Traumatic injuries of peripheral nerves: a review with emphasis on surgical indication

Lesões traumáticas de nervos periféricos: uma revisão com ênfase na indicação cirúrgica

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ABSTRACT

Traumatic peripheral nerve injury is a dramatic condition present in many of the injuries to the upper and lower extremities. An understanding of its physiopathology and selection of a suitable time for surgery are necessary for proper treatment of this challenging disorder. This article reviews the physiopathology of traumatic peripheral nerve injury, considers the most used classification, and discusses the main aspects of surgical timing and treatment of such a condition.

Keywords: peripheral nerve, peripheral nerve surgery, peripheral nerve injury, nerve.

RESUMO

Traumatismos dos nervos periféricos resultam em lesões incapacitantes e estão presentes em muitas das lesões dos membros. A compreensão da fisiopatologia dessas lesões e a seleção do momento operatório mais adequado são imprescindíveis para que o tratamento seja adequado. Neste artigo revisamos a fisiopatologia das lesões traumáticas dos nervos periféricos, apresentamos a classificação mais utilizada dessas lesões e discutimos os principais aspectos relacionados ao momento da cirurgia e às formas de reparo cirúrgico.

Palavras-chave: nervo periférico, cirurgia de nervo periférico, traumatismo de nervo periférico, enxerto de nervo, reparo do nervo.

Acute peripheral nerve injuries are one of the complications of trauma affecting the extremities, and is present in 3–10% of patients, depending on the mechanism of trauma1–3. These traumatic injuries are a significant cause of physical disability that affects mainly young adults of working age. 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. Indications for surgery in patients with peripheral nerve injury depends on several variables including mechanism of injury, interval between injury and treatment, lesion severity, findings of the clinical examination, and intensity of neuropathic pain4.

In this article we review the classification, mechanisms and evaluation of peripheral nerve injuries, with emphasis on indications for surgical treatment.

CLASSIFICATION OF PERIPHERAL NERVE INJURY

A key issue in defining surgical treatment for patients with peripheral nerve injury is to determine whether the injury results in an open or closed lesion5. The severity of the injury is variable and can be classified according to Seddon’s classification in three types: neuropraxia, axonotmesis, and neurotmesis4 (Figure 1).

Figure 1. Schematic drawing of a normal nerve fiber and the three grades of nerve injury according to Seddon’s classification.
Open versus closed injuries

Nerve injuries can be classified as closed and open depending on whether the cutaneous integrity has been disrupted or not. Closed injuries are more frequently associated with nerve injuries in continuity, characterized by absence of nerve rupture and by occurrence of neuropraxia 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) and improvement identified on clinical or electromyographic evaluation. Classical examples of closed injuries are those resulting from stretching after brachial plexus injuries secondary to motorcycle falls and peroneal nerve injuries associated with knee dislocation and concomitant ligament lesion.

Conversely, the occurrence of an open injury related to a nerve course has been more frequently related to neurotmesis and must be treated with early surgery. Examples of these injuries include those provoked by knives, propellers, piece of glass, and scalpel iatrogenic lesions. Within this context, it is important to keep in mind that the distal portion of the nerve undergoes wallerian degeneration that occurs up to 2 to 3 weeks after the injury. So, electrophysiological assessment is not indicated in these cases before 3–4 weeks, since false results may compromise the evaluation.

**Sharp versus blunt injuries**

The aspect of the nerve stumps identified during surgery is another important factor to be considered for the definitive treatment. Two situations can be distinguished: identification of a sharp stump with homogeneous aspect and no significant inflammation; or finding a blunt or rugged stump, associated with significant inflammatory process, heterogeneous aspect, and contusion (Figure 2). Sharp instruments like knives or scalpels have been identified as a frequent causative factors resulting in sharp stumps. In these cases, the repair should be done promptly, if possible within

**Figure 2.** Intraoperative view of ulnar nerve approach in the right forearm. This 22-year-old patient suffered a stab wound 4 months before his presentation at our center. A complete palsy of the ulnar nerve was identified at physical examination and a neurotmesis was demonstrated during surgical procedure. Note the large neuroma of the proximal stump. L: lateral side; P: proximal.
the first 3 days after the injury. Usually a direct coaptation of the nerve ends can be performed with a termino-terminal tension-free suture12.

