Evidence-Based Medicine: Current Evidence in the Diagnosis and Management of Carpal Tunnel Syndrome

Steven J. Hermiz, M.D.
Loree K. Kalliainen, M.D., M.A.

Chapel Hill, N.C.

Learning Objectives: After studying this article, the participant should be able to: 1. Create a safe and effective plan for management of carpal tunnel syndrome. 2. Support his or her rationale for the use of diagnostic tests. 3. Discuss elements of management that have been controversial, including anesthesia, the use of a tourniquet, postoperative pain control, and cost of care.

Summary: This is the fourth MOC-PS CME article on carpal tunnel syndrome. Each of the prior three has had a slightly different focus, and the reader is invited to review all to generate a comprehensive view of the management of this common, and often controversial, topic. The operative goal—to release the transverse carpal ligament—is straightforward: diagnosis, cause, and technique have generated more vibrant discussions. (*Plast. Reconstr. Surg.* 140: 120e, 2017.)

PREOPERATIVE ASSESSMENT

History

Carpal tunnel syndrome, compression of the median nerve at the level of the transverse carpal ligament, is the most common compressive neuropathy, present in approximately 4 percent of adults in the United States.[1] Patients may present with a variety of symptoms and signs; the key to the correct diagnosis is a thorough history and physical examination. Classically, the patient complains of numbness and tingling in the median nerve distribution. Numbness can be intermittent or constant, with constant symptoms being consistent with more advanced disease.[2] Night wakening because of symptoms may progress to daytime symptoms as the disease process worsens.[3] Other common symptoms include dropping things, subjective hand swelling, and weakness with pinch and grip.[2]

Physical Examination

The physical examination should begin with observation of posture, habitus, limb deformity, upper extremity edema, skin color and temperature, range of motion, and muscle atrophy. Pain proximal to the carpal tunnel should be evaluated in greater depth, as other conditions involving the median nerve can confuse the clinical picture. Consider the double-crush phenomenon, where a nerve may be compressed in more than one spot along its path, or pronator syndrome, where altered palm sensation and weakness with grip can be confused with carpal tunnel syndrome. Carpal tunnel release performed in isolation in these situations would incompletely address the underlying cause. Bilateral motor testing should be performed. When assessing thenar muscle strength, the clinician should test thumb abduction to diagnose weakness, as the abductor pollicis brevis is innervated solely by the median nerve.[4,5]

Sensory testing includes functional tests (i.e., two-point discrimination) and provocative tests: Phalen wrist flexion test, Tinel percussion test, and Durkan compression test.[6,7] The sensitivity and specificity of the Phalen test range from 68 to 70 percent and 73 to 83 percent, respectively.[8] The sensitivity and specificity of the Tinel test range from 20 to 50 percent to 76 to 77 percent, respectively.[8] The sensitivity and specificity of the Durkan test are 87 and 90 percent, respectively.[9] A novel test, yet to be widely adopted, is the scratch collapse test.[10,11] The examiner applies medially directed force against resisted external shoulder rotation, lightly scratches the skin

From the Division of Plastic Surgery, University of North Carolina.
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over the nerve being examined, and reapplies force. A positive test is defined by loss of the patient's ability to resist the medially directed force on the affected side. The physiology underlying this phenomenon is unproven but may be related to a "cutaneous silent period" elicited in skeletal muscle by applying a noxious stimulus over a functionally impaired nerve.[12] In the experience of Cheng et al., the scratch collapse test is more sensitive than the Tinel or Phalen test (64 percent compared with 32 and 44 percent), but specificity was 99 percent for all three examinations.[10] Blok et al. found sensitivity to be lower at 32 percent but with a substantial interrater reliability of 0.63.[11]

The Semmes-Weinstein monofilament examination has been proposed as an adjunctive test. The sensitivity and specificity vary widely depending on the testing method: sensitivity has ranged from 13 to 98 percent and specificity has ranged from 15 to 97 percent.[13] As with other diagnostic examinations, sensitivity and specificity are positively correlated with disease severity.

