Direct Plexus Repair by Grafts Supplemented by Nerve Transfers

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There is much literature available concerning nerve transfers for plexus stretch injures, which recently has been thoroughly analyzed [1]. Nonetheless, when injury to the plexus requiring repair is caused more by focal damage, such as laceration or gunshot wound (GSW), direct repair either with or without grafts is usually preferable to substitution for loss by nerve transfers. Thus, in many cases where one or more plexus elements were transected or in a relatively large panel of brachial plexus injuries caused by GSWs, and where elements were still in continuity but did not conduct a nerve action potential (NAP), direct repair, usually by grafts, has been the current authors' standard [2,3]. This approach also has been used in the past for stretch injuries before the use of nerve transfers was popularized [4–8]. Thus, an accounting of the reasoning and outcomes for direct repair is important, even for today's clinicians dealing with stretch or avulsion injury to the plexus. Finally, this article describes the approach used by the authors in recent years for stretch injuries, which involves direct repair of plexus elements, whenever possible supplemented by nerve transfers.

Methods

During a 30-year period (1968–1998) at Louisiana State University Health Sciences Center (LSUHSC), 1019 adult patients with plexus injury,

tumors, or presumed entrapment underwent surgery (Table 1). Although one half of these patients (509) had stretch or contusion as their mechanism of injury, 12% had GSWs involving the plexus (118 patients), and 7% (71 patients) had plexus laceration. The remainder, or 321, operative patients were equally divided by mechanism between tumor (161 patients) and thoracic outlet (160 patients). Thirty patients had iatrogenic injury involving either transection or contusion/stretch and avulsion and were incorporated under either plexus laceration or stretch/contusion categories. Excluded from this analysis were birth palsies because the management of these patients differs in some respects from adults with stretch injuries. Some of the following analysis was recently published and is redistilled for this article [9].

In addition to clinical workup and electromyographic (EMG) studies for each category of injury, stretch/contusion injuries were evaluated by myelography followed by CT scan cuts. There is a false-positive and false-negative incidence of findings, even with CT myelography, but these studies usually provided reliable information about each plexus root and whether avulsion or injury close to the spinal cord was likely. EMG studies were done in each patient 2 to 4 weeks post injury and included paraspinal and extremity muscle sampling and sensory conduction studies but seldom included noninvasive somatosensory studies [10].

At the time of surgery for supraclavicular stretch injuries, the current authors dissect out the elements in a 360° fashion and make direct recordings by stimulating proximal spinal nerve and recording from distal trunks or divisions and

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Table 1
Operated brachial plexus lesions[a]

Type of lesion	No. of patients
Stretch/contusion	509 (50%)
Supraclavicular	366
Infraclavicular	143
Gunshot wound	118 (12%)
Laceration	71 (7%)
Thoracic outlet syndrome	160 (16%)
Tumor	161 (16%)
Total	1019 (100%)

Percentages indicated in parentheses indicate percentage of total number.
[a] LSUHSC series 1968–1998.

cords. If the trace is flat, then injury is either postganglionic or pre- and postganglionic, and the authors section proximal spinal nerve looking for usable fascicular structure for lead-out to grafts, which are usually harvested by using sural nerves. If the NAPs are positive but small in amplitude and slow in conduction, the element is regenerating and is not sectioned. If the response has high amplitude and is rapid in conduction, preganglionic injury with sensory fiber sparing is likely unless there has been preoperative clinical or EMG evidence of sparing in its distribution. This finding suggests that it is an intact or partially injured element. When NAP recordings are positive, the element (usually spinal nerve) is not sectioned in looking for fascicular structure unless visual inspection suggests the possibility of split repair, which is unusual in the stretch/contusion category. In the authors' experience, repairs were usually done with an interfasicular technique and donor nerves were usually sural, although, if healthy, the antebrachial cutaneous nerves were sometimes used [11].

Approximately 93% of patients returned for postoperative follow-up at least once. Subsequent visits were made by 70% of these patients, whereas others had a secondary follow-up by telephone in 20% and mail in 10% of cases. The minimal follow-up period was 18 months but averaged 4.2 years. Most of these follow-ups were in-person evaluations performed by the senior author, but some follow-up after 3 years post surgery was performed by other physicians closer to the patient's home or, in a few instances, by phone or mail with the patient or his or her family.

Results

The LSUHSC system for evaluating outcomes in plexus lesions was used (Box 1). This system

> **Box 1. System of grading by elements of brachial plexus**
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> 0: no muscle contraction
> 1 (poor): proximal muscles contract but not against gravity
> 2 (fair): proximal muscles contract against gravity, distal muscles do not contract; sensory grade, if applicable, was usually 2 or lower
> 3 (moderate): proximal muscles contract against gravity and some resistance; some distal muscles contract against gravity; sensory grade, if applicable, was usually 3
> 4 (good): all muscles contract against gravity and some resistance; sensory grade, if applicable, was 3 or 4
> 5 (excellent): all muscles contract against moderate resistance; sensory grade, if applicable, was 4 or better

differs from the Medical Research Council (MRC) system in that LSUHSC grade 3 includes at least some muscle contraction against mild resistance and gravity, whereas a grade 2 is against gravity only, which would correspond to an MRC grade 3. Favorable outcomes were therefore determined in patients with elements recovering to an LSUHSC grade of 3 or better level not to an MRC grade 3.

Lacerations

Outcomes in which the mechanism was from presumed laceration by glass, knife, or other sharp object (sharp) versus propeller blades, chain saws, or auto metal (blunt) are seen in Table 2. Data combine unfavorable with favorable elements for repair by suture versus grafts, or neurolysis based on NAPs across contused but not lacerated elements. Thus, outcomes with lower plexus elements, such as C8, T1 spinal nerves and medial cord, were blended with those with more favorable elements for repair.

Table 2 shows reasonably favorable outcomes for suture: 81% of elements recovered to a grade 3 or better level if the laceration was sharp and the repair was done within 72 hours, and 70% of elements recovered to this level after delayed or secondary end-to-end suture. Delayed repair by grafts had grade 3 or better outcomes in 53% of elements. If sharp transection could be explored