Secondary Carpal Tunnel Surgery

S. E. Mackinnon, MD, FRCS(C), FACS*

First described by Paget in 1854, carpal tunnel syndrome is now recognized as the most common of all peripheral entrapment neuropathies. As the incidence of carpal tunnel syndrome increases and it is recognized with increasing frequency, carpal tunnel release is now estimated to be the most common hand surgical procedure performed. Although simple decompression of the transverse carpal ligament predictably improves symptoms in the majority of patients, there remains a significant group of patients who fail to improve or who develop a new set of symptoms following carpal tunnel release.

The simplicity of the surgical management of carpal tunnel syndrome has been emphasized and its lack of complications stressed. However, as the incidence of this surgical procedure increases, there has been greater recognition of the incidence of complications associated with this procedure.

In the context of carpal tunnel surgery, its complications, and secondary surgery for these complications, it is worthwhile to review the history of surgery for this syndrome. Learmonth has been credited for performing the first carpal tunnel release in 1933 for a patient of the neurologist Woltman. Amadio has recently reviewed the early history of carpal tunnel surgery for the Mayo Clinic Proceedings. Amadio relates from review of the Mayo Clinic records, “On February 21, 1924, Drs. Galloway and Mackinnon explored the median nerve downward for an inch and upward for two 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 trapped in scar. The palmar cutaneous nerve was excised. The patient had some improvement but continued to have some difficulty.” It is clear from these historical records that what was probably the first surgical case of carpal tunnel release was itself associated with a significant complication.

Complaints following this procedure can be considered in three broad areas (Table 1). Patients may have persistent symptoms of median nerve compression. Patients may have a temporary relief from their symptoms followed by a recurrence of the initial problem. Finally, in the postoperative period patients may develop new symptoms quite different from the presurgical complaints.

**COMPLICATIONS FOLLOWING CARPAL TUNNEL SURGERY**

**Persistent Symptoms**

The most common complication following carpal tunnel surgery is a failure to relieve the patient’s symptoms. The incidence of

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forearm trauma and compresses the nerve. The standard incision for carpal tunnel release must be extended proximally in these patients in order to achieve adequate decompression of the median nerve (Fig. 2). In some patients, particularly those with work-related nerve compression, the median nerve may be entrapped at a more proximal level between the two heads of the pronator teres. These patients are frequently improved with surgery. There exists, however, a group of Workers’ Compensation patients who fail to respond to primary carpal tunnel release who are best managed with job change that avoids repetitive activities or vibration tools.

Preoperative evaluation of patients with carpal tunnel syndrome should include a careful examination of the neck and forearm. The association between cervical disc disease and carpal tunnel syndrome is well recognized.13 Rarely, the persistence of some patients’ preoperative symptoms may relate to a completely wrong diagnosis of their complaints as median nerve compression.

**Recurrent Symptoms**

Patients may have a temporary relief of symptoms followed subsequently by recurrence of their same preoperative symptoms.

![Figure 1. A, Following left carpal tunnel release through a proximal transverse incision, this patient had persistent symptoms of carpal tunnel syndrome requiring re-exploration. In this photograph of the left carpal tunnel, the distal portion of the flexor retinaculum is identified and has not been released. B: Release of the flexor retinaculum shows significant compression of the underlying median nerve. Finger is located to the right and the forearm is to the left. (From Mackinnon SE, Dellon AL: Surgery of the Peripheral Nerve. New York, Thieme Medical Publishers, 1988, p 160, with permission.)](image)

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<p>| Table 2. Results of Treatment of Carpal Tunnel Syndrome by Decompression |
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<th><strong>Patient</strong></th>
<th><strong>Surgery</strong></th>
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<th><strong>Atrophy Corrected</strong></th>
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| Unfortunately, patients may develop new complaints following carpal tunnel release. These may be considered in several broad areas of neurological, vascular, tendon, and wrist complaints (Table 3).

**Neurologic Complications**

Injury to the median nerve has been described with injury to palmar cutaneous branch of the median nerve as the most common problem. Incisions that cross the territory of the palmar cutaneous branch of the median nerve may cause damage to this nerve with neurotmesis formation (Fig. 4). Compression of the palmar cutaneous branch of the median nerve has been described.4 Compression of this nerve, subsequent to carpal tunnel surgery, also has been described. The palmar cutaneous branch of the median nerve may have its own separate tunnel into the hand. Postoperative swelling and edema may result in compression of this nerve (Fig. 5). Injury to the median nerve itself, the recurrent motor branch,5, 6, 7 and the common digital nerves,8, 9, 10 can occur (Fig. 6). Recently, the tragic complication of complete transection of the median nerve following carpal tunnel release has been reported.3 "Bow-stringing" or "anterior dislocation" of the median nerve has been described in two cases.22