Diagnostic Modalities

Carpal tunnel syndrome is a clinical diagnosis, and adjunctive tests are most useful when the diagnosis is in question or confounded by another disease process.[2,3,14] Electrodiagnostic studies are the most commonly used modality for assessment of carpal tunnel syndrome.[5,8,15] They are useful when there is a low pretest probability of carpal tunnel syndrome but suspicion of a different peripheral nerve disorder. They add little to the diagnosis of carpal tunnel syndrome.[15] They are no more sensitive or specific than physical examination tests (49 to 84 percent sensitive and 95 to 99 percent specific), are expensive, and can be uncomfortable.[5,16] Although professional societies' clinical practice guidelines have advocated their use, publications since the 1990s have failed to show superiority to combinations of other physical examination tests.[7,16–18] Surveys of hand surgeons have shown that many surgeons do not order them and many who do, do so for fear of medicolegal retribution.[7]

Imaging studies may play a role in the diagnosis of carpal tunnel syndrome, but no consensus has yet been reached.[8] Ultrasound is noninvasive, portable, rapid, painless, and safe.[19] The diagnostic criteria include hypoechoic median nerve cross-sectional area greater than 10 mm^2.[19] The sensitivity and specificity of ultrasound in the diagnosis of carpal tunnel syndrome are 82 and 92 percent, respectively.[8,19]

Magnetic resonance imaging has been used to measure the cross-sectional area and microarchitecture of the median nerve, but the procedure is expensive and time-consuming, and may not be tolerable for patients with claustrophobia.[8,20] Sensitivity and specificity of magnetic resonance imaging range from 65 to 83 percent and 78 to 80 percent, respectively.[8] Computed tomography has also been proposed for diagnosing carpal tunnel syndrome. It has the advantages of measuring altered density of a compressed median nerve and the ability to find space-occupying lesions but the same disadvantages of magnetic resonance imaging with the addition of radiation exposure. Sensitivity and specificity are 67 percent and 87 percent, respectively.[8]

The incorporation of expensive and time-consuming adjunctive modalities has not significantly improved the diagnosis, treatment, or outcome of carpal tunnel syndrome; it is reasonable to avoid them when the history and physical examination are consistent with carpal tunnel syndrome.

Making the Diagnosis

Multiple studies have calculated the sensitivity and specificity of individual elements of the physical examination. No single test in isolation is sufficient to make a definitive diagnosis of carpal tunnel syndrome: integration of multiple findings is likely to lead to the maximum likelihood of arriving at a correct diagnosis and therefore having the best chance of a successful treatment outcome. Levine et al. developed an 11-item questionnaire in an attempt to correlate symptom severity and disability with treatment outcome.[4] For greater utility in clinical practice, it was shortened to a six-item symptom scale focusing on symptoms rather than function.[21] Atroshi et al. concluded that the six-item carpal tunnel syndrome scale had good reliability and validity.[21] A Web-based carpal tunnel syndrome questionnaire has been developed by Bland et al.[22] It estimates the probability of diagnosing carpal tunnel syndrome with a sensitivity and specificity of 78 percent and 68 percent, respectively. Another six-item scale, the carpal tunnel syndrome-6, was developed using a Delphi method.[15,23] Key elements of diagnosis include median nerve distribution numbness, nocturnal wakening, thenar atrophy, a positive Phalen test, loss of two-point discrimination, and a positive Tinel sign.[15] By establishing a high degree of consensus among clinical experts, a gold standard has effectively been created for the diagnosis of carpal tunnel syndrome. This is a form of probabilistic reasoning similar to methods used to diagnose medical syndromes such as rheumatoid arthritis and polymyalgia rheumatica.

Coexisting Conditions

Type 1 diabetes mellitus predisposes the patient to musculoskeletal disorders of the upper extremity, including carpal tunnel syndrome.[2,24,25]

Medical conditions associated with carpal tunnel syndrome include hypothyroidism, hemodialysis, pregnancy, obstructive sleep apnea, obesity, and rheumatoid arthritis.[25–27] Carpal tunnel syndrome is the most common neuropathy seen in rheumatoid arthritis patients. Carpal tunnel syndrome of pregnancy presents most commonly in the third trimester because of edema around the median nerve.[25] Distal radius fractures and volar lunate dislocations are two acute conditions that increase the risk of development of carpal tunnel syndrome.[5]

