

Timing for Brachial Plexus Injury: A Personal Experience

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The editors have requested the author's personal views on the timing of surgery for nerve injury and especially that for brachial plexus injuries. Although the author appreciates the experimental data and less frequent clinical outcomes suggesting that early repair gives better results than delayed repair, there are other considerations that may favor a more measured approach for repair. The following observations are personal and based on the author's own experience; thus, they must be read or viewed in that context.

The mechanism of injury producing the plexopathy is important, because some injuries have the potential for recovery, whereas others are less likely to recover on their own. Early surgery on all, especially if suture or graft repairs are done, might preclude spontaneous recovery, which, in the author's experience, almost always exceeds, when graded properly, what can be gained by repair. Conversely, neglect of repair or greatly delayed repair is equally deleterious, because, many useful outcomes can now be gained by nerve repair or transfer.

INDICATIONS FOR ACUTE REPAIR

Associated Vascular Lesions

Expanding clot, arteriovenous (A-V) fistula, and pseudoaneurysm can convert a partial injury to a more complete one and require attention in the

early hours or on the first or second day after injury or shortly after the diagnosis or suspicion of such.

Decompression of the plexus and repair of the fistula or pseudoaneurysm are indicated, as is evacuation of any clot. When done in a timely fashion, outcomes can be gratifying. Later, a secondary operation with nerve action potential (NAP) recordings may be necessary for plexus element lesions in continuity associated with these vascular lesions, because acute decisions regarding their resection and repair are usually not feasible. Certainly, elements found disrupted or apart in association with vascular injury may merit acute repair but only if the mechanism is sharp by glass or knife. If blunt, repair should be delayed for several weeks so that the extent of resection needed to reach healthy tissue is evident.

Sharp Transection

Another category that merits acute repair (within 72 hours) is sharp transection of a nerve or plexus element. Here, acute repair is certainly indicated. Retraction has had little time to occur, the amount of trimming needed to reach healthy tissue is minimal, and end-to-end suture with minimal tension rather than graft repair is almost always possible. Nerve repair can be done at the same time as repair of injuries to associated structures, such as tendons and vessels.

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Blunt Transection

By comparison, a delay of several weeks is indicated for blunt transactions attributable to automobile metal, chain saws, axes, or propeller blades, for example. Here, the force is a blunt one, and there is a variable amount of proximal and distal stump damage. The extent of this injury is unpredictable acutely but becomes evident by 2 to 3 weeks, when inspection of the proximal and distal stumps begins to delineate the extent of resection needed to reach healthy tissue. If the wound is explored acutely, the bluntly transected plexus stumps can be tacked down to adjacent but different fascial planes to maintain length, making it more possible for a delayed end-to-end repair rather than repair by grafts. In these settings, a technically good end-to-end repair with minimal tension always outperforms grafts. Despite the apparent inherent logic in these observations, the author and his colleagues are sent failed acute or primary repairs each year that have seemingly been done well technically but have been done on bluntly transected elements, usually injured by boat propellers, chain saws, or skill saws. At the author's institution, the data for transecting plexus injuries are fairly extensive and strongly support the previously discussed contentions.

INDICATIONS FOR DELAYED REPAIR

Gunshot Wounds

Although penetrating in nature, most gunshot wounds (GSWs) leading to severe neurologic deficit leave the nerve in continuity and injure it by stretch associated with cavitation injury. A few (12%–15%) of these wounds transect one or more nerves or elements; however, because of the nature of the missile tract, they do it in a blunt fashion. Thus, plexus element nerve transaction is seen during acute exploration for vascular, bone, or other soft tissue wounds associated with GSWs, the nerve ends should be tacked to adjacent tissue planes. Subsequent repair is undertaken after a few weeks elapse, just as for other mechanisms of blunt transaction. Roughly one half of civilian GSWs, when gross continuity is maintained, show some definitive evidence of recovery by 3 months after the wound occurs; thus, it makes sense to obtain baseline clinical and electrical examinations (the latter at 2 to 3 weeks to allow for Wallerian degeneration). These examinations should be repeated monthly, and if clinical or electrical recovery does not begin to occur by 2 to 4 months, exploration and intraoperative NAP recordings can be done to determine which

elements or nerves need resection and repair and for which ones neurolysis alone should suffice.

The value of such an approach is also illustrated by a relatively large cohort of cases cared for at the Louisiana State University Health Sciences Center (LSUHSC). When recovering NAPs across the lesion were present several months after wounding and outcomes were graded by the LSUHSC scale, neurolysis alone gave a grade 3 or better recovery in more than 90% of cases. By comparison, when no NAP was transmitted, resection and histologic examination of the resected specimen uniformly indicated a neurotmetic lesion, and thus one unlikely to recover spontaneously with further time. Graft repair was more likely in this latter category than end-to-end suture, but the latter was achievable sometimes. Outcomes were as expected for the element involved, age of the lesion, and length of the lesion replaced in the case of grafts.