Injury to the ulnar nerve, in particular the ulnar palmar cutaneous nerve and the communicating ramus between the median and ulnar nerves, has been described.33 Injury to the radial sensory nerve with neuroma formation and multiple nerve dysfunction following carpal tunnel surgery have been reported. Reflex sympathetic dystrophy (RSD) following carpal tunnel release is a recognized but rare complication.2, 5, 9, 10 The reverse association (that is, primary median nerve compression in the carpal tunnel causing or exacerbating RSD) has been observed. In these cases, contrary to surgical dogma, surgical release of the carpal tunnel syndrome can improve the RSD. Careful preoperative psychological evaluation is necessary in these patients and pre-, intra-
and postoperative sympathetic blockade will facilitate a good surgical response.

Hypertrophic and painful scars following carpal tunnel release probably relate to injury to small cutaneous branches divided at the time of surgery.

Vascular Injury

Vascular injury to the superficial palmar arch with a palmar hematoma formation has been reported. Massive necrosis of the palmar skin, secondary to palmar hematoma requiring a free flap coverage, has been described.

Wrist Pain

Carpal arch alterations, pillar pain, and pisotriquetral syndrome have all been described following carpal tunnel surgery. Attempts to reconstruct the carpal ligament, either by designing transposition flaps using the flexor retinaculum or resurfacing the flexor retinaculum to the palmar fascia, have been associated with recurrence of the carpal tunnel syndrome as the flexor retinaculum reforms.

Tendon Problems

We have recognized an increased incidence of trigger finger complaints following carpal tunnel release. This may relate to increased pressure across the first annular ligament, consistent with the hypothesis that the flexor retinaculum is in its intact state in the "first tendon pulley." Release of this flexor retinaculum transfers increased forces to the tendons as they cross the first annular ligament, accounting for the subsequent increase in trigger finger complaints after carpal tunnel release. Bowstringing of the flexor tendons and flexor tendon adhesions are well-recognized complications following surgery for carpal tunnel syndrome. Table 4 tabulates the series in the literature dealing with complications following carpal tunnel surgery.

Clinical Evaluation of the Patient with Failed Carpal Tunnel Release

A careful history coupled with a detailed sensory examination will allow the surgeon to determine quite accurately the preoperative status of the median nerve. Patients may report that their original symptoms of carpal tunnel syndrome were not relieved by the
first surgery. Unless there is a more proximal element of compression on the median nerve, these complaints are likely due to inadequate decompression of the median nerve in the carpal tunnel or in the situation of forearm trauma at the level of the antebrachial fascia. If the history is of relief of symptoms for a period of time followed by recurrence of symptoms, this supports the diagnosis of pathologic scar formation around the median nerve or scar formation resulting in the reorganization of the flexor retinaculum. In a small percentage of patients, a subclinical entrapment point in the proximal forearm may become symptomatic following carpal tunnel surgery. Finally, if the patient describes a new set of symptoms that were not present before the surgery, such as pain and numbness or motor weakness, this suggests iatrogenic nerve injury.

Physical Diagnosis

A compressed nerve is more sensitive to mechanical pressure, and pressure provocative tests can be used to demonstrate entrapment points along the peripheral nerve. Pressure over the median nerve just proximal to the carpal tunnel will produce paresthesia into the median nerve distribution if compression is still present at this level. Likewise, pressure over the median nerve just proximal to the pronator teres will produce paresthesia into the median nerve distribution if a significant entrapment exists at this site. Holding the forearm into maximum supination may produce paresthesia into the median nerve distribution. Resisted pronation and resisted superficialis muscle contraction will also produce paresthesia into the median nerve distribution if an entrapment exists at this proximal forearm level.

When actual injury to the median nerve is suspected, then each component of the median nerve is examined separately. The location of the initial surgical incision is often a good indicator of potential problems. In particular, injury to the palmar cutaneous nerve lying between the flexor carpi radialis tendon and the palmaris longus tendon is frequently associated with inappropriate incisions that cross the territory of this nerve. The recommended incision is well ulnar to the palmar cutaneous nerve territory in line with the fourth digit. The patient with injury to the palmar cutaneous branch will have abnormal sensation in the distribution of this nerve and a Tinel sign in the distribution of this nerve at the level of the injury. Occasionally, entrapment of the palmar cutaneous nerve has mimicked a neuritis. Injury to the recurrent motor branch is easily detected by the presence of weakness or atrophy in the adductor pollicis brevis muscle. If a portion of the median nerve itself has been injured, the patient will describe abnormal sensibility in the distribution of the injured fascicles. The fascicles to the third web space are located on the most superficial or anterior aspect of the median nerve, and these are the fascicles most likely to be injured. The patient will have a Tinel sign at the site of the injury that will radiate into the distribution of the injured nerve.
There must be testing for sensibility in the autonomous zone of each of the digital nerves in order to identify separate digital nerve injury. Our sensory examination includes testing for innervation density (moving and static two-point discrimination) and threshold tests (vibration and pressure monofilaments).29

