Secondary Carpal Tunnel Surgery

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Learning Objectives: After studying this article, the participant should be able to: 1. Describe and classify the problems commonly seen after carpal tunnel surgery and their probable causes. 2. Be familiar with the relevant anatomy of the median nerve and its branches. 3. Discuss the clinical evaluation of the patient after failed carpal tunnel release. 4. Describe the surgical techniques used in secondary carpal tunnel surgery, including neuroma management, nerve grafting, and flap coverage.

A small but significant group of patients with carpal tunnel syndrome “fail” primary carpal tunnel release and require secondary surgery. The persistence or recurrence of previous symptoms or the development of new symptoms is often indicative of the nature of the patient’s problem. Postoperative complications may be classified into the general areas of neurological, vascular, tendon, and wrist complaints. A thorough clinical evaluation, including a complete neurological examination of the hand and upper extremity, provides an accurate assessment of the status of the median nerve. Important surgical techniques that may be used during secondary carpal tunnel surgery include internal neurolysis, neuroma-in-continuity assessment, neuroma management, nerve grafting, and tissue interposition flaps. (Plast. Reconstr. Surg. 107: 1830, 2001.)

Carpal tunnel syndrome was first described by Sir James Paget in 1854. The first carpal tunnel release is credited in most historical reviews to Learmonth in 1929 for a patient with posttraumatic nerve compression. However, a review of the Mayo Clinic records by Amadio indicates that the first surgical release of the transverse carpal ligament for median nerve compression was done by Drs. Herbert Galloway and Andrew Mackinnon in Winnipeg, Manitoba, Canada, in 1924, in a patient with a posttraumatic neuropathy. The following is a description from those records: “On February 21, 1924, Drs. Galloway and Mackinnon explored the median nerve downward for an inch and upward for 2 inches from the wrist crease. The patient continued to have pain and was seen at Mayo by Dr. A. W. Adson, who diagnosed median neuritis. On August 27, 1925, Dr. Galloway reoperated and found that the palmar cutaneous nerve was excised. The patient had some improvement but continued to have some difficulty.” It would appear that the earliest case of carpal tunnel surgery began with a significant and unfortunately still common complication of injury to the palmar cutaneous branch of the median nerve. The recognition and popularization of spontaneous carpal tunnel syndrome as a diagnostic entity has only been as recent as the late 1940s and 1950s, and this occurred largely through the writings of George Phalen. In 1951, he initially described his technique using a transverse incision at the distal wrist crease, with proximal and distal extension as needed. Not until the 1970s, with the work of Taleisnik and others, did the longitudinal incision along the line of the ring finger become the recommended approach.

Carpal tunnel syndrome remains the most understood and the most common of peripheral compression neuropathies, and because it continues to be diagnosed with increasing frequency, it remains the most common hand operation performed. The open method remains the standard surgical approach for patients who have failed to improve satisfactorily with conservative measures. Two alternative approaches have been reported: the endoscopic carpal tunnel release and limited incision techniques. The latter came about in response to concerns about the safety of the endoscopic approach. Both of these approaches...
may be performed through one or two smaller incisions. The reported advantages, especially of the endoscopic approach, have included a faster return of preoperative strength, less mid-palm and scar tenderness, and more rapid return to work in non-worker’s compensation patients but not in those receiving worker’s compensation.13,14 Furthermore, the higher incidence and severity of the reported complications with the endoscopic technique and the subsequent need for secondary surgery have continued to generate much controversy.

The simple release of the transverse carpal ligament consistently relieves symptoms in most patients. A small but significant group of patients, however, will have similar symptoms after surgery or will experience new symptoms in the postoperative period. Problems following the surgical treatment of carpal tunnel syndrome that may lead to secondary surgery can be classified into three general types (Table I). Symptoms may be persistent after surgery, with little or no improvement. Alternatively, there may be a significant improvement or relief of symptoms that lasts only temporarily, with eventual recurrence of the same problem. Finally, new symptoms may arise after surgery that are distinct from the initial complaints.

**Complications after Carpal Tunnel Surgery**

*Persistent Symptoms*

The persistence of preoperative complaints is the most common complication of carpal tunnel release, with an incidence of 7 to 20 percent (Table II).15–24 Persistence occurs for three primary reasons. Most often, the transverse carpal ligament (flexor retinaculum) is incompletely released, with the problem usually in the most distal portion of the ligament (Fig. 1).25–27 This may be due to inadequate exposure or visualization, as in the endoscopic approach or with limited incision techniques. Continued compression on the median nerve may also occur more proximally by inadequate release of the most distal portion of the antebrachial fascia. Patients who develop carpal tunnel symptoms after trauma to the wrist and hand may be particularly prone to proximal compression because the fascia may be scarred and thickened (Fig. 2). As the basal metabolic index of the population increases, the “simple” carpal tunnel release becomes more difficult. Lack of adequate exposure in an obese patient also makes the distal release more difficult.

