Major Peripheral Nerve Injuries

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KEYWORDS

• Nerve injury • Neurorrhaphy • Nerve allograft • Major peripheral nerves

KEY POINTS

- Proper use of electrodiagnostic and advanced imaging studies such as magnetic resonance imaging and ultrasound improves timely identification of appropriate surgical candidates for nerve exploration.
- Nerve injuries with an unknown zone of injury should be allowed to demarcate, and aggressive debridement of all damaged nerve tissue should be performed before repair.
- End-to-end fascicular alignment is critical to successful nerve regeneration and may be facilitated by use of nerve connectors during coaptation.
- Nerve conduits have a limited role in overcoming major peripheral nerve gaps.
- Decellularized nerve allograft is a promising reconstructive tool for major peripheral nerve repairs.

INTRODUCTION

Despite decades of advancements in peripheral nerve research, the treatment of major peripheral nerve injuries remains challenging. These injuries can be devastating to patients who often must suffer months and even years of uncertainty as they wait for the recovery that may never come. Families must remain supportive even when they do not appreciate the unique pain associated with many nerve injuries or the difficult-to-comprehend handicap that comes with loss of tactile sensation. Even the care providers (the surgeons, the therapists, and the pain management physicians) must all maintain conviction and optimism even when the perfect repair fails to progress, the recovery that should have occurred does not, and the functional return does not allow a return of function. Although positive results cannot be guaranteed, a better appreciation of the obstacles to nerve regeneration can translate to more effective treatment paradigms and repair techniques and strategies. In this way, the potential for an acceptable or even good outcome when dealing with major peripheral nerve injuries in isolation or as part of a more complex injury pattern can be maximized.

This article discusses current concepts regarding the diagnosis, treatment, and expected outcomes of injury to the median, ulnar, and radial nerves. Although the principle of expectant observation of closed nerve injuries has not changed, there has been a shift toward earlier exploration. Advances in nerve imaging technology, specifically magnetic resonance imaging (MRI)[1] and ultrasound, have also facilitated identification of ruptured nerves, which allows earlier treatment. Proper nerve repair technique continues to emphasize atraumatic handling of the nerve, tensionless approximation, and accurate alignment of fascicles. New coaptation tools such as nerve connectors can now help achieve these goals. Likewise, a growing awareness of the limitations of nerve conduits as well as the recent introduction of acellular nerve allograft has redefined the management of short nerve gaps.

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DIAGNOSES

The identification of a significant major nerve injury is not difficult, and neurologic deficits such as complete or partial muscle paralysis and paresthesias should be diagnosed on most posttrauma examinations. The occasional miss can usually be attributed to examiner inexperience, a failure to recognize the potential for such an injury (so the proper examination is never even performed), or a sense of denial by either the examiner or the patient (the numbness is probably caused by swelling and the lack of movement caused by pain). The challenge is to identify which nerve injuries will recover on their own, and which require surgical treatment.

The answer to this question starts with an understanding of the spectrum of anatomic and physiologic effects of nerve trauma and how nerves regenerate.

UNDERSTANDING THE DECISION TREE

An injured nerve begins the regeneration process immediately following the injury. If the only damage is to the myelin sheath, complete recovery can occur, but may take 3 months. When the neural elements are disrupted, each axon forms multiple filopodia, which advance and form multiple branches toward the distal nerve stump. For an axonotmetic injury, in which the endoneural tubes are still intact, the regenerating axons progress uninhibited with an excellent chance of eventually achieving reinnervation. The length of recovery is based on an approximate regeneration rate of 1 mm/d, although this is typically faster for proximal injuries, slows as regeneration time becomes longer, and may be slower in areas of partially damaged nerve tissue in which the axons must work around scar tissue. For partial and complete internal ruptures, the axons still try to advance but become tangled in disrupted internal architecture and scar tissue and are often unable to bridge the zone of injury. Even though the nerve is technically still intact, spontaneous regeneration does not occur. A neuroma in continuity may form, in which the nerve feels firm and scarred or, conversely, the nerve may become thin and stretched out (like taffy), or even appear normal. Neuropraxic injuries recover spontaneously and neurotmesis requires surgical intervention. Axonotmetic injuries may recover spontaneously, but depend on the axons being able to regenerate uninhibited to the distal nerve stump. If it occurs, spontaneous recovery is typically better than nerve reconstruction. Adding complexity to this dilemma, more than one degree of injury (part of the nerve can be neuropraxic and another part axonotmetic) can coexist.

MAKING THE DECISION

A patient presenting with a laceration and a neurologic deficit is presumed to have a nerve transection and surgery is recommended. There are biological and clinical implications for doing the surgery as soon as possible.[2] The insult to the nerve cell following transection of the axon is substantial and often results in cell death, which decreases the number of regenerating axons and diminishes reinnervation potential.[3] Early repair has been shown to improve axon survival,[4] although the clinical significance of this is unknown. Early surgical exploration minimizes nerve stump retraction and fibrosis,[5] as well as loss of surface landmarks. Clean lacerations repaired within a few days are typically amendable to primary repair.

Nerve injuries associated with blunt trauma, such as avulsion, tearing, or penetrating missile trauma, have a greater zone of injury and primary repair is unpredictable. Immediate surgical exploration is based on non-nerve indications, and the nerve is only exposed if accessible in the established surgical wound. For example, irrigation and debridement with open reduction and internal fixation of an open humerus fracture offers easy access to the radial nerve, which should be inspected. In contrast, median nerve exploration concurrent with treatment of an open dorsal wrist wound following a gunshot injury is not necessarily indicated. The nerve stumps of ruptured or torn nerves, if visualized, should be sutured together with a blue 2-0 prolene (or analogous stitch) to prevent excessive retraction and to facilitate delayed reconstruction. Primary repair at the time of exploration is doomed if the damaged nerve is not resected[6] and a delay to allow demarcation is recommended (**Fig. 1**). At around 3 weeks, the scarred nerve tissue can be resected and the nerve repaired secondarily. Ring and colleagues[7] reported 100% failure when ruptured radial nerves were fixed at the same time as initial treatment of associated open humerus fractures. If the nerve is intact or not visualized, further assessment should be analogous to a closed nerve injury.

For closed nerve injuries (or nerves found to be intact at early exploration) the dilemma is determining whether the nerve will regenerate on its own (neuropraxic or axonotmetic injuries) or whether the zone of injury needs to be excised and reconstructed.

The use of electrodiagnostic studies following nerve injuries is discussed elsewhere in this issue.