Painful sequelae of carpal tunnel surgery are difficult to manage. Patients have to be educated as to the nature of their injury and the potential benefits of the proposed second surgery. Preoperatively they will be taught the techniques of desensitization on a nonpainful area. This familiarizes them with these techniques so that they can begin this desensitization early in the postoperative period. When there is significant pain, a pain evaluation scale is given to the patients in order to evaluate the degree of organic, functional, or psychological overlay involved in the problem.30

Surgical Techniques in Secondary Carpal Tunnel Surgery

Internal Neurolysis

The role of internal neurolysis in primary carpal tunnel syndrome has recently been evaluated in a prospective randomized trial.29 This study demonstrated no benefit of internal neurolysis over simple carpal ligament release in some primary carpal tunnel patients. Similar studies in patients requiring secondary carpal tunnel surgery are not available. We use a technique of internal neurolysis in almost all patients coming to secondary carpal tunnel surgery. The technique of internal neurolysis involves opening the epineurium using microsurgical instrumentation. The external and internal epineurium is removed until a good fascicular pattern with normal perineurial markings (bands of Fontana) is identified. Damaged fascicles can be identified using this technique. The amount of fibrosis within the median nerve varies between nerves, and the degree of internal neurolysis required will vary accordingly (Fig. 7). The perineurium is an anatomical site of the blood-nerve barrier, and it is not opened during this procedure.

Median Nerve Compression in the Forearm

Anatomical variations in the pronator teres and superficialis muscle contribute to the possible sites of nerve entrapment on the median nerve in the proximal forearm (Fig. 8).12 If the patient demonstrates significant evidence of compression of the median nerve at this level, then exploration and release of the median nerve in the proximal forearm are warranted. Frequently there is a tendinous arch around the median nerve be-
tween the superficial and deep heads of the pronator teres muscles (Fig. 9). Less commonly, the superficialis muscle also has a second fibrous leading arch that entrap the median nerve.

Neuroma of the Palmar Cutaneous Branch of the Median Nerve

Experimental work in primates has demonstrated that a neuroma is both spontaneously active and mechanically sensitive. This property of mechanical sensitivity is addressed surgically by excising the neuroma and placing the nerve in an area where it is least likely to be mechanically stimulated. Other experimental studies have demonstrated that the microenvironment of the painful nerve influences its histological behavior and regenerative potential. Denervated skin acts as a trophic “lure” to regenerating sensory nerves. Innervated muscle, by contrast, significantly inhibits sensory nerve regeneration. The surgical management of painful nerve injuries should make use of this information.

Injuries to the palmar cutaneous nerve are managed by identifying the neuroma and using microsurgical internal neurolysis technique, dissecting the palmar cutaneous
nerve proximally from the main median nerve. This allows a long section of the nerve to be separated from the median nerve so that it can be flipped proximally between deep and superficial flexor forearm muscles. The mature neuroma is excised, and the palmar cutaneous branch of the median nerve is transferred proximally into the forearm to lie well away from the overlying skin and scar and in an innervated muscle environment. Rarely, the palmar cutaneous branch will be entrapped and compressed in its own separate tunnel. In these cases, only release of the palmar cutaneous branch is required. If there is any question as to whether or not the nerve has been injured, then it should be treated as a neuroma and flipped back into the forearm.

Nerve Grafting

Occasionally, a portion of the median nerve itself will be injured. Management will require identification of the injured portion and repair with an interposition nerve graft (Fig. 10). Microsurgical techniques are used to evaluate the nerve injury. Careful preoperative examination will allow the surgeon to identify the components of the median nerve that are working normally, those that are not working at all, and those that are functioning partially. The surgeon then treats the median nerve as a sixth degree nerve injury, separating the normal part from the injured nerve (Fig. 11). Our nerve graft of choice for repairing such injuries is the anterior branch of the median antebra

Figure 8. Relationship of the number of arches that cross the median nerve. (From Delice A, Markinon SE. Muscular-aponeurotic variations along the course of the median nerve in the proximal forearm. J Hand Surg [Br] 1987;12:391-395, with permission.)

Figure 9. In the proximal forearm, the median nerve is seen to be compressed by a fibrous arch from the superficial to the deep head of the pronator teres.