Second, preoperative symptoms may persist because of compression of the median nerve further proximally in the forearm or the neck. There is a well-established association between carpal tunnel syndrome and cervical disc disease.28 These regions must be thoroughly examined preoperatively to rule out additional areas of compression that may be contributing to the patient’s complaints. In particular, patients with work-related symptoms may have multiple areas of nerve entrapment, and they often improve after carpal tunnel surgery. A number of workers’ compensation patients, however, continue to have problems after surgical management, and they may respond best to a different job that does not involve the use of vibration tools or repetitive activities.

Of course, patients whose symptoms are initially misdiagnosed as carpal tunnel syndrome will respond poorly to carpal tunnel surgery. These patients often have more vague, diffuse, and atypical carpal tunnel complaints in the upper extremity. In the worker with very mild carpal tunnel syndrome but a host of other musculoskeletal problems, a carpal tunnel release will fail to relieve the majority of the patient’s symptoms.

*Recurrent Symptoms*

Many patients may do well initially after surgery only to have the same preoperative symptoms recur, often after a few months. Postoperative scarring may be significant in many of these patients. The scar tissue may involve the median nerve directly by forming around it and entrapping the nerve. Hypothetically, contributory factors may include poor hemostasis and hematoma formation, prolonged postoperative immobilization, or inadequate range-of-motion exercises and therapy. Excess scar tis-

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**TABLE I**

<table>
<thead>
<tr>
<th>Complain</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Persistent symptoms</td>
<td>Inadequate release of flexor retinaculum or antebrachial fascia</td>
</tr>
<tr>
<td></td>
<td>Proximal median nerve compression</td>
</tr>
<tr>
<td></td>
<td>(forearm, neck)</td>
</tr>
<tr>
<td>Recurrent symptoms</td>
<td>Wrong diagnosis</td>
</tr>
<tr>
<td>New symptoms</td>
<td>Pathological scar formation around median nerve</td>
</tr>
<tr>
<td></td>
<td>Reformation of flexor retinaculum</td>
</tr>
<tr>
<td></td>
<td>Proximal median nerve compression</td>
</tr>
<tr>
<td></td>
<td>Iatrogenic injury</td>
</tr>
</tbody>
</table>

sue may also indirectly affect the nerve by leading to reformation of the transverse carpal ligament (Fig. 3).

Alternatively, preoperative symptoms may recur because of compression of the median nerve at a more proximal level, as in pronator syndrome. According to the theory of the multiple-crush syndrome, release of a distal site of compression, such as the carpal tunnel, may unmask a more proximal site of compression, such as at the proximal forearm, which preoperatively may not have been diagnosed as a clinically significant area of entrapment.

New Symptoms

A third group of patients with postoperative problems experience symptoms different from their original complaints. These can be broadly classified into the general areas of neurological, vascular, tendon, and wrist complaints (Table III).

Neurological complications. New neurological problems usually involve one of the branches of the median nerve and, less commonly, the median nerve itself. Injury to the palmar cutaneous branch or one of its branches is most frequently the problem. A more radially placed incision is more likely to cross the distribution of the palmar cutaneous branch, with subsequent injury and neuroma formation (Fig. 4). A tender hypertrophic scar is likely to be the result of injury to small cutaneous branches. Primary entrapment neuropathy of the palmar cutaneous branch has been reported, as has secondary compression after carpal tunnel release. Transection of the transverse carpal ligament may not release pressure on the palmar cutaneous branch because it may have its own distinct tunnel to the hand, and postoperative swelling and edema may lead to compression of this tunnel (Fig. 5). Other branches that may be injured include the recurrent motor branch and common digital nerves (Fig. 6).

Direct injury to the median nerve itself can occur, and, unfortunately, even complete transection of the nerve during carpal tunnel surgery has been reported. The portion of the median nerve to the third webspace is frequently injured, especially with endoscopic release. Patients complain of burning, pain, and numbness in the long and ring fingers. Additionally, a rare but clinically significant problem that has been described as a sequelae of carpal tunnel release is