The cause of carpal tunnel syndrome is multifactorial, with physical and genetic factors playing a larger role than occupational ones, but it has been associated with certain occupations.[25–28] Occupational risk factors believed to be associated with an increased risk of carpal tunnel syndrome include excessive vibration, nonneutral wrist postures, and vigorous hand activity involving both high force and high repetition. Frozen-food workers have the highest incidence of carpal tunnel syndrome compared with other occupations.[26] Typing has not been found to be associated with the development of carpal tunnel syndrome.[26,28,29] In an effort to reduce work-related risk factors and protect workers, the American Conference of Governmental Industrial Hygienists established an acceptable combination of hand activity and peak force, known as a threshold limit value or hand activity level.[30]

Nonoperative Treatment

Most patients suffering from mild to moderate symptoms (i.e., without neurologic deficit) of carpal tunnel syndrome respond to conservative management.[5,31] Up to two trials of nonoperative treatment may be appropriate for patients with carpal tunnel syndrome.[18] In a 2003 Cochrane Review, the effectiveness of nonsurgical treatment was reviewed.[31] The overall data are of low quality, but splints, therapeutic ultrasound, yoga, and oral steroids improved symptoms; diuretics, nonsteroidal anti-inflammatory drugs, and vitamin B_6 (pyridoxine) did not.[31] Nonoperative management is beneficial when the diagnosis is in question.

Local corticosteroid injections improve symptoms related to carpal tunnel syndrome, but the effects are short-lived.[32] Even if the effect is not lasting, a positive response to injection may signal a higher likelihood of benefit of surgery.[33] Incomplete effect of an injection does not, however, predict poor response to surgery.[33] Although the use of nonoperative treatments has been recommended before consideration of surgery, no strong evidence supports multiple trials of injections.[18]

PROCEDURE

Shared Decision-Making

Decision-making has transitioned from a more paternalistic to a more shared process over the past several decades.[34] In quality-of-life conditions such as arthritis or carpal tunnel syndrome, patients appear to prefer a more active decision-making role than when facing life-threatening disorders.[34,35] Shared decision-making includes provision of information and decision aids, allowing time to think about options, accurate assessment of patient expectations, and appropriate education regarding options and realistic outcomes of each.[34,36–39]

Facility Type, Safety, and Outcomes

Historically, most carpal tunnel releases have been performed in an operating room under general or regional anesthesia.[40] Performing carpal tunnel surgery in a main operating room is up to four-times more expensive than in an ambulatory center or clinic procedure room and is significantly less efficient.[40–42] Bismil et al. developed a "total one-stop (i.e., patient seen and treated in one appointment) wide-awake" hand surgery service and found it more efficient and cost-effective compared with hospital-based care.[43] Cagle et al. compared the outcomes of 826 patients with and without medical comorbidities who underwent carpal tunnel release under local anesthesia in a minor-procedure room.[44] Comorbidities included diabetes, rheumatoid arthritis, radiculopathy, polyneuropathy, gout, and thyroid disease. Diabetic patients took longer to improve but had similar outcomes compared with patients without diabetes by 6 weeks. Workers' compensation patients were included; they had worse symptom scores at 2 and 6 weeks, but there were no differences between workers' compensation and non–workers' compensation scores by 3 months.

Anesthesia

Hand surgery can be performed with local anesthesia (with or without sedation), intravenous regional, or general anesthesia. The WALANT (wide-awake, local anesthesia, no tourniquet) technique is becoming increasingly popular, with demonstrable improvement in postoperative nausea and vomiting, decreased cost, increased procedural efficiency, and high patient satisfaction.[45,46] Reduction of injection-associated pain can be achieved with slow injection of 20 ml of bicarbonate-buffered lidocaine using a 27-gauge

needle into the volar wrist and allowing adequate time (20 to 30 minutes) for the anesthetic to take effect.[45–47] Yeo and colleagues prospectively randomized patients to receive hyaluronidase powder in the local anesthetic, significantly reducing tourniquet time and postoperative pain.[48] The use of epinephrine in local anesthetic is safe and effective in prolonging the duration of anesthesia and minimizing local blood loss and has not been associated with skin necrosis or systemic absorption in multiple studies.[40,45,46,49–51]

Lee and colleagues conducted a prospective study on remifentanil-propofol continuous sedation involving 80 patients who underwent carpal tunnel release under local anesthesia with tourniquet use. They concluded that continuous sedation produced less pain and anxiety during the operation, with high patient satisfaction.[52] Rozanski and colleagues conducted a prospective observational study with surgery with and without sedation; they had equivalent patient satisfaction with surgery.[53] A prospective cohort study was conducted by Davison et al. comparing carpal tunnel release under local anesthetic only in a clinic to endoscopic release under sedation in an operating room. Both groups of patients were highly satisfied with their procedures, and 93 percent would have the same type of procedure, but the sedation group had higher use of opioids, more nausea and vomiting, more preoperative anxiety, and spent more time in the hospital.[54]