Stretch/Contusive Injuries: Supraclavicular

By far, this is the largest category of plexus injuries needing or serving as candidates for surgical repair. Management is also the most controversial of all the plexus injuries. Having said this, there are some facts that are often glossed over or forgotten. The first is that somewhat more than 40% of adults presenting with complete or near-complete loss in only the C5 and C6 distribution recover relatively useful function spontaneously. Usually, this is evident or beginning to be evident by 3 to 4 months after the injury and even includes an occasional case in which one root has been avulsed. Early surgery and replacement by grafts or nerve transfers would be premature in this group of patients; yet, there is not a reliable noninvasive method of identifying this subset "out front" or earlier except by careful repetitive clinical and electrodiagnostic follow-up. The circumstances for spontaneous recovery are not as robust for C5, C6, and C7 loss with C8 and T1 sparing, in which the incidence of useful spontaneous recovery decreases to 15% or 16%. Nonetheless, it does occur and sometimes even though one of the three involved roots has studies favoring avulsion. Again, in the author's experience, a 3- to 4-month interval is needed to "winnow out" this group of patients with the potential for spontaneous recovery.

When operated on at 3 to 4 months because of lack of recovery, patients with C5-to-C6 loss or C5-to-C7 loss can have NAP studies and operative somatosensory studies added to operative inspection so that the occasional element with regeneration evident by such a study at this point in time is not falsely resected and repaired. Such

an approach permits direct plexus element repair when possible, because operative NAPs, along with section of those elements with flat NAP traces, can differentiate between preganglionic, postganglionic, more lateral rupture or stretch, and regenerative lesions. Such a direct repair, when possible, can then be added to the currently popular nerve transfers to optimize outcomes. In a group of 55 C5-to-C6 stretch injuries operated on in a delayed fashion, 14 patients had neurolysis of one or more plexus elements because of regenerative NAPs. In a group of 75 patients with C5-to-C7 stretch injuries operated on in a delayed fashion, 18 patients had neurolysis of one or more elements because of regenerative NAPs.

Unfortunately, the natural history of flail arm (C5 through T1 loss) is less fortuitous, because only 4% to 5% of patients have spontaneous recovery that is useful. In the author's opinion, this is a group in which earlier surgery is indicated if associated injuries and the overall condition of the patient permit. The incidence of nerve root avulsion in flail arm is higher than in other types of supraclavicular plexus stretch injuries. As a result, the incidence of regenerating NAP recordings is much lower than in other categories of brachial plexus stretch/avulsion injuries. Only a few of the patients in the flail arm group operated on in a delayed fashion had regenerative NAPs. They were usually from C5 or its outflows and less frequently from C6, but there were also occasional exceptions to that trend in other distributions in the 112 patients studied by such recordings. Thus, the need for nerve transfer or intraplexal neurotization is higher in flail arm than in other groups of stretch injuries. Nonetheless, in only 5% of patients are all roots avulsed, and in many patients, C5 is usable for direct repair after operative recordings exclude preganglionic or regenerative activity. In some cases, C6 is also available for direct repair to add to any nerve transfer to be done. Of course, the need for NAP recordings is less in the flail arm group than in those with C5-to-C6 or C5-to-C7 patterns of loss; however, when NAP recordings are used, they work best after a few months rather than more acutely. Outcomes in these supraclavicular stretch/avulsion injuries are available, at least from the approach used by the author and his colleagues, and some attempt to use the previously discussed timing guidelines. The major problem is delay in referral, and that needs to be corrected somehow for this large group of patients.

Infraclavicular Stretch/Contusive Injuries

Some of these injuries undergo spontaneous improvement. Infraclavicular plexus injuries are associated with a high incidence of associated injuries to major vessels, bones, and other soft tissues. Occasionally, these associated injuries require an acute operation and correction. If infraclavicular element(s) are pulled apart (which is usually not the case), delayed repair is once again indicated, as it is for those in continuity. Visual inspection alone cannot reliably differentiate a non-conducting neuroma-in-continuity requiring repair from a recovering neuroma-in-continuity requiring only external neurolysis. These observations necessitate a delay before exploration for the infraclavicular plexus stretch/compression or GSW injury so as to allow recovering axons to regrow across the lesion. This concept is supported in the author and his colleagues' series of axillary nerve injuries, in which 17 of 86 patients with complete clinical and electromyographic (EMG) loss 5 or more months after the injury had an NAP transmitted across their lesion in continuity and had neurolysis alone ($n = 15$) or split repair ($n = 2$), with an averaged outcome LSUHSC grade of 4.0. Distribution of findings and results was equally good for lateral and posterior cord injuries and their outflows but was, of course, poorer for medial cord and medial cord-to-ulnar nerve injuries. Had all these recovering neuromas been excised soon after injury and subjected to graft repair without delayed NAP evaluation, the results would have been substantially worse.

Iatrogenic Injuries

Management of these injuries follows the same principles as for other types of peripheral nerve injuries. For example, elements transected by a scalpel or scissors are ideally treated with acute repair. Blunt transaction attributable to Bovie or other instrumentation is repaired after a few weeks have elapsed. Injuries attributable to retraction/compression/stretch are likely to result in lesions in continuity and are explored if possible after a 3- to 4-month delay. This strategy permits operative NAP recordings to guide the need for graft repair versus external neurolysis. Regrettably, referral of iatrogenic nerve injuries typically are needlessly delayed for a prolonged period in the hope that spontaneous recovery might obviate the need for another operation.