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**TABLE II**

Results of Treatment of Carpal Tunnel Syndrome by Decompression

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of Patients Followed</th>
<th>Staging</th>
<th>Just Decompression (%)</th>
<th>Symptomatic Relief Complete</th>
<th>Atrophy Corrected</th>
<th>Weakness Corrected</th>
<th>Sensory “Loss” Corrected</th>
<th>Two-Point Discrimination Corrected</th>
<th>Recurrence (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paine, 1963²⁰</td>
<td>133</td>
<td>NA</td>
<td>100</td>
<td>99%</td>
<td>0%</td>
<td>25% *</td>
<td>50% *</td>
<td>ND</td>
<td>1</td>
</tr>
<tr>
<td>Patrick, 1965²⁷</td>
<td>32</td>
<td>NA</td>
<td>100</td>
<td>100%</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>2</td>
</tr>
<tr>
<td>Phalen, 1966⁴¹</td>
<td>212</td>
<td>Minimal to moderate, 44%; severe, 56%</td>
<td>100</td>
<td>NA</td>
<td>—</td>
<td>NA</td>
<td>78%</td>
<td>ND</td>
<td>2</td>
</tr>
<tr>
<td>Cruz et al., 1966²⁵</td>
<td>313</td>
<td>NA</td>
<td>100</td>
<td>NA</td>
<td>68%</td>
<td>83%</td>
<td>78%</td>
<td>ND</td>
<td>—</td>
</tr>
<tr>
<td>Rietz and Omne, 1967²²</td>
<td>65</td>
<td>Minimal to moderate, 40%; severe, 60%</td>
<td>100</td>
<td>100%</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Semple and Cargill, 1969²⁴</td>
<td>150</td>
<td>NA</td>
<td>100</td>
<td>75%</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>ND</td>
<td>—</td>
</tr>
<tr>
<td>Posch and Marcotte, 1976²¹</td>
<td>681</td>
<td>NA</td>
<td>100</td>
<td>91%</td>
<td>NA</td>
<td>NA</td>
<td>ND</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Eversmann and Retsick, 1978²⁰</td>
<td>51</td>
<td>Moderate, 86%</td>
<td>100</td>
<td>NA</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>ND</td>
<td>—</td>
</tr>
<tr>
<td>Graham, 1983²⁸</td>
<td>214</td>
<td>Minimal to moderate, 44%</td>
<td>100</td>
<td>75%</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>ND</td>
<td>—</td>
</tr>
<tr>
<td>Gelberman et al., 1987²⁷</td>
<td>33</td>
<td>Severe, 100%</td>
<td>100</td>
<td>62%</td>
<td>65%</td>
<td>90%</td>
<td>—</td>
<td>85%</td>
<td>31%</td>
</tr>
<tr>
<td>Kulick et al., 1986²⁹</td>
<td>100</td>
<td>Minimal to moderate, 80%; severe, 20%</td>
<td>100</td>
<td>85%</td>
<td>70%</td>
<td>NA</td>
<td>ND</td>
<td>6%</td>
<td>—</td>
</tr>
</tbody>
</table>

NA, data not available; ND, examination not done.

* Estimated.
† Ninety-one percent of these patients had improvement in motor conduction latencies, the only parameter tested.
‡ Epineurotomy added.

"bowstringing" or "anterior dislocation" of the median nerve. Other neurological complications may include injury to the ulnar nerve, especially its palmar cutaneous branch, and/or a communicating branch between the median and ulnar nerves, neuroma formation around the radial sensory nerve, and multiple nerve dysfunction. Injury to the ulnar nerve is more common with the endoscopic release. Complex regional pain syndrome type I (formally, reflex sympathetic dystrophy) is rare, but it may follow carpal tunnel surgery, or, alternatively, may be caused or exacerbated by carpal tunnel syndrome. In the latter case, surgical treatment with carpal tunnel release may actually improve rather than worsen the syndrome.

Vascular injury. Injury to the superficial palmar arch may be insignificant if recognized or may lead to accumulation of a hematoma in the palm. If not managed in a timely manner, this may progress to massive necrosis of the palmar skin and require a free flap for coverage.

Wrist pain. Various entities have been reported after carpal tunnel release; they include
carchal arch alterations,42,43 pillar pain, and piso-
triquetral44 syndrome. In an attempt to mini-
mize these effects, some advocate reconstruc-
tion of the transverse carpal ligament, either by
resuturing one side of the carpal ligament (usu-
ally radial) to the opposite side of the palmar
aponeurosis (ulnar) by a step-lengthening type
of transection or by using transposition flaps
from the carpal ligament. Such reconstruction,
however, has been associated with reformation
of the carpal tunnel and the subsequent recur-
rence of symptoms.