Hemostasis and the Tourniquet

Pneumatic tourniquets create a bloodless field in hand surgery but are only tolerated for short periods in awake patients because of discomfort.[43,50,55,56] Sedation is often preferred if tourniquets are used.[46] In a study comparing tourniquet to local anesthetic with epinephrine, Ralte and colleagues found that the tourniquet group subjects had significantly more intraoperative pain and discomfort.[50] The pneumatic tourniquet can be placed in the upper arm, distal forearm, or wrist. Placement at the distal forearm is safe and relatively painless when combined with a complete nerve block of the distal forearm.[56] The necessity of a tourniquet has been increasingly questioned given the safety and efficacy of epinephrine added to local anesthetic.[40,43,53] Tourniquets are not risk free: associated complications include digital ischemia, neurovascular injury, and deep venous thromboemboli.[50,51] It follows that if a tourniquet is not used, sedation allowing tolerance of the tourniquet would not be needed.

Timing of tourniquet deflation after carpal tunnel release depends on surgeon preference. Hutchinson and Wang prospectively compared 36 wrists in 18 patients undergoing bilateral carpal tunnel release. They concluded that there was no advantage with respect to hemostasis or postoperative pain relief/ecchymosis if the tourniquet was released before wound closure.[57]

Procedure

Division of the transverse carpal ligament to relieve pressure on the median nerve has been long recognized as an effective and safe treatment.[58,59] Many variations of the basic technique have been described, and there is no single ideal method.[59] An acceptable technique should combine high efficacy, low rates of complication and recurrence, ease of performance, high patient satisfaction, and an acceptable cost profile. The main development in open procedures has been reduction of the incision size from one crossing the wrist crease to a "mini" approach limited to the palm.[60,61] Figure 1 shows a safe incision location in the midpalm on the ulnar aspect of the concavity between the thenar and hypothenar muscles. Figure 2 demonstrates effective release of the transverse carpal ligament. The endoscopic technique was developed to decrease complications of the open procedure, primarily that of scar discomfort.[62] It, however, involves a learning curve and requires specialized equipment.

The risks and benefits of open compared to endoscopic releases have been continuously debated in the literature. Endoscopic carpal tunnel release and open carpal tunnel release are both highly effective in relieving the symptoms of nerve compression.[59] Open release requires minimal equipment and allows more complete visualization of the nerve. It is more straightforward to perform in a variety of settings and may have a shorter learning curve. Wong and colleagues prospectively compared the endoscopic technique to the limited open technique in patients with bilateral carpal tunnel syndrome undergoing simultaneous release. They concluded that the limited open group had less scar tenderness, and less thenar and hypothenar (pillar) pain compared with the endoscopic group.[63] In a similar study comparing endoscopic and limited open techniques, patients preferred the endoscopic technique because of less scar or hypothenar pain, despite both techniques having similar improvements in symptoms.[64] Thoma and colleagues found that

