Editorial

Surgical repair of brachial plexus injury

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As is the case in much of medicine as well as in life, “the devil is in the details.” Too often in talks and even in some publications concerning nerve injuries operative indications, surgical procedures, and outcomes are painted in broad strokes because details in individual cases can vary widely. Belzberg, et al., are to be applauded for attempting to focus the reader’s attention on a specific, albeit frequent type of injury to the brachial plexus, the closed stretch–contusion.

Questionnaires were sent to brachial plexus surgeons in different disciplines in multiple countries and 49 (39%) of 126 surveyed responded. In addition to queries about preoperative workup, surgical solutions to four hypothetical cases were sought. The first patient was an infant with a birth-related palsy involving C5–6, who at 5 months of age had recovery of biceps but not shoulder function. The second patient had a flail arm due to avulsion of all five brachial plexus nerve roots. The third patient had a C5–7 stretch injury with avulsion of the C-5 and C-6 nerve roots and a postganglionic lesion at C-7, and the fourth patient had a C7–T1 stretch injury with nerve root avulsion as well as meningocoeles at all three levels. Not pursued by the questionnaire, because of the nature of the cases presented, are two other important but smaller categories of plexus injury: lacerating injuries and gunshot wounds (GSWs). Of interest, incorrect management in these two categories due to failure to operate or an incorrect intraoperative decision regarding resection and repair (or not) of a lesion-in-continuity have an even greater impact on potential outcome than they do in the stretch–contusion category. This is because correct management of lacerations and GSWs leads to comparably better results than ‘correct’ management of stretch injuries. Thus, there may be a consensus favoring acute repair rather than neurolysis.9,18

Interposed grafts work 60 to 70% of the time to restore nerve root avulsion as well as meningocoeles at all three levels. Not pursued by the questionnaire, because of the nature of the cases presented, are two other important but smaller categories of plexus injury: lacerating injuries and gunshot wounds (GSWs). Of interest, incorrect management in these two categories due to failure to operate or an incorrect intraoperative decision regarding resection and repair (or not) of a lesion-in-continuity have an even greater impact on potential outcome than they do in the stretch–contusion category. This is because correct management of lacerations and GSWs leads to comparably better results than “correct” management of stretch injuries. Thus, there may be a consensus favoring acute repair rather than neurolysis.9,18

Direct repair without the requirement of nerve transfer is usually possible in these categories. These conclusions support in part the authors’ selection of stretch–contusion cases for their survey because management of these injuries is much more controversial than that focused on other types of injury. For me, a review of published series and their outcomes is more likely to change my mind about management than responses to a questionnaire, even though the latter does, I agree, point out the lack of uniformity among the respondents and makes interesting reading. Despite these considerations, it is important to consider carefully the points raised in this presentation about stretch injury.

Certainly, in terms of the number of publications in the literature and variations in management, stretch–contusion as a topic is a comparatively large one.5,11 Nevertheless, most of the surgical literature on stretch injuries is focused on nerve transfers with little or no attention given to the possibility of direct repair. Because the surgeons who responded to this questionnaire preferred to perform neurotization by means of nerve transfers, a very important article published in 2001 to be considered is the one by Merrell, et al.,15 which is a metaanalysis of the value of such transfers for adult patients with brachial plexus stretch injuries. A total of 1088 nerve transfers described in 27 published studies met the inclusion criteria of this analysis. With reference to nerve transfers there are some generally accepted observations from this metaanalysis as well as our own experience and that of others.

1) The direct transfer between a working nerve and the one to undergo neurotization works better than placement of an intervening graft.5,15 Transfer of the nerve to a locus as close as possible to the site at which the receiving nerve innervates the function to be restored is critical.17

2) Use of the spinal accessory nerve works best as a direct transfer to the suprascapular nerve and not as well to the axillary nerve or the musculocutaneous nerve, in which case interposed grafts are necessary.4,15

3) Intercostal nerve transfers are valuable but do not always work when involving the musculocutaneous nerve, let alone the radial or median nerve.3,14 Nonetheless, intercostal nerve transfers to the musculocutaneous nerve without intervening grafts work 60 to 70% of the time to restore some biceps function.15,16,20

4) A medial pectoral–musculocutaneous nerve transfer works much of the time if input to the pectoralis muscle through these branches is strong.1 A relatively new type of
transfer, called the Oberlin procedure, in which a portion of intact ulnar nerve is coapted to a more distal motor portion of the musculocutaneous nerve, seems promising.6,12

5) Use of the contralateral C-7 nerve as a donor nerve requires a lengthy graft unless this is done at a spinal level.14,16 There is some, albeit very little, risk of contralateral limb dysfunction.