Tendon problems. There seems to be a higher
frequency of trigger finger after carpal tunnel
surgery. A possible explanation is that the trans-
verse carpal ligament may also normally func-
tion as the “first” tendon pulley. When this is
released, greater forces are then transmitted to
the first annular ligament, which is now the
most proximal pulley and may contribute to
triggering at this site. Anterior dislocation or
bowstringing of the flexor tendons32 has already
been mentioned, and flexor tendon adhesions
can also be a problem.26 Table IV summarizes
the complications reported in the literature af-
after carpal tunnel surgery. Table V shows the
results of a recent survey of the members of the
American Society for Surgery of the Hand that
was undertaken by Palmer and Toivonen45 re-
garding the complications of the endoscopic
and the open approaches.

TABLE III
Complications following Carpal Tunnel Release

<table>
<thead>
<tr>
<th>Neurological complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injury to median nerve</td>
</tr>
<tr>
<td>Palmar cutaneous branch (compression, neuroma)</td>
</tr>
<tr>
<td>Recurrent motor branch</td>
</tr>
<tr>
<td>Median nerve</td>
</tr>
<tr>
<td>Injury to ulnar nerve</td>
</tr>
<tr>
<td>Ulnar palmar cutaneous neuroma</td>
</tr>
<tr>
<td>Main ulnar nerve</td>
</tr>
<tr>
<td>Communicating ramus between median and ulnar nerves</td>
</tr>
<tr>
<td>Reflex sympathetic dystrophy</td>
</tr>
<tr>
<td>Vascular injury</td>
</tr>
<tr>
<td>Ulnar artery</td>
</tr>
<tr>
<td>Superficial palmar arch</td>
</tr>
<tr>
<td>Palmar hematoma</td>
</tr>
<tr>
<td>Wrist pain</td>
</tr>
<tr>
<td>Carpal arch alteration</td>
</tr>
<tr>
<td>Pillar pain</td>
</tr>
<tr>
<td>Piso-triquetral syndrome</td>
</tr>
<tr>
<td>Tendon problems</td>
</tr>
<tr>
<td>Trigger finger</td>
</tr>
<tr>
<td>Bowstringing of flexor tendons</td>
</tr>
<tr>
<td>Flexor tendon adhesions</td>
</tr>
<tr>
<td>Wound complications</td>
</tr>
<tr>
<td>Infection, wound dehiscence</td>
</tr>
<tr>
<td>Hypertrophic or painful scar</td>
</tr>
</tbody>
</table>


FIG. 3. (Above) Secondary carpal tunnel surgery was per-
formed on this diabetic patient after median nerve function
was lost after primary release. The flexor retinaculum had
reformed from scar tissue and the median nerve, adherent to
its underside, was compressed. (Below) The gross appear-
ance of the nerve improved with neurolysis. The resected
epineurium is seen on the hypothenar eminence. The patient
ultimately experienced a return of median nerve function but
required a full 10 months for recovery at a rate of 1 inch per
month. Reprinted with permission from Mackinnon, S. E.,
and Dellon A. L., Surgery of the Peripheral Nerve. New York:

most proximal pulley and may contribute to
triggering at this site. Anterior dislocation or
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and the open approaches.

CLINICAL EVALUATION OF THE PATIENT WITH
FAILED CARPAL TUNNEL RELEASE

An accurate assessment of the status of the
median nerve after primary carpal tunnel sur-
cery can usually be made from a thorough
history and careful sensory examination. If the
initial complaints were not resolved after the
first surgery, the persistent symptoms are prob-
ably due to incomplete release at the carpal
tunnel or the distal antebrachial fascia or to a
more proximal compression. If the initial com-
plaints were relieved after surgery but then
recur after a period of time, the cause is likely
to be either pathological scar formation
around the median nerve or scarring with sub-
sequent reformation of the transverse carpal
ligament. More rarely, there may be a point of compression in the proximal forearm that previously was not clinically significant until after the carpal tunnel was released. If the presenting symptoms are new and different from the initial complaints, such as pain or motor weakness, an iatrogenic nerve injury should be considered.

**Physical Diagnosis**

Pressure provocative tests are helpful to determine the area of compression of a peripheral nerve, because an entrapped nerve will be more sensitive to mechanical pressure. Digital pressure just proximal to the level of entrapment, such as the carpal tunnel or the pronator teres, will cause paresthesias in the territory of the median nerve if there is ongoing compression at that site. Other maneuvers that may produce paresthesias in the median nerve distribution from a compression in the proximal forearm include maximum passive supination of the forearm, resisted pronation, and resisted contraction of the flexor digitorum superficialis.

If an iatrogenic injury to the median nerve is being considered, then each region of the...

