The surgical treatment of painful traumatic neuromas

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Pain following suspected nerve injury was comprehensively evaluated with detailed examination including history, neurological evaluation, electrodiagnostic studies, quantitative sensory testing, thermography, anesthetic agents, and sympathetic nerve blocks. Forty-two surgically treated patients fell into four discrete groups: Group 1 patients had distal sensory neuromas treated by excision of the neuroma and reimplantation of the proximal nerve into muscle or bone marrow; Group 2 patients had suspected distal sensory neuromas in which the involved nerve was sectioned proximal to the injury site and reimplanted; Group 3 patients had proximal in-continuity neuromas of major sensorimotor nerves treated by external neurolysis; and Group 4 patients had proximal major sensorimotor nerve injuries at points of anatomical entrapment treated by external neurolysis and transposition, if possible. Patient follow-up monitoring from 2 to 32 months (average 11 months) was possible in 40 (95%) of 42 patients. Surgical success was defined as 50% or greater improvement in pain using the Visual Analog Scale or pain relief subjectively rated as either good or excellent, without postoperative narcotic usage. Overall, 16 (40%) of 40 patients met those criteria. Success rates varied as follows: 44% in 18 Group 1 patients, 40% in 10 Group 2 patients, 0% in five Group 3 patients, and 57% in seven Group 4 patients. Twelve (30%) of 40 patients were employed both pre- and postoperatively.

It is concluded that: 1) neuroma excision, neuratomy, and nerve release for injury-related pain of peripheral nerve origin yield substantial subjective improvement in a minority of patients; 2) external neurolysis of proximal mixed nerves is ineffective in relieving pain; 3) surgically proving the existence of a neuroma with confirmed excision may be preferable; 4) traumatic neuroma pain is only partly due to a peripheral source; 5) demographic and neurological variables do not predict success; 6) the presence of a discrete nerve syndrome and mechanical hyperalgesia modestly predict pain relief; 7) ongoing litigation is the strongest predictor of failure; and 8) change in work status is not a likely outcome.

Key Words: neuroma • discrete nerve syndrome • neurolysis • microsurgery

Although the clinical recognition of painful traumatic neuromas began in the 17th century with the work of Paré, and later in the early 19th century with Odier and Wood, it was Virchow who established in 1863 the initial histological analysis and classification system for neuromas. Surgical intervention for neuromas has generally failed. Most neurosurgeons believe that surgery on patients with painful nerve injuries is ineffective and increases neurological morbidity. Certainly, patients with painful nerve injuries should be approached with caution and with scientific objectivity. Recent improvements in diagnostic and microsurgical techniques have justified reserved optimism and, with careful clinical trials, the surgical indications for neuroma surgery may eventually be established. An algorithm for the surgical management of posttraumatic neuropathic pain has been previously described. The preliminary clinical results of the application of this strategy are presented. This study was conducted to establish indicators that may be useful for predicting surgical outcomes for surgery on painful nerve injuries.

Clinical Material and Methods

Preoperative Assessment

Extensive preoperative evaluation (Table 1) provided a large base of information for postoperative outcome measurement in 42 patients. Several aspects of the preoperative assessment require additional explanation. Prior attempted therapies included sympathetic and anesthetic nerve blocks, medications, transcutaneous nerve stimulation, acupuncture, cortisone injections, physical therapy, splinting, biofeedback, and multidisciplinary pain clinic. The number of prior surgical procedures has been implicated as a poor prognostic factor, so this too was assessed. One would expect that poorly localized pain and ill-defined signs and symptoms would be poor prognostic factors. To study this from a more scientific approach, the concept of a
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Table 1

<table>
<thead>
<tr>
<th>Pre- and postoperative variables analyzed in 42 neurectomy/neurolysis patients</th>
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<tbody>
<tr>
<td><strong>Histories</strong></td>
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<td>nerve involved</td>
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<td>preop narcotic use</td>
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<tr>
<td>postop narcotic use</td>
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<td>preop employment status</td>
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<td>postop employment status</td>
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<tr>
<td>litigation involved</td>
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<tr>
<td>worker's compensation</td>
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<tr>
<td>number &amp; type of prior surgical procedures</td>
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<tr>
<td><strong>Physical Features</strong></td>
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<tr>
<td>Tinel's sign</td>
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<tr>
<td>reflex sympathetic dystrophy</td>
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<tr>
<td>mechanical hyperalgesia</td>
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<tr>
<td>thermal hyperalgesia</td>
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<tr>
<td>discrete nerve syndrome</td>
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<tr>
<td><strong>Patient Assessment</strong></td>
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<tr>
<td>preop Visual Analog Scale (VASP)</td>
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<tr>
<td>postop Visual Analog Scale (VAPO)</td>
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<td>subjective overall result</td>
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*Percent improvement (change in Visual Analog Scale) was calculated as:

\[
\text{VASP} - \text{VAPO} \times \text{VASP} 
\]