Some motor innervation can be gained using spinal nerves or their distal branches.2,19,21 The use of descending cervical plexus or the C3–4 nerves exclusive of what goes to the phrenic nerve provides some, albeit weak, motor outflow.

7) At least in our hands the use of the phrenic nerve is accompanied by a pulmonary price in some patients and thus we are cautious about its use in nerve transfers as advocated by Gu and Ma.7 Chuang and colleagues4 point out that the phrenic nerve may provide some stabilization of the shoulder but does not provide good shoulder abduction.

8) The hypoglossal nerve is not good for neurotization of the plexus, even though in some cases it works for the facial nerve.13

Most respondents (80%) believed that myelography followed by CT scanning of slices at each plexus root level was important in the preoperative workup of stretch injuries. Nonetheless, 55% of respondents still used magnetic resonance (MR) imaging and 41% used both computed tomography (CT) myelography and MR imaging. Some MR imaging machines and programs for their use can show the ventral and dorsal root and the foraminal exit zone on cross-sections not only at each level, but also contralateral to the level of concern for a comparison and thus CT myelography is not necessary. Unfortunately, at this time, these units are not uniformly available. Each week my colleague, Dr. Robert Tiel, and I receive many MR imaging studies that are next to useless for the assessment of stretch injury and the question of avulsion. Hopefully, this will change with improved technology and more uniformity of machines. For the present, however, we believe that CT myelography is still necessary for the preoperative workup of a supraclavicular stretch injury. It should be kept in mind, however, that in patients in whom meningoceles are found at one or more levels, one often can attain successful direct repair at other levels. In addition, of course, the presence of a meningocele does not always preclude future spontaneous regeneration at those levels, although usually it does. Finally the absence of a meningocele at a given level does not preclude proximal and therefore irreparable damage at that level, let alone at other levels.

We perform electromyography (EMG) to document the degree of denervation and its pattern as well as any signs of reinnervation. Nevertheless, the most important test is still a careful clinical examination in which muscle strength is graded. Muscle contraction can occur despite the presence of a denervational change, and even the presence of nascent units does not guarantee eventual recovery (although it favors it) especially in a muscle that does not contract.11 I fail to grasp the value added to EMG and good sensory potential testing by noninvasive preoperative somatosensory evoked potential (SSEP) studies, yet 39% of those surveyed use them. Such preoperative studies are performed by stimulating nerves more peripheral to the plexus and recording SSEPs over the cervical spine or contralateral scalp. It takes many months or years before there is enough spontaneous growth between a plexus element and its peripheral nerve(s) to evoke such responses. If the nerve is intact initially, a thorough clinical examination will show that. If a preganglionic injury is in doubt, sensory conduction studies recorded from nerves that have absolute hypesthesia in their autonomous ones will settle that point. Preoperative noninvasive stimulation at the region where the Erb point is located produces a diffuse input that is not specific even for upper plexus elements; therefore, any SSEP that is recorded centrally may have several possible origins. By comparison, SSEP recordings obtained intraoperatively by direct stimulation of a spinal nerve whose central integrity is in question is of some value, at least for the dorsal root, although experimental work has shown that only a few hundred intact, spared, or regenerated fibers are needed for a positive response.22

In addition to the clinical findings of Horner syndrome, an absent Tinel sign, and a winged scapula (unusual in adults but common in early infancy among children born with plexus palsy), the finding of paralysis of the diaphragm on chest x-ray films indicates a proximal and usually irreparable—at least by direct repair—injury of the C-5 nerve. My “devil is in the details” comment extends to the cases of adult patients with stretch injuries selected for discussion. To begin with, the circumstances in Case 2, in which an adult patient has a stretch injury with all five roots avulsed, only occur in 4 to 5% of flail arm cases, at least in our experience, provided that each level, especially C-5, C-6, and C-7, is carefully examined preoperatively and then inspected and electrically tested intraoperatively. A group of 208 patients with flail arms underwent preoperative clinical observation, cervical myelography usually followed by CT scanning, EMG, and intraoperative inspection of 1040 spinal nerves.8 Recordings of NAPs and intraoperative inspection and sectioning of spinal nerves into their foramina indicated either preganglionic and/or postganglionic injury at 470 levels. At those levels the spinal nerve roots of course were irreparable. Thirty-five percent of the irreparable levels, which usually had root avulsion, involved C7–T1. Another 35% involved C-7 and C-8 and 20% had other combinations including C-6. A substantial number of these latter cases had avulsions at nonadjacent levels. Only 10% of patients with flail arm had avulsion of C-5 as part of their pattern of loss. Thus, direct repair on some of the levels was feasible and effective in some patients, especially if the C-5 and/or C-6 nerves were usable for outflow.