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**FIG. 4.** (Above) The scar from previous carpal tunnel surgery may be indicative of the type of release and also possible nerve injury. The incisions previously used in this patient are outlined. One portion of the scar intersects the path of the palmar cutaneous branch of the median nerve at the wrist, and exploration revealed an injury to this nerve. (Center) In another patient, transection of the palmar cutaneous branch had occurred. (Below) A close-up view demonstrates neuroma formation of the proximal palmar cutaneous branch between the tendons of the palmaris longus and the flexor carpi radialis. Reprinted with permission from Mackinnon, S. E. Secondary carpal tunnel surgery. *Neurosurg. Clin. North Am.* 2: 75, 1991.

**FIG. 5.** (Above) After carpal tunnel release, this patient developed symptoms consistent with a neuroma of the palmar cutaneous branch of the median nerve. The palmar cutaneous branch, seen with the visibility background, was not damaged but was compressed in its own tunnel. (Below) The patient’s symptoms resolved after release of this separate tunnel. Reprinted with permission from Mackinnon, S. E., and Dellon, A. L. *Surgery of the Peripheral Nerve.* New York: Thieme Medical Publishers, 1988. P. 513.
nerve should be evaluated separately. Potential problems can often be anticipated by the location of the scar from the first carpal tunnel release. An injury to the palmar cutaneous branch of the median nerve, which runs between the flexor carpi radialis tendon and the palmaris longus tendon, can often be suspected if the initial incision was placed inappropriately and crossed the territory of the nerve radially. The recommended approach is well ulnar to the distribution of the palmar cutaneous branch (proximal background, at upper right). The palmar cutaneous branch will be transposed proximally into the forearm musculature, the sensory branch to the index finger neurolysed, and the sensory and motor branches to the thumb reconstructed with nerve grafts. Reprinted with permission from Mackinnon, S. E. Secondary carpal tunnel surgery. Neurosurg. Clin. North Am. 2: 75, 1991.

Symptoms consistent with an injury to the palmar cutaneous branch will usually include abnormal sensation in the territory of the nerve and a Tinel sign at the level of the injury. Sometimes there may be entrapment of the palmar cutaneous nerve itself in its own separate tunnel, and the presentation will be similar to a neuroma. The presentation of an injured recurrent motor branch is usually straightforward and will consist of weakness or atrophy of the abductor pollicis brevis muscle. A partial injury to the median nerve itself will present as abnormal sensation in the territory of the injured fascicles. The most superficial or anteriorly located fascicles of the median nerve are the most vulnerable to injury, and these usually supply the third web space. A Tinel sign radiating to the territory of the injured nerve will help to identify the level of the injury.

We found that a simple clinical test is useful in determining which nerve(s) is injured. It is important that all of the nerves involved be identified and appropriately managed to ensure the best possible result. A Tinel-like response can be obtained 2 to 4 inches proximal to the actual area of injury. Frequently, palpation at the level of injury is so painful that the patient has difficulty in accurately describing the distribution of the pain. For example, gentle tapping between the flexor carpi radialis and palmaris longus starting proximal to the level of the scar will illicit a response into the distribution of the palmar cutaneous branch if it is involved. A careful physical examination should also include sensibility testing of the autonomous zone of each digital nerve to further determine which nerves are involved. Our sensory examination consists of testing for innervation density (moving and static two-point discrimination) and threshold tests (vibration and pressure monofilaments). The ten test for clinical sensibility is also very rapid and reliable, with consistent interexaminer and intraexaminer results.

Painful sequelae of carpal tunnel surgery require careful preoperative and postoperative management. Patients should become familiar with the techniques of desensitization on a nonpainful area before secondary surgery so that desensitization can be started early after surgery. If the pain is significant, a pain evaluation scale will help determine the extent of
### TABLE IV
Incidence of New Complaints after Carpal Tunnel Release