Discrete nerve syndrome was developed. A discrete nerve syndrome was considered to be a condition in which a single nerve could account for all the neurological findings and pain distribution. The presence and distribution of mechanical and thermal hyperalgesia were considered very important in the determination of a discrete nerve syndrome. Symptoms of reflex sympathetic dystrophy were determined by assessing for trophic, vasomotor, color, and temperature changes, bone scan, and the results of sympathetic nerve blocks. The terms “neuroma” and “neuroma in continuity” were used to describe end-bulb neuromas or in-continuity nerve lesions, respectively, as suggested by Sunderland.

**Surgical Treatment**

The surgical treatment varied according to the nerve involved, providing four discrete subgroups. Group 1 included patients with distal sensory neuromas treated by excision of the neuroma and reimplantation of the proximal nerve into muscle or bone marrow. Group 2 patients had suspected distal sensory neuromas in which the involved nerve was sectioned proximal to the injury site and reimplanted. In Group 3, proximal in-continuity neuromas of major sensorimotor nerves were treated by external neurolysis. Group 4 included patients with proximal major sensorimotor nerve injuries at points of anatomical entrapment treated by external neurolysis and nerve transposition, if possible.

**Intraoperative Methods**

Operations were performed under local anesthesia with intravenous sedation and analgesia. The presence of Tinel's sign can be taken as a reliable guide to the location of the neuroma. Prior scars or incisions are also helpful indicators of the region for exploration. The skin was superficially anesthetized with Marcaine (bupivacaine) 0.25% + Xylocaine (lidocaine) 0.5% + epinephrine 1:200,000. Dissection was carried out using loupe or microscopic magnification. Mechanosensitivity of the injured nerve segment with production of Tinel's sign was often an important guide to the dissection. Once the nerve with the suspected neuroma was isolated, electrical stimulation of the nerve (0.5 to 1.5 mA, 100 usec pulse width, 50 to 100 Hz, balanced biphasic constant-current square-wave impulses) was carried out using electrified nerve hooks (Fig. 1). This method was very useful for identifying the neural structure in the surrounding scar, and in replicating the patient's pain distribution with stimulation-induced paresthesias. The latter was particularly critical given the normal variation in peripheral nerve anatomy.

In Groups 1 and 2, once mapping of the neuroma was completed, the proximal nerve was locally anesthetized and sharply divided. The nerve was then im-

**Figure 1.** Left: Electrified insulated nerve hooks attached to a constant-current stimulus generator used intraoperatively to identify the nerve responsible for the pain syndrome. Right: Nerve hooks applied to the sural nerve (posterior calf) for intraoperative stimulation.
planted retrograde into an intramuscular pocket using 6–0 Prolene suture, or into bone marrow if no muscle was available (for example, in digital neuromas). In Group 3 an external neurolysis was performed, that is, dissection in the plane of the external epineurium, with translocation of the injured segment into a virgin tissue bed if possible. In Group 4, external neurolysis was performed and the nerve transposed using standard techniques appropriate to the site of entrapment.11

Postoperative Follow-Up Evaluation

Patients were assessed by both clinical evaluation and telephone conversation at a mean follow-up time of 11 months (2 to 32 months) in 40 (95%) of 42 patients. The Visual Analog Scale (VAS) score for pain was determined preoperatively and at each subsequent contact. The VAS is the basis for the patient’s subjective pain rating, ranging from 0 (no pain) to 10 (maximum pain), and narcotic use was also serially determined. The patients were also asked to give an overall assessment of the results of surgery (excellent, good, poor, or failure). The surgical outcome was considered successful if there was a 50% or greater improvement based on the VAS rating or a subjective rating of good to excellent while the patient was not receiving narcotics.

