Editorial

Surgical repair of brachial plexus injury

DAVID G. KLINE, M.D.
Department of Neurosurgery, Louisiana State University Health Sciences Center, New Orleans, Louisiana

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 meningoceles 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 for sharp lacerating plexus injuries and delayed repair for blunt ones.10,14 Less certain, but generally accepted is the need for a relatively early exploration of complete or relatively severe lesions-in-continuity due to GSWs and the use of operative nerve action potential (NAP) recording at 2 to 4 months postinjury to determine the need for resection and 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.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 There is some, albeit very little, risk of contralateral limb dysfunction.

6) Some motor innervation can be gained using spinal nerves or their distal branches.2,10,21 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 colleagues 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 computerized 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 (SSSEP) studies, yet 39% of those surveyed use them. Such preoperative studies are performed by stimulating nerves more peripheral to the plexus and recording SSSEPs 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.12

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 extend 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 infrequent 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-