Figure 10. A. This patient had a previous release of the carpal tunnel through a transverse incision. The branch of the median nerve to the thumb, both motor and sensory, has been divided by the attempt to release the ligament in the distal portion of the carpal tunnel without distal exposure. B. The anterior branch of the median antebra-chaotic cutaneous nerve, which is noted lying on the ulnar side of the hand, will be used to reconstruct the defect in the median nerve.
Figure 11. The injury pattern in the median may vary from fascicle to fascicle and also along the length of the nerve. A diagrammatic representation of the cross-section of a nerve demonstrates a mixed or sixth degree injury pattern. At 12 o'clock, a normal fascicle is seen. The adjacent fascicle at 1 o'clock demonstrates a first degree injury (neuropathy) with segmental demyelination. The fascicle at 3 o'clock demonstrates a second degree injury (neuropathy). The two smaller fascicles in the center of the nerve demonstrate a third degree injury, with injury to the axon, myelin, and endoneurium. The fascicle at 9 o'clock demonstrates a fourth degree injury with marked tearing across the nerve, with only the epineurium intact. A fifth degree injury with complete division of the nerve and loss of physical continuity of the fascicles is noted. During surgery, the surgeon will identify the fourth and fifth degree injury patterns and reconstruct them. The normal fascicles and those with first, second, and third degree injuries will at most be neurolyzed. (From Mackinnon SE: Surgical management of the peripheral nerve gap. Clin Plast Surg 16:389, 1989.)

chial cutaneous nerve. The anterior branch gives sensibility to the volar aspect of the forearm, and over a number of months this sensory loss is not recognized by the patient. The scar is located in the medial aspect of the arm in a cosmetically acceptable location. The median anterobrachial cutaneous nerve is identified in the arm adjacent to the basilic vein on the medial border of the biceps muscle. The anterior branch of the nerve is harvested, and the posterior branch, providing sensation to the elbow, is preserved. Occasionally, the lateral anterobrachial cutaneous nerve can be used as a short nerve graft. This nerve lies adjacent to the cephalic vein in the proximal forearm on the medial border of the brachioradialis muscle. The scar from this donor site is less acceptable than that associated with harvesting the median anterobrachial cutaneous nerve. The use of a sural nerve graft to repair short nerve gaps is not recommended. The scar and the donor deficit are significant, and frequently painful neuromas will develop in the distal leg where the divided end of the sural nerve develops a neuroma adjacent to the Achilles' tendon or overlying scar.

The surgical technique of nerve grafting is the same as for any other type of nerve graft. In particular, tension on the proximal and distal ends of the nerve repair is to be avoided, and a long enough nerve graft, al-

owing for a full range of movement of the wrist without tension, should be used. The patient's wrist is immobilized for a 2-week period, but finger flexion is encouraged in order to allow the flexor tendons to move around the median nerve or median nerve graft so that scar does not develop between these structures. The metacarpal phalangeal joints are blocked for this 2-week period, but active movement of the distal and proximal interphalangeal joints is encouraged.

Muscle Flaps

In those patients with significant hyperesthesia and pain at the wrist level, the flap of innervated muscle can be transferred to cover the median nerve to serve as an interposition tissue between the painful skin and the underlying median nerve. The abductor minimi muscle flap can be transposed over the median nerve with significant success (Fig. 12). The pronator quadratus flap similarly be used, although this is more distal. The pronator minimi flap will provide coverage over the more proximal portion of the median nerve in an area that is not easily covered by the abductor minimi flap.

CONCLUSION

Although carpal tunnel release relieves symptoms for the majority of patients, there remains a group of patients who fail to respond to this surgery. For the majority...
these patients with persistent or recurrent symptoms, secondary release with neurolysis or more proximal surgical intervention will relieve their symptoms.

There exists an unfortunate group of patients who develop a new set of symptoms following carpal tunnel surgery. Frequently these are patients who have suffered intra-articular nerve injury; these intraneural injury mechanisms are often associated with surgical approaches that do not allow direct visualization of the nerve. Such “blind” incisions and approaches should not be used. Technics of endoscopic release of the carpal ligament have recently been reported.

Such a technique that visualizes the tunnel endoscopically and then cuts the ligament blindly will likely also be associated with unnecessary neurologic complications. Management of these patients’ problems is complex, requiring thorough preoperative sensory and psychological pain evaluation and careful intraoperative microsurgical assessment of their injury. Peripheral nerve surgical techniques of neurolysis, neuroma-in-continuity assessment, nerve grafting, neuroma management, and muscle flap transposition will provide reliable improvement in the majority of these patients.

The simplicity of carpal tunnel surgery has been stressed in the literature. However, increasing awareness of the frequency and significance of complications associated with this surgery will encourage greater respect for the procedure.

ACKNOWLEDGMENT

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