Results

Of the initial 42 patients evaluated and surgically treated, adequate information was available on 40 patients (95% follow-up data). Figure 2 depicts the incidence of successful outcome for the four patient groups. Patients with proximal in-continuity neuromas of major sensorimotor nerves (Group 3) had the worst surgical outcomes, since there were no successes in this small group of five patients. In contrast, patients with traumatic in-continuity neuromas at areas of anatomical entrapment (Group 4) did quite well, as four (57%) of the seven patients had successful surgical outcomes. The most common neuroma treated involved distal sensory nerves, either proven at surgery (Group 1) or strongly suspected by physical examination (Group 2).

![Graph showing the number (N) of successful outcomes by groups. Group 1 = distal sensory neurona (18 cases); Group 2 = suspected distal sensory neurona (10 cases); Group 3 = proximal in-continuity neurona (five cases); Group 4 = nerve injury at anatomical permits of entrapment (seven cases). There were no successful outcomes in Group 3 patients, who were treated by external neurolysis only.](image)

These groups had a success rate of 44% (eight of 18 cases) and 40% (four of 10 cases), respectively.

Ten potential predictors obtained through history-taking and physical examinations were correlated with successful surgical outcome, and the results and incidence of each are listed in Table 2. Although none of the predictive factors reached statistical significance by chi-squared analysis, statistical significance was approached in the presence of the following: litigation involvement, discrete nerve syndrome, preoperative employment, and Tinel’s sign. The presence of a discrete nerve syndrome was moderately correlated to pain improvement on the VAS. Patients with a discrete nerve syndrome had an average reduction of 30 points on the postoperative VAS for pain, compared to the 17-point drop for patients without (Pearson’s R analysis, Fig. 3). Mechanical hyperalgesia (allodynia), either dynamic or static, as an independent variable, was not significantly related to success as assessed by chi-squared analysis. When both a discrete nerve syndrome and mechanical hyperalgesia were considered together, there was a moderate correlation with pain improvement (Fig. 4). The group of patients with both discrete nerve syndrome and mechanical hyperalgesia had an average pain score reduction of 44 points, which was greater than the patients with either factor alone. After surgery, many of the patients in this group had dramatic reductions compared to their preoperative pain scores (Fig. 5). Overall, among the four groups, the average reduction of pain level was 30%, while the mean overall success rate was 40%.

Discussion

Central nervous system effects of peripheral nerve injury are profound and their relevance to painful nerve injuries cannot be ignored.18,19 Nevertheless, we have adopted the thesis that, in many patients, the majority of the pathophysiologic abnormalities are peripheral rather than central. The physiological consequences of nerve injury have been extensively studied in the laboratory in recent years. The basic properties of axons are altered by injury such that, rather than high-fidelity conductors of neuronal signals, they become generators of abnormal activity. The pathophysiology of injured axons has been extensively reviewed.10,17 Suffice it to
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Fig. 3. Graph showing pre- and postoperative pain ratings graded by the Visual Analog Scale (VAS), in patients with or without a discrete nerve syndrome (DNS). The 16 patients without DNS had an average drop in VAS score of 17 points, and the 24 with DNS had an average drop in VAS score of 30 points. Of the 14 potential variables analyzed, DNS had the most significant correlation with pain improvement, but this was not statistically significant (Pearson's R analysis, r = 0.27, p = 0.10). Numbers in parentheses are average VAS scores.

say that injured axons develop several properties, including ectopic discharge, mechanosensitivity, and chemosensitivity, particularly to α-adrenergic agents or neurotransmitters.4,6,8,9,16,17,22,25,36,53,60 These properties would logically lead to the conclusion that removal of the generator of abnormal neuronal activity or transposition of the injured nerve segment to a less mechanically stressed area should be beneficial. It is on this basis that an algorithm for the management of these patients has been described.11

Recent Approaches

The development of a painful neuroma appears to be uncommon, however, if posttraumatic pain develops after nerve injury, conservative nonsurgical care can be difficult.30,42,61 In the past, when nonsurgical management of nerve injuries failed, surgical options, including nerve repair of neurotmetic injuries, have been successful in improving sensorimotor outcome.2,3,17,25,38,50,63 In general, treatment of painful nerve injuries by restricting the regeneration of axons and neuroma formation has been ineffective, however, some success has been reported23,27,58 even in some cases with recurrent neuromas.24 Other recent surgical approaches to painful neuromas have included free neurovascular tissue flap transfers,38 microfascicular ligation,12,23 sealing of the nerve end with biological tissue adhesive,34 and laser transection.1,34 Long-term success rates for these procedures have not been forthcoming.