Technical conditions in performing surgery is another important issue that must be taken into consideration when deciding on an early repair14, as an adequate surgical technique has been accepted as one of the factors that influence the final result after a nerve surgery15. This implies the use of microscope magnification, 9.0- or 10.0-caliber sutures, and a careful manipulation of nerve structures using microsurgical instrumental16. If there are no such conditions for surgery, the epineurium of each nerve stump should be sutured to some adjacent structure, such as a tendon or fascia, in order to avoid excessive retraction of the stumps and to facilitate its identification in a second surgical procedure14. Any attempt to suture the nerve beyond these conditions will result in unnecessary damage to nerve tissue, increase in local fibrosis, and worse functional results at long-term follow-up.

When blunt stumps are identified during surgery (Figure 2), the repair should not be performed immediately because the inflammatory process that takes place extends for up to 3 weeks after the injury14. 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 axons. When blunt nerve stumps are identified, the surgeon should interrupt the procedure and perform the definitive repair 3 weeks after the injury14. During the definitive repair the inflammatory tissue and fibrosis must be resected by trimming the nerve ends with a scalpel blade until viable fascicles have being exposed17.

THE “RULE OF THREE”

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 injury18.

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 previously. An emergency vascular intervention nearby the nerve is an example of such a condition19. Another example is an orthopedic exploration of an open humerus fracture exposing the adjacent radial nerve20. In both situations the lesion originally classified as closed may result in nerve transection, and the early exploration allows performing nerve surgery before the usual 3-month period of observation.

SURGICAL CONSIDERATIONS

Classically surgery for treatment of peripheral nerve injuries should be considered in patients demonstrating complete palsy after the traumatism. Persistent neuropathic pain besides 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 relief21.

Adequate surgical management of peripheral nerve injuries requires that the surgeon, beyond knowing precisely the anatomical details of the region to be assessed, also be familiarized with microsurgical techniques and dispose of the necessary equipment to perform the surgery14. The basic procedure in peripheral nerve surgery is the re-establishment of nerve continuity, which can be obtained by direct coaptation between the two stumps of the ruptured nerve or by interposition of nerve grafts22. 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 loss23. However, in many cases approximation of the nerve stumps results in tension on the suture line. Tension at the site of repair results in ischemia, connective tissue proliferation, and scar formation that impair or prevent the regenerating axons to progress21. In these cases the reconstruction of nerve continuity is accomplished by the interposition of autologous nerve grafts, usually from the sural nerve.

Intraoperative electrophysiologic evaluation has been accepted as an important tool in the management of lesions in continuity (Figure 3A)21. In this type of lesion, also named neuroma in continuity, it is difficult to define the extent of internal nerve damage by macroscopic inspection only. In some cases, the presence of healthy axons inside the neuroma allows spontaneous regenerations, but in others the scar tissue represents an obstacle to the regenerating axons. In this last situation, the scar tissue needs to be resected and substituted by normal nervous tissue usually by interposition of autologous nerve graft. These specific cases should be evaluated through nerve action potential (NAP) measurement (Figure 3B). This evaluation is performed using a portable electromyography device and two electrodes. With a hook form, the stimulating and the recording electrodes are positioned under and around the nerve, proximal and distal to the neuroma, respectively, elevating and isolating the nerve. A supramaximal stimulus is then applied to generate an action potential. When a recordable NAP (axonotmetic injury)
is identified there are regenerating axons passing through the neuroma, regeneration will likely occur, and an external neurolysis is the only surgical procedure to be done. When there are no regenerating axons crossing the lesion no NAP will be recorded and resection of the neuroma followed by nerve re-construction, usually with grafts, is performed (Figure 3C, D).

In conclusion, the social cost of traumatic peripheral nerve injuries is significant since it has a higher incidence on young, previously healthy, and economically active people. A prompt and adequate handle of these lesions can result in the recovery, at least partially, of the lost function. Therefore it is fundamental to understand the mechanisms and peculiarities of these lesions in order to define an acceptable time for surgical intervention. Timely nerve reconstruction performed with suitable microsurgical technique improves the functional recovery of this disabling condition.

References