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of Cases</th>
<th>No. of Complications</th>
<th>Incomp Div</th>
<th>Neurological Complaints</th>
<th>Wound</th>
<th>Tendons</th>
<th>Wrist</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Median Nerve</td>
<td>Ulnar Ramus</td>
<td>Radial Nerve</td>
<td>Multiple Nerves</td>
</tr>
<tr>
<td>Crow, 1960&lt;sup&gt;63&lt;/sup&gt;</td>
<td>40</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goodman and Gilliatt, 1961&lt;sup&gt;64&lt;/sup&gt;</td>
<td>20</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paine, 1963&lt;sup&gt;20&lt;/sup&gt;</td>
<td>119</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goodwill, 1965&lt;sup&gt;55&lt;/sup&gt;</td>
<td>55</td>
<td>6</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patrick, 1965&lt;sup&gt;27&lt;/sup&gt;</td>
<td>32</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phalen, 1966&lt;sup&gt;46&lt;/sup&gt;</td>
<td>212</td>
<td>4</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Langlough and Linscheid, 1972&lt;sup&gt;26&lt;/sup&gt;</td>
<td>2053</td>
<td>34</td>
<td>21</td>
<td>22</td>
<td></td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>Das and Brown, 1986&lt;sup&gt;30&lt;/sup&gt;</td>
<td>120</td>
<td>10</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>MacDonald, 1978&lt;sup&gt;66&lt;/sup&gt;</td>
<td>186</td>
<td>34</td>
<td>12</td>
<td>11</td>
<td>4</td>
<td>2</td>
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<tr>
<td>Conolly, 1978&lt;sup&gt;79&lt;/sup&gt;</td>
<td>35</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>2</td>
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<td>Inglis, 1980&lt;sup&gt;37&lt;/sup&gt;</td>
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<td></td>
<td></td>
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<td>May, 1981&lt;sup&gt;38&lt;/sup&gt;</td>
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<td></td>
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<td></td>
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<td></td>
<td>1</td>
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<tr>
<td>Eason et al., 1985&lt;sup&gt;28&lt;/sup&gt;</td>
<td>47</td>
<td>4</td>
<td>3</td>
<td>2</td>
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<tr>
<td>Lilly and Magnell, 1985&lt;sup&gt;45&lt;/sup&gt;</td>
<td>249</td>
<td>2</td>
<td></td>
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<td>Louis et al., 1985&lt;sup&gt;31&lt;/sup&gt;</td>
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Incomp div, incomplete division of carpal ligament; Hem, palmar hematoma; Adhsns, adhesions; Bow, bowstringing; Inf, infection; Scar, hypertrophic painful scar; PTP, pisotriquetral pain.

nonorganic, functional, or psychological components contributing to the problem. Patients should have a complete understanding of the nature of their injury and the potential risks and benefits of having secondary surgery.

**SURGICAL TECHNIQUES IN SECONDARY CARPAL TUNNEL SURGERY**

**Internal Neurolysis**

We advocate internal neurolysis in the majority of patients undergoing secondary carpal tunnel release. With the use of microsurgical instrumentation, the external and internal epineurium is opened until a normal fascicular appearance with visible perineurial markings (bands of Fontana) is seen. Injured fascicles may be identified in this manner. The extent of internal neurolysis required for each case will vary with the amount of scarring and fibrosis within each nerve (Fig. 7). Opening the perineurium is avoided because it is an anatomical site of the blood-nerve barrier. The benefit of internal neurolysis during primary carpal tunnel surgery has been examined in a prospective, randomized study. No benefit could be shown over simply transecting the transverse carpal ligament in the setting of primary carpal tunnel surgery. The role of internal neurolysis in secondary carpal tunnel release has yet to be evaluated, but it is a technique we use in essentially all secondary carpal tunnel cases.

**Median Nerve Compression in the Forearm**

If the physical examination supports a diagnosis of median nerve compression in the proximal forearm, then exploration at this level and decompression should be considered. The entrapment usually involves the pronator teres and, less commonly, the flexor digitorum superficialis muscle. The superficial and deep heads of the pronator teres muscle often form a tendinous arch around the median nerve. Slightly more distally, the flexor digitorum superficialis muscle may have a fibrous leading edge that also compresses the nerve.

**Neuroma of the Palmar Cutaneous Branch of the Median Nerve**

The surgical management of painful nerve injuries is based on experimental studies using primates, which showed that a neuroma is both spontaneously active and mechanically sensitive. By excising the neuroma and inserting the nerve stump in an area that will minimize its exposure to mechanical stimulation, the nerve will be much less likely to be clinically problematic. The regenerative potential and behavior of an injured nerve is influenced by its environment and tissue bed.
proximity to denervated skin will encourage sprouting and attempts at regeneration by trophic influences, innervated muscle will inhibit such nerve activity.

The surgical management of an injured palmar cutaneous nerve, therefore, includes the identification and excision of the neuroma and dissection of this branch proximally from the main trunk of the median nerve by microsurgical internal neurolysis. This permits a long enough segment of the nerve to be transposed further proximally between the deep and superficial layers of the flexor muscles to provide an environment for the nerve stump in an innervated muscle bed as far away as possible from the overlying skin and scar. We also coagulate the end of the nerve using microbipolar cautery before transposing the nerve. Much less common, the palmar cutaneous branch may simply be compressed in its own distinct tunnel, in which case the release of this tunnel will be all that is required. The injury to the palmar cutaneous branch often occurs distally in the palmar incision, and this distal injury may be difficult to visualize. Therefore, if it is at all unclear whether the nerve has been injured or not, then based on the clinical examination, an injury should be assumed and the nerve transposed proximally, as in the case of a neuroma.