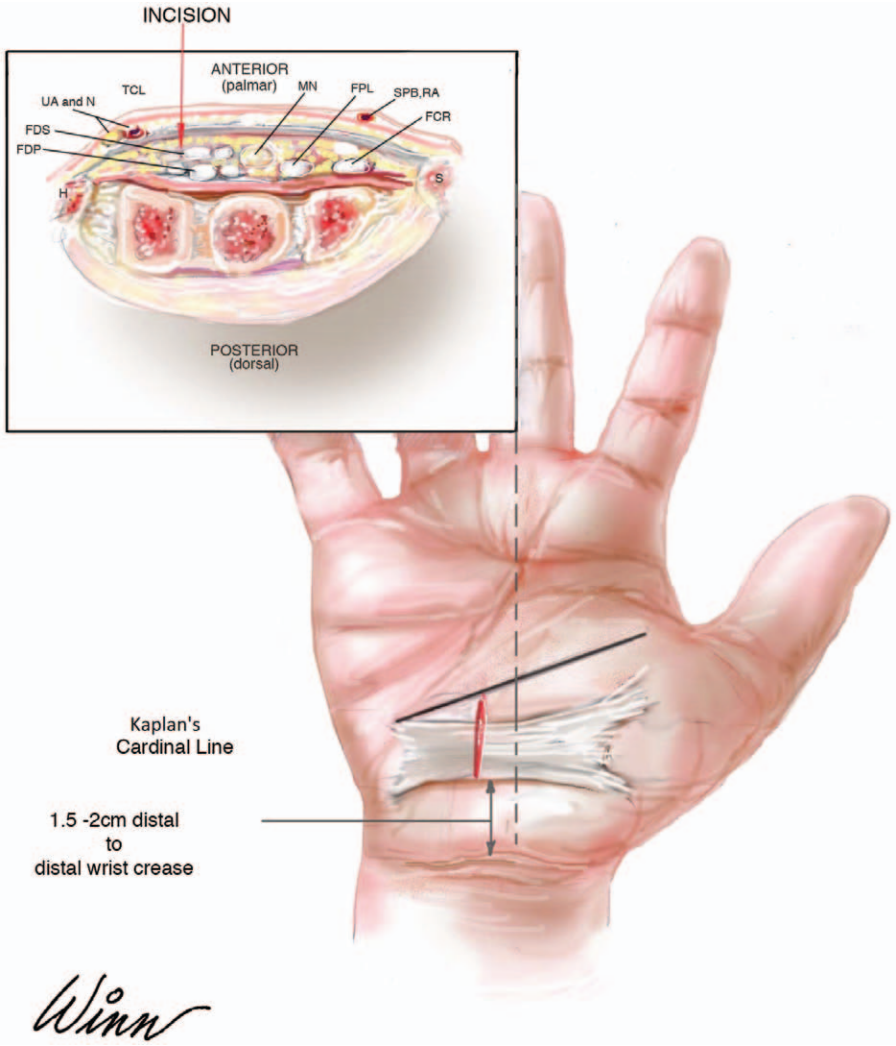

Fig. 1. Palmar incision for mini-approach carpal tunnel release with cross-section (*inset*) showing the senior author's (L.K.K.) preferred line of incision in the transverse carpal ligament. *FDP*, flexor digitorum profundus; *FDS*, flexor digitorum superficialis; *UA*, ulnar artery; *N*, nerve; *TCL*, transverse carpal ligament; *MN*, median nerve; *FPL*, flexor pollicis longus; *SPB*, superficial palmar branch; *RA*, radial artery; *FCR*, flexor carpi radialis. (Published with permission from illustrator, Bill Winn.)

in the short term (12 weeks), endoscopic carpal tunnel release provided better grip and pinch strength compared with open carpal tunnel release, but there was no difference by 1 year.[65,66] In a recent meta-analysis, Zuo and colleagues concluded that endoscopic carpal tunnel release and open carpal tunnel release have similar benefits and complication rates despite past studies showing increased major complications rates in endoscopic carpal tunnel release.[59]

The larger open carpal tunnel release incision may be associated with more scar hypertrophy and tenderness, the need for longer immobilization and recovery time, and more time away from work.[59,63,66,67] Cagle et al. reported a 16 percent rate of negative postoperative endpoints (pillar and palm pain, wound dehiscence, wound infection, and persistent symptoms) after open carpal tunnel release.[44]

The complication rates of endoscopic carpal tunnel release range between 2 and 35 percent, and include injury to the median or ulnar nerve, incomplete division of the ligament, and recurrence.[59,67,68] In a meta-analysis of 13 randomized controlled trials comparing the safety and efficacy of endoscopic and open carpal tunnel release, endoscopic carpal tunnel release had an increased risk of reversible postoperative median nerve injury (transient neurapraxia), but both techniques were equally safe and effective.[46,48–51,55]