Stump Reimplantation

Considering the tenacious propensity for the injured nerve to regenerate, Dellon and Mackinnon15,26 have proposed a bifurcated treatment regimen to protect the nerve end from mechanical stimulation and implant it into a muscle bed. This has been accomplished either with9,25 or without9,34,35,61 an intervening nerve graft. This strategy derived from earlier work,39,41,47,49,57 which suggested that when a nerve is placed into muscle tissue there was less production of connective tissue and little evidence of invasion or regeneration into surrounding innervated muscle.37 Good results have also been reported after implanting the nerve into bone marrow.5,30,25

Based on these reimplantation data, we surgically reimplanted the nerve endings in 18 patients with distal sensory neuromas and 10 with suspected distal sensory neuromas. The neuroma or nerve proximal to the suspected neuroma was resected, and the nerve reimplanted into either muscle or bone marrow. The success rate was 44% and 40%, respectively, while the average drop in VAS-registered pain was 32% and 24%. We believe that surgically confirming the presence of a neuroma is important and should be attempted if possible. If nerve section proximal to the suspected neuroma is performed, our preliminary data indicate that the outcome may not be as successful.

Internal Neurolysis

Surgical intervention in cases of in-continuity neu-
romas of major proximal sensorimotor nerves with significant residual distal function has unavoidable attendant risks. Internal neurolysis (dissection in the plane of the investing internal epineurium\textsuperscript{21,22}) may cause further damage to remaining axons.\textsuperscript{21,22} Our first hypothesis was that it might be of benefit. In our series, five patients with proximal in-continuity neuromas of major sensorimotor nerves were treated by this method. Although it is difficult to make accurate statements based on such a small group, none of these patients improved. We conclude that this group of patients would best be managed by some other method, such as peripheral nerve stimulation. In contrast, the seven patients with proven in-continuity neuromas of proximal sensorimotor nerves at points of anatomical entrapment did quite well, with five (71\%) of seven having successful outcomes. Whether this improvement in outcome is due to the external neurolysis or the transposition, which diminished the subsequent trauma, is a point of conjecture.

Treatment Recommendations

After such a thorough investigation, it is disappointing to be unable to identify prognostic factors to help influence future surgical outcomes for neuroma patients. However, these results are promising and do tend to question the widespread pessimism that is associated with the treatment of these patients. For example, patients who were receiving worker’s compensation did no worse than the group as a whole. Neither preoperative narcotic use nor employment status was predictive of outcome. Of particular note, no patient who was unemployed preoperatively became employed postoperatively, even if the surgery was a success by our criteria, and all preoperatively employed patients remained employed postoperatively, even if the surgery was a failure. The physical findings sometimes associated with reflex sympathetic dystrophy, mechanical or thermal hyperalgesia, or the presence of Tinel’s sign did not independently reach predictive significance; however, when combined under the collective term of “discrete nerve syndrome,” these factors were moderately correlated with pain improvement. Finally, patients with discrete nerve syndrome in combination with mechanical hyperalgesia had greater reduction of pain than with either factor alone.

Although painful nerve injuries are fairly common, there has been surprisingly little recent clinical investigative work on neuromas. The numerous nonsurgical treatment options for neuroma reflect that no single approach has shown uniformly superior or effective results. As in other chronic pain syndrome cases, the use of chronic narcotics should be avoided. Furthermore, preoperative evaluation by a psychologist with particular experience in treating patients with chronic pain should be completed to screen out patients with major psychopathology or functional overlay. Finally, we consider it imperative that specialists treating the condition avoid the tendency to lump patients with painful nerve injuries into vague and possibly pejorative diagnostic categories, such as “reflex sympathetic dystrophy,” “causalgia,” and “neuroma pain.” Only by careful clinical study can we differentiate patients who may achieve palliation by surgical means.

References

16. DeSantis M, Duckworth JW: Properties of primary afferent neurons from muscle which are spontaneously active after a lesion of their peripheral processes. Exp Neurol 75:261–274, 1982
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