Stretch lesions at the C5–6 or C5–7 level comprise approximately 40% of all operative stretch injuries to the plexus. In Case 3 of the questionnaire there was avulsion of both the C-5 and C-6 nerve roots and a postganglionic lesion-in-continuity on C-7 to the middle trunk. In our experience avulsion of both the C-5 and C-6 nerve roots is also an frequent finding with C5–6 or C5–7 nerve stretch injuries. Of 55 of our patients with C5–6 stretch injuries only seven had avulsion of either the C-5 or C-6 nerve root, whereas among 75 of our patients with C5–7 stretch injuries, 10 had avulsion of the C-6 and C-7 roots, 10 avulsion of the C-7, and six avulsion of the C-5 root.8 None of these patients had avulsion of both C-5 and C-6 nerve roots, although this does occur and we have observed it in a few patients with C5–6 and C5–7 nerve stretch injuries since our 2003 publication. As a result, some form of direct repair by grafts is usually possible not only for C5–6 and C5–7 nerve stretch inju-
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ries but also for those affecting C5–T1, provided that the spinal nerves are dissected into their foramina, intraoperative electrophysiological testing is done, and spinal nerves are sectioned until healthy fascicular tissue is seen. These observations are not meant to diminish the importance of nerve transfers because they are very important for plexus stretch injuries and sometimes are the only form of neural repair possible. Nerve transfers also bring fibers closer to potentially functional destinations, whereas direct repair for stretch injuries may require intervening and sometimes lengthy grafts. On the other hand, sometimes direct repairs can be made to some portion of the brachial plexus injured by stretch and transfers can be added to the direct repair to optimize results. The usual nerve transfers performed at the Louisiana State University Health Sciences Center have been accessory-suprascapular nerve and medial pectoral—or intercostal–musculocutaneous nerve transfers. If some direct repair is possible and might result in regeneration of the musculocutaneous nerve, the latter is split longitudinally and one half is used for medial pectoral or intercostal nerve input and one half is kept for potential regeneration from above.

Selection of Case 4 as a test case also pushes both the respondent and the reader in the direction of nerve transfers because the loss was in the lower plexus elements, the C-7, C-8, and T-1 nerves, and each site had meningoceles, indicating avulsion. This is an exceptionally difficult pattern of paralysis to help. In addition to the transfers described in which the accessory, intercostal, and contralateral C-7 nerves were used, transfer of the lateral pectoralis branches to the medial cord contribution to the median nerve may be of value.

The hypothetical Case 1 involved a birth-related palsy with a stretch injury involving the C-5 and C-6 nerve roots. This is a much smaller category in terms of occurrence than adult stretches but an important one. In an infant 5 months of age, in whom there is recovery of biceps and no shoulder motion, one can see what a few more months’ time can bring, but if no shoulder function (supraspinatus and/or deltoit) eventually occurs, transfer of the accessory nerve (the 11th cranial nerve) to the suprascapular nerve can be performed. Another possibility in this case is that C-7 and the middle trunk anterior division constituted the major contribution to recovery of biceps function. This can be ascertained by operative stimulation and NAP recording studies from C-7 to the middle trunk to musculocutaneous nerve. If C-7 conducts to musculocutaneous nerve and there is no regenerative NAP transmitted across the upper trunk neurotomy, then the latter can be resected as proposed by many respondents.

Although much progress has been made in the workup, operative management, and evaluation of postoperative outcomes in stretch–contusion injuries, restoring enough function to make the limb useful for patients’ day-to-day living, let alone some form of employment, remains quite challenging. It should be obvious from this editorial that the survey and its results raise many interesting issues. The article is a good read and obviously stimulating, and I appreciate the opportunity to comment on it.