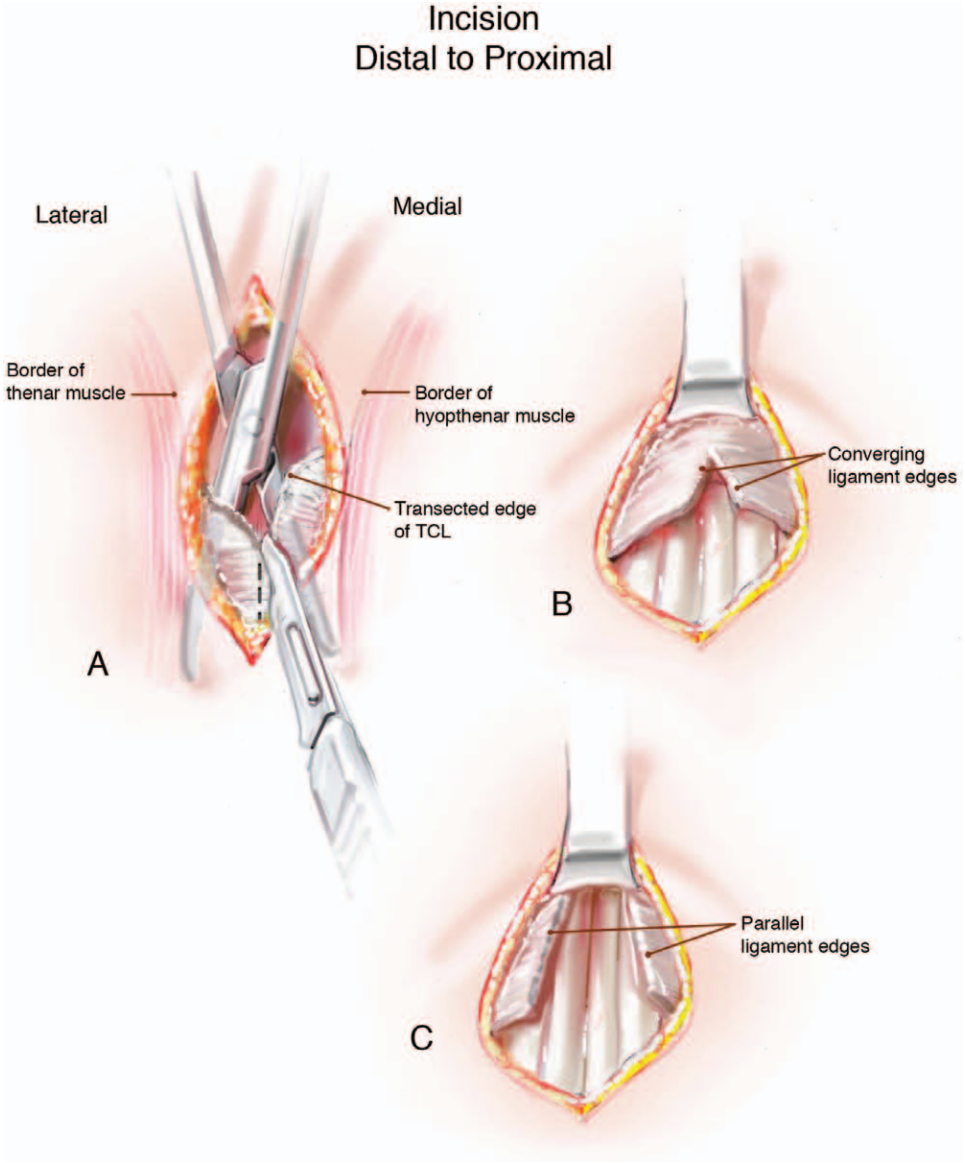

Fig. 2. Release of transverse carpal ligament (*TCL*). (*Above*, *left*) A hemostat or small tissue scissors is inserted beneath the distal edge of the transverse carpal ligament and gently spread. A no. 15 blade scalpel is used to gently divide the distal ligament. (*Above*, *right*) Looking proximally, the surgeon can see the leaves of the transverse carpal ligament converging, demonstrating incomplete release. (*Below*) When the TCL has been completely released, the edges of the transverse carpal ligament should assume a parallel position. (Published with permission from illustrator, Bill Winn.)