Nerve Grafting

Management of an injury to the main portion of the median nerve itself will usually require an interposition nerve graft (Fig. 8). Again, microsurgical techniques are used to evaluate the extent of damage and to identify the injured portion. A thorough preoperative evaluation provides a good understanding of the components of the nerve that are uninjured, those that are only partially injured, and those that are not functioning at all. The median nerve is then managed as a sixth-degree injury, dissecting and replacing only the affected portion of the nerve (Fig. 9). Our first choice of donor nerve in these cases is usually the anterior branch of the medial antebrachial cutaneous nerve. The landmark for finding the medial antebrachial cutaneous nerve is the adjacent basilic vein located along the medial border of the biceps muscle. The anterior branch supplies sensation to the ulnar volar aspect of the forearm, and the posterior branch that supplies the elbow is left intact. The ulnar medial location of the scar on the forearm is a less visible and more cosmetically acceptable location, and the area of sensory loss diminishes with time. In cases in which a short nerve graft is needed, the lateral antebrachial cutaneous nerve may be used instead. It lies adjacent to the cephalic vein along the medial border of the brachioradialis muscle in the proximal forearm, and the donor scar is therefore more visible. The use of the sural nerve for grafting should be reserved for cases in which long grafts or multiple cable grafting will be needed. The resulting scar and sensory deficit are more unsatisfactory, and the formation of a problematic neuroma in the lower leg where the distal end is in proximity to the Achilles tendon or the overlying scar is likely if just a short segment of sural nerve is harvested. Recently, we used the terminal branch of the anterior interosseous nerve as a donor nerve graft. We harvest this nerve just proximal to the pronator quadratus muscle. Because it is an
expendable motor nerve, there is no sensory loss.

The same general principles of nerve grafting apply to secondary carpal tunnel surgery. Sufficient length of nerve graft should be harvested to avoid any tension at the repair sites and to permit a full range of motion at the wrist. Postoperatively, the wrist is immobilized, and the metacarpal phalangeal joints are blocked for 2 weeks. Active motion should be continued at the distal and proximal interphalangeal joints, and finger flexion should be maintained to permit gliding of the flexor tendons and to minimize scarring to the nerve and graft.

**Tissue Interposition Flaps**

For patients with significant pain and hyperalgesia at the proximal palm and wrist, a flap of innervated muscle or soft tissue can be raised and inset over the median nerve to provide padding and interposition tissue beneath the sensitive skin. The hypothenar fat pad flap is an easy dissection through the same incision and has good results in some cases. However, it provides only a small amount of tissue. Several donor muscle flaps have been described, including the abductor digiti minimi, the pronator quadratus, the palmaris brevis, and the first or second radial lumbrical muscles. The abductor digiti minimi is easily dissected and is our coverage flap of choice (Fig. 10). The pronator quadratus requires a more tedious mobilization but can provide better coverage more proximally in the distal forearm. It has a very limited reach distally, and we have not used it in the last decade. The palmaris brevis is rather thin and somewhat variable in its size and thickness. The use of the first or second radial lumbrical muscles has also recently been reported without any obvious motor deficit or weakness. We have not used these muscles.

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**Fig. 9.** The pattern of nerve injury may vary along the length of the nerve and from fascicle to fascicle at a given level. This illustration of a cross-section of a nerve reveals a sixth-degree or mixed injury pattern. The fascicle at the 12 o'clock position is normal. Moving in a clockwise direction, the fascicle at 1 o'clock demonstrates a first-degree injury (I), or neurapraxia with segmental demyelination. At the 3 o'clock position, a second-degree injury (II), or axonotmesis, is shown. Injury to the axon, myelin, and endoneurium, or third-degree injury (III), is demonstrated by the two smaller fascicles, which are more centrally located. A fourth-degree injury (IV), as shown by the fascicle at the 9 o'clock position, has marked fibrosis across the nerve, with only the epineurium remaining intact. At the 5 o'clock position is a fifth-degree injury (V), which involves transection of the nerve and complete loss of continuity. The surgeon’s role is to identify and reconstruct those fascicles with fourth- and fifth-degree injury patterns. Those with a first-, second-, or third-degree injury or a normal pattern should, at most, be neurolysed. Reprinted with permission from Mackinnon, S. E. Surgical management of the peripheral nerve gap. Clin. Plast. Surg. 16: 589, 1989.