References


RESPONSE: We appreciate the comments by Dr. Kline and concur with his insights concerning the critical role outcome studies play in guiding decision making for peripheral nerve cases. Dr. Kline has a wealth of experience and his
numenous publications include sizeable retrospective nerve injury series providing detailed outcome data.

The aim of our study was to demonstrate the great variability among peripheral nerve surgeons regarding management of brachial plexus injury. Our hope is that the issues raised in this publication provoke discussion among peripheral nerve specialists and lead to prospective studies. We focused our survey on the diagnosis and management of closed stretch–contusion injuries because these represent the majority of brachial plexus injuries. Each case was designed to illustrate points of controversy as well as to provide insight as to how experienced surgeons would handle the problem.

Nerve transfer—division of a functioning nerve with coaptation of the proximal end to a distal nonfunctioning nerve—has become a principal tool for the peripheral nerve surgeon. Dr. Kline provides a summary of the published literature on this field augmented by his own experience in the use of transfers. Three of the four cases presented in our study involve at least the potential use of nerve transfers and, thus, the reader gains insight into how, in a specific clinical situation, experts may make use of them. Our study reflects a trend among peripheral nerve surgeons to select distal nerve transfers over very proximal graft repairs. This trend is bolstered by the increasing amount of literature demonstrating efficacy of distal nerve transfers. Because distal nerve transfers are placed closer to the target tissue and rarely require a graft, they provide rapid reinnervation and improved functional recovery. The success reported with transfer of an ulnar fascicle to the biceps innervation (Oberlin procedure) illustrates these points. Our experience with the Oberlin procedure has been very encouraging and it has emerged as our preferred approach for restoring elbow flexion in patients with proximal injuries who present longer than 8 to 12 months after injury.

In the first hypothetical clinical case presented in our questionnaire, an infant has suffered a classic birth palsy with predominant involvement of the C-5 and C-6 roots and some involvement of the C-7 root. The expert is faced with the following predicament: at 5 months of age there is some recovery of elbow flexion, but it appears that no further recovery will occur. The most likely intraoperative finding will be a neuroma-in-continuity of the upper trunk. Dr. Kline would perform conduction studies and if there was conduction of an NAP across the neuroma, he would leave it in place. Many of the experts would resect the neuroma and graft across it and perform distal nerve transfers. The consequence of resecting the neuroma is to downgrade the child’s function during the time of nerve regeneration in anticipation that eventually functional outcome will be superior to the original function. In a future review of the data we will determine if our international group of experts displays geographic differences. Our hypothesis is that in more litigious societies surgeons are less apt to perform a procedure that even transiently downgrades function.

In the second case, there is a panplexus avulsion injury. Dr. Kline makes the observation that when one is diligent in exploring the nerve roots, there is often at least one functional root that can be used to reinnervate a portion of the plexus. In the third case, there is avulsion of the C-5 and C-6 nerve roots but preservation of the C-7 root. Despite the availability of an intact C-7 spinal nerve root, the majority of our respondents still opted for nerve transfers accomplished using extraplexal donor nerves. With this in mind, it would have been interesting to present hypothetical Case 2 with a functional C-5 root. We believe that many respondents would have opted for direct repair, but there would have been variability with respect to where the C-5 graft would be targeted and whether nerve transfers would be used to optimize recovery. There would certainly be disagreement regarding whether C-5 should be grafted proximally to the upper trunk or distally to the terminal nerves of the upper plexus. In such a case, we generally opt for a repair similar to that proposed by Dr. Kline. Specifically, we would graft C-5 to the upper trunk and augment this with a split-thickness nerve transfer to the musculocutaneous nerve by using either the medial pectoral nerve and/or a fascicle of the ulnar nerve to the biceps innervation. For shoulder abduction we would transfer the spinal accessory to the suprascapular nerve. In addition we would consider reinnervating the axillary nerve with the phrenic nerve, the medial pectoral nerve, or a graft from the C-5 nerve.

In the fourth clinical vignette, the patient has loss of the lower brachial plexus roots. The injury pattern is one that is particularly devastating to the patient with loss of function in the hand and limited ability on the part of the surgeon to provide functional nerve reinnervation. Dr. Kline does suggest an important nerve transfer, lateral pectoralis branches to medial cord contribution to median nerve. We thank Dr. Kline for his insightful comments and are pleased that he found the article to be “a good read.”

Reference

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