POSTOPERATIVE CARE

Pain Management

Postoperative analgesic treatment traditionally consists of opioids with or without nonsteroidal antiinflammatory drugs (i.e., acetaminophen). Postoperative edema and inflammation contribute to postoperative pain and discomfort. Husby and colleagues compared acetaminophen, naproxen, and a placebo for postoperative pain control in patients undergoing either open carpal tunnel release or Dupuytren's contracture release. They concluded that there was no difference in pain control or swelling between groups.[69] Rodgers et al. performed a survey of postoperative opioid use in hand surgery patients. An average of 10 pills per patient were used, and most subjects used opioids for no more than 2 days.[70] Multiple studies have shown that postoperative opioids are overprescribed, making them available in the

community for diversion and increasing the likelihood of habituation, overdose, and death.[71,72]

Dressings

Williams and colleagues prospectively randomized 100 patients to wear a bulky postoperative dressing for 24 hours or for 2 weeks.[73] There was no difference in postsurgical pain or wound healing and thus they recommend that the patients wear a bulky dressing for at least 24 hours and then transition to a light dressing for the next 2 weeks as desired.[73] In a similar study, Ritting et al. used a bulky dressing replaced by an adhesive bandage between 40 and 72 hours versus a bulky dressing for 2 weeks. They concluded that replacing the dressing with an adhesive strip did not lead to increased wound complications.[74]

Splinting

Three high-level studies have shown that postoperative wrist splints after carpal tunnel release surgery are not necessary.[75–77] The theoretical benefits of splinting include prevention of bowstringing of the flexor tendons, median nerve entrapment, and wound dehiscence, but those concerns have not been supported. Immobilization does not decrease scar pain or improve pinch strength and it may delay functional recovery.

Rehabilitation

Postsurgical hand therapy has debatable benefit, but is commonly used. Provinciali and colleagues randomized 100 patients to receive multimodal rehabilitative treatment or a progressive home exercise program designed to gradually increase strength and endurance. The multimodal rehabilitative group showed a quicker return to work and improved motor dexterity than the home exercise program group, but the differences were absent by 3 months.[78] In a similar study, Pomerance et al. randomized 100 patients to receive home exercises or home exercises plus a therapist-guided program for 2 weeks. They found no statistical differences between the two groups in time to return to work, grip strength, pinch strength, and pain scores.[79] Fagan and colleagues compared high arm elevation to a standard sling and found no significant difference in swelling or pain between the two groups.[80]

Outcome and Satisfaction

The outcome of carpal tunnel release is generally good to excellent.[60,61,81,82] Poor outcomes have been associated with perceived disability, workers' compensation, active legal claims, a dysfunctional doctor-patient relationship, diabetes, thoracic outlet syndrome, double-crush phenomenon, alcohol and tobacco use, a normal preoperative nerve conduction study, thenar atrophy, depression, poor coping, and lack of fulfillment of expectations.[35,37,39,83]

Cost of Care

Increasing attention is being paid to the triple-aim philosophy, whereby quality, satisfaction, and cost are optimized at societal and patient levels.[84] Carpal tunnel release is effective and safe. Patients are generally satisfied with the procedure. Outcomes have not been markedly and lastingly improved by adding expense by means of the endoscopic technique, performing the procedure in a hospital, or using sedation or general anesthesia.[16,41,44,85] Given similar benefit, procedural value can be best increased by decreasing the total cost of care (where value = benefit/cost). Multiple studies have demonstrated the significant cost and time savings of carpal tunnel surgery when performed in the clinic versus ambulatory care or hospital settings in the United States and Canada.[16,41,42,44,86,87] Studies of other operative hand conditions support the negative effects of facility and individual surgeon preferences as drivers of cost unrelated to improvement in outcome.[87,88] Procedures performed with local anesthetic alone have a 27 percent cost reduction compared with sedation, and local anesthetic can be injected with minimal discomfort.[16,89] There is no evidence that carpal tunnel release performed under local anesthetic in a clinic setting is associated with increased infection, decreased satisfaction, or substandard outcomes.[42,44]

CONCLUSIONS

Surgeons are being increasingly required to demonstrate rationale for therapy. Although carpal tunnel release is the most common hand operation performed in the United States, with annual direct and indirect costs in the billions of dollars, there is still wide variation in practice. For patients with classic signs and symptoms of isolated carpal tunnel syndrome, electrodiagnostic tests should be discouraged. Performing carpal tunnel release in lower-acuity settings such as clinic treatment rooms is safe, efficient, cost-effective, and satisfactory to patients. Minimizing the use of opioid pain medication is reasonable and safe. Further research and quality improvement efforts should focus on changing physician practices and addressing systemic impediments to change.

Loree K. Kalliainen, M.D., M.A.
7043 Burnett Womack Building
Campus Box 7195
Chapel Hill, N.C. 27599-7195
loree_kalliainen@med.unc.edu

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