**Fig. 10.** (Above) The abductor digiti minimi muscle is exposed through a longitudinal incision along the ulnar border of the hand. It is mobilized with a pedicle based on the proximal neurovascular bundle. (Below) The muscle can then be transferred across the carpal tunnel to provide coverage for the median nerve. Reprinted with permission from Mackinnon, S. E. Secondary carpal tunnel surgery. Neurosurg. Clin. North Am. 2: 75, 1991.
More aggressive approaches have also been described, mostly as salvage procedures for particularly recalcitrant cases. A reverse radial artery fascial flap has been used to envelop the median nerve and restore a suitable gliding bed with reportedly good results. Free tissue transfers have included a thoracodorsal fascial flap from the latissimus dorsi muscle and the omentum. The use of these flaps attests to the potential severity of the complications from carpal tunnel surgery and the dilemma that the patient and the surgeon may experience. In our experience, coverage of a painful median nerve injury or nerve graft with a free muscle flap will not necessarily relieve pain. In these recalcitrant cases, if a psychological evaluation is acceptable and anesthesia nerve block of the median nerve relieves symptoms, then a peripheral nerve stimulator inserted on the median nerve is recommended.

CONCLUSIONS

Carpal tunnel release successfully resolves symptoms for most patients, but a small group continues to have problems. The majority of these patients will have persistent or recurrent symptoms similar to the initial complaints, and secondary surgery to complete the decompression or decompression in the proximal forearm will relieve their symptoms.

Another group of patients will present with new and different symptoms after their carpal tunnel release. In many of these cases, the cause will be an iatrogenic nerve injury. A contributing factor to this problem and to incomplete carpal ligament release will often be a surgical approach, such as the endoscopic and limited incision techniques, that provides suboptimal exposure and visualization of the important structures. These cases are much more difficult and complex and will require careful preoperative sensory and psychological pain assessment and meticulous intraoperative microsurgical technique to accurately determine the extent of injury. The techniques and principles of internal neurolysis, neuroma-in-continuity assessment, neuroma management, nerve grafting, and muscle flap or tissue interposition grafting can reliably improve most of these patients. In the patient with severe pain, a nerve stimulator should be considered.

Carpal tunnel surgery is considered by many to be a simple and easy procedure. However, significant complications can occur, and an increasing awareness of their frequency and potentially disabling nature should continue to encourage greater respect for the procedure.

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REFERENCES

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Self-Assessment Examination follows on page 1844.
 Secondary Carpal Tunnel Surgery
by Thomas H. H. Tung, M.D., and Susan E. Mackinnon, M.D.

1. Persistence of symptoms after carpal tunnel release is most likely due to:
   A) Pathological scar formation around the median nerve
   B) Incomplete release of the transverse carpal ligament
   C) Compression of the median nerve at a more proximal site
   D) Direct injury to the median nerve
   E) Inadequate postoperative immobilization

2. Complex regional pain syndrome type I (formerly, reflex sympathetic dystrophy):
   A) May be improved by carpal tunnel release in some cases
   B) Is uniformly worsened by carpal tunnel release
   C) Is never caused by carpal tunnel syndrome per se
   D) May eventually lead to carpal tunnel syndrome in longstanding cases
   E) In a patient with carpal tunnel syndrome is always best managed nonsurgically

3. Injury to the palmar cutaneous branch of the median nerve, the most common neurological complication after carpal tunnel release, is most likely to occur if:
   A) The skin incision is made along the interthenar depression
   B) The skin incision is made ulnar to the interthenar depression
   C) The skin incision is made radial to the interthenar depression
   D) A separate tunnel for the palmar cutaneous branch exists and is released
   E) The ring finger axis is used to place the skin incision

4. The most superficial or anteriorly located fascicles of the median nerve are the most vulnerable to injury and usually supply:
   A) The palmar cutaneous branch
   B) The recurrent motor branch
   C) Small cutaneous branches to the palmar skin
   D) Sensation to the index finger
   E) Sensation to the third webspace

5. Optimal management of a neuroma of the palmar cutaneous branch of the median nerve consists of:
   A) Neuroma excision and bipolar coagulation of the nerve stump
   B) Neuroma excision, nerve stump coagulation, and insertion of the stump into the hypothenar fat pad
   C) Neuroma coagulation and subcutaneous transposition of the nerve stump proximal to the skin incision
   D) Neuroma excision, nerve stump coagulation, dissection of the nerve branch proximally from the main nerve, and proximal transposition into the forearm musculature
   E) Neuroma excision, dissection of the nerve branch proximally from the main nerve, and transection of the branch close to the main nerve and as proximally as possible

6. Internal neurolysis of the median nerve:
   A) Is recommended during primary carpal tunnel release
   B) Involves opening the scarred external epineurium only
   C) Involves opening the external and internal epineurium until a normal fascicular appearance is seen
   D) Involves opening the external and internal epineurium and the perineurium
   E) Should not be considered if scar formation around the nerve is too extensive

To complete the examination for CME credit, turn to page 1933 for instructions and the response form.