery is the reestablishment of nerve continuity, which can be obtained by direct coaptation between the two stumps of the ruptured nerve or by interposition of nerve grafts. The best results are achieved with end-to-end nerve repair without tension, as the regenerating axons need to cross just one site of coaptation. In contrast, when using nerve graft, the regenerating axons need to cross two sites of repair, which may have a distinct inflammatory process, resulting in higher axonal loss.

PATIENTS & METHODS
This is a retrospective study that included twenty patients with traumatic radial nerve injury who were treated between February 2013 and May 2014 at Cairo University Hospitals and were followed up until July 2015. Eight cases were managed by primary repair and twelve cases were managed by secondary repair.

Inclusion criteria were as follows:
1. Patients of all ages, sexes, and occupations.
2. The study included patients having wrist drop due to radial nerve affection along with paralysis or weakness of extensors of wrist, fingers and thumb, supinator and an anesthesia on the dorsal aspect of hand and muscle wasting.

Exclusion criteria were as follows:
1. Patients with wrist drop due to upper motor neuron lesions like cerebral palsy (in children), following stroke (in adults) and brain tumors were excluded from the study.
2. The study also excluded patients with wrist drop due to systemic manifestations like diabetes mellitus, Rheumatoid Arthritis, Leprosy etc. and due to brachial plexus injury (post. cord injury or injury to roots C6, 7, 8).

All patients were subjected to the following complete history including personal history, complaints, present history (with special references to mode of injury) and past history.

Complete neurological evaluation, which was divided into: sensory examination (superficial sensation and deep sensation), motor examination for muscle state, tone, power and deep tendon reflexes. Plain radiography for the affected area to exclude any associated fracture. Electroconductive study in patients with close nerve injuries.

Preoperative evaluation of injuries
PNIs were classified into open and closed injuries. In open injuries, primary repair was the first choice. If nerve ends were found to be confused and the extent of neural injury could not be accurately determined, delayed primary repair was the choice. Both neurapraxic and axonotmetic were followed up for 3-4 month. If there is no clinical or electro diagnostic evidence of nerve regeneration and muscle reinnervation, a surgical exploration was performed.

Surgical technique:
The primary nerve repair was conducted by end to end anastomosis using the microscope and fine monofilament or multifilament sutures (i.e. 4-0 to 6-0), placed within the external epineurium, and were used to approximate either single or groups of fascicles. In secondary repair neurolysis was done in all cases as surgical resection of tethering and/or compressive extra neural scar may therefore promote the recovery of nerve.

Postoperative care:
Included limb immobilization by cast splint for 4-6 weeks and (2-3weeks in non grafting cases) with giving care for active finger motion.

Follow-up:
By serial clinical examinations, as a general rule, all patients were seen postoperatively at 4 weeks for 3 months, and then at 3-month intervals for 1 year. Range
of movement, as well as recovery of strength and sensation were tested and documented on each visit. Follow-up electrodiagnostic studies carried out every 3 months were useful in detecting early signs of muscle reinnervation.

The results at the end of follow-up were analyzed according to the scaling system followed by the Medical Research Council (MRC) nerve injury center developed in 1954. The results were classified into:

(a) Satisfactory:
   - Motor nerve recovery of M4 or better.
   - Sensory nerve recovery of S3 or better.
(b) Unsatisfactory:
   - Motor nerve recovery of M3 or less.
   - Sensory nerve recovery of S2 or less.

**RESULTS**

Out of twenty patients, fourteen patients were males and six females. The age ranged between 10 and 34 years (mean age was 22 years). The most common cause of injury was stab wound in ten patients, falling from height in two patients, fire arm injury in two patients, motor car accident in five cases, and misplaced injection in one patient. Sixteen (80%) patients sustained trauma resulting in open injury, and four (20%) patients had closed injury. The right hand was involved in fourteen cases while the left hand was injured in six cases. The functional result of nerve repair in young patients is better than that in adults. The nerve involved according to NCS and EMG was fourteen patients were affected mid arm, four cases interosseous nerve and two cases a branch of the radial nerve was involved. Eight patients were managed by primary repair. Seven of them showed improvement. The secondary repair was the policy in twelve cases and improvement was achieved in six cases as shown in [Figure 2, Table 2].

<table>
<thead>
<tr>
<th>Cause of injury</th>
<th>Number of patient</th>
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<tbody>
<tr>
<td>Stab wound</td>
<td>10</td>
</tr>
<tr>
<td>Falling from height</td>
<td>2</td>
</tr>
<tr>
<td>Fire arm</td>
<td>2</td>
</tr>
<tr>
<td>Motor car</td>
<td>5</td>
</tr>
<tr>
<td>Misplaced injection</td>
<td>1</td>
</tr>
</tbody>
</table>

In primary nerve repair, three cases needed nerve grafting using sural nerve, two cases showed improvement; one within the 3 month follow up and the other within the 6 month follow up. The 3rd case did not improve. In secondary repair nerve grafting was used in four cases, only one case showed delayed improvement.

**DISCUSSION**

Peripheral nerve injuries remain of great economic and industrial importance because of their effect on human quality of life. The present work aimed to study nerve repair and the factors that affect the results. In this study, cases of radial nerve injury were used as example on nerve injury. Wrist drop is a common presentation of many localized or systemic disorders involving peripheral or central nervous system. Radial nerve is one of the most frequently injured of all nerves. The most common cause of injury was stab wound in ten patients. This does not match with study of Guo Y. et al who found that gunshot wounds and trauma (blunt) are the leading causes. Motor car accident was the second common cause followed by fire injury and falling from a height. In our study iatrogenic injury occurred in one case (5%), in the study of Huang which revealed that iatrogenic nerve injuries through injection of therapeutic agents occurred in (19%) patients. In our study, younger patients showed better sensory and motor recovery. Hidalgo and Shaw had similar results. This fact has been attributed to better adaptability of the brain in children to a new afferent impulse pattern presented by misdirected axons.

In this study, the shorter the graft used and the earlier nerve repair will improve the result of nerve grafting repair, this goes with the study Renner, et al they found graft less than 2 cm will give moderate recovery, 2-4 cm recovery is poor. They also found that good results are related to young ages and early management. The mechanism of injury has an important effect on the results of the repair. The best results in this study were achieved in patients injured by sharp objects compared with other types of injuries. This is probably due to the extent of neural injury. This is in agreement with the results of Omer and Lundborg who demonstrated better sensory and motor recovery in sharp lacerations than in crushing or avulsion injuries.
Kline and Hudson reported that nerve repair in high-energy war wounds is significantly inferior to nerve repair in civilian wounds. In this study, the results were consistent with the above results: sharp laceration injuries showed better results than crush injuries. Our results found primary repair shows itself to be the best strategy for injuries. This matches with the results of Birch and Raji, which favor primary repair whenever possible. However, the value of secondary repair in selected cases cannot be ignored, as in cases of blunt injuries, which should be repaired with secondary repair.

CONCLUSION

Recovery after primary repair is faster than other methods. If there is an open injury with a clean sharp nerve transection, immediate repair can be done, but if there is an open injury with a blunt nerve transection, then delayed nerve exploration is indicated after repair and/or healing of other wounded tissues. In contrast, if there is a closed injury follow-up by clinical assessment and electrophysiological studies are indicated at 3 months and if there is failure of recovery then surgical exploration is indicated. Microsurgical repair of peripheral nerves improves the ultimate functional recovery.

Declaration

The author(s) declare no conflict of interest or any financial support and confirm the approval of the submitted article by the concerned ethical committee.

REFERENCES
