Endoscopic Carpal Tunnel Release: A Review of 753 Cases in 486 Patients

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Background: Endoscopic carpal tunnel release is gaining increasing acceptance relative to the standard open carpal tunnel release for the treatment of carpal tunnel syndrome. Concerns about endoscopic carpal tunnel release include effectiveness of therapy and complication rates. This study attempted to evaluate outcomes of endoscopic carpal tunnel release in a large patient cohort.
Methods: Four hundred eighty-six patients (753 hands) with carpal tunnel syndrome who underwent endoscopic carpal tunnel release by a single surgeon were reviewed retrospectively. Data included demographics, subjective complaints, prior interventions, preoperative examination findings, and postoperative follow-up. All follow-up data were obtained from a single, independent, occupational therapy clinic.
Results: Median patient age was 48 years. Three hundred seventy-seven patients were gainfully employed at presentation, and 206 filed a worker's compensation claim. Median symptom duration was 2 years. Nonoperative therapy was ineffective in 151 patients. Preoperative nerve conduction studies were consistent with carpal tunnel syndrome in 472 patients (97 percent); all patients had either physical examination findings or nerve conduction studies consistent with carpal tunnel syndrome. Four hundred eighty-six patients (100 percent) obtained symptom relief. Complications included one transient median nerve neurapraxia, six complaints of residual pain, and one complaint of hypersensitivity. Worker's compensation patients and non–worker's compensation patients returned to work full-duty at similar times postoperatively. Ninety percent of employed patients returned to their original occupation.
Conclusions: The authors' data indicate that an endoscopic approach for the treatment of carpal tunnel syndrome is safe and effective. Patients demonstrated a high return-to-work rate and an extremely low complication rate. The data challenge the belief that endoscopic carpal tunnel release results in higher complication rates. (*Plast. Reconstr. Surg.* 117: 177, 2006.)

Carpal tunnel syndrome is the most frequently encountered compression neuropathy of the upper extremity, with a prevalence of 1 percent in the general population.[1] The first open carpal tunnel release is credited to Learmonth in 1929 and was later popularized by Phalen et al. in the 1950s.[2–4] Since then, open carpal tunnel release has been the standard of care for the treatment of carpal tunnel syndrome, because of extensive anatomical exposure that results in efficacious and safe release of the transverse carpal ligament. The most commonly reported complications of the open technique include hypertrophic or painful scars, pillar pain, slow return of pinch and grip strength, and slow return to activities of daily living or work.[5–7]

Endoscopic carpal tunnel release has been developed in principle to obviate these problems. The initial description was in 1989 by Okutsu et al. Several other techniques for endoscopic carpal tunnel release have been described since that time, using either one or two entry portals.[8–10] Endoscopic approaches appear to offer potential advantages related to reduced scarring, minimized postoperative pain, less initial loss of grip and pinch strength, faster recovery, and better cosmesis.

Several studies in the literature demonstrate that endoscopic carpal tunnel release fulfills its objective in reducing pain, with faster return to activities of daily living and less scar tenderness than open carpal tunnel release.[11–13] However,

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skepticism has been expressed by surgeons regarding the safety of this technique, with reports documenting an increased rate of major neurovascular injuries.[14–17] Controversy remains, as reports in the literature continue to question the safety and efficacy of endoscopic carpal tunnel release as compared with open carpal tunnel release. A persistent underlying motif, however, appears to be that results of endoscopic carpal tunnel release are most often limited by the surgeon's experience.

This study represents a 13-year retrospective review of endoscopic carpal tunnel release in 486 patients (753 hands) diagnosed with carpal tunnel syndrome. Our aim is to present our experience with endoscopic carpal tunnel release in an effort to evaluate our outcomes, specifically, regarding the long-term safety and efficacy of this approach.

PATIENTS AND METHODS

A retrospective review was conducted of all patients undergoing endoscopic carpal tunnel release for carpal tunnel syndrome by a single surgeon (D.A.C.) during the period 1990 through 2003. The Agee uniportal endoscopic technique (currently the Micro-Aire uniportal system; Micro-Aire Surgical Instruments, Charlottesville, Va.) was used for all cases. Follow-up was accomplished at a single occupational therapy clinic not affiliated with this surgical practice. The exclusion criterion used was follow-up at another occupational therapy clinic, to improve consistency in objective evaluation of surgical outcomes.

Data extracted from the patient record included demographics, subjective complaints on presentation, history of prior interventions, physical examination findings, results of nerve conduction studies, and follow-up data. Demographic data extracted included gender, race, hand dominance, age, labor type (manual, nonmanual, retired, unemployed), worker's compensation status, medical comorbidities, and history of tobacco or alcohol use. Subjective complaints included symptomatic side, weakness, pain, clumsiness, tingling, awakening from sleep by symptoms, exacerbation of symptoms by driving, and duration of symptoms.

Patients were polled on prior interventions, such as corticosteroid injection, splinting, prior surgery, use of nonsteroidal anti-inflammatory drugs and/or vitamin B_6, therapy, work modification, and others, and response to such interventions. The presence of "unrelated hand problems" was also documented. Physical examination data included the presence or absence of hand/wrist scars, thenar atrophy, Tinel's sign, Phalen's sign, positive median nerve compression test, decreased light touch sensibility, and degenerative arthritis. Follow-up data included time to final follow-up, symptomatic relief, scar tenderness, return to light and regular duty at work, final work status, and complications.

A thorough review of preoperative nerve conduction study data was accomplished. Nerve conduction studies were carried out by independent entities and often were carried out before referral to our clinic. Data regarding return to work were tabulated, and median times for return to light and regular duty were calculated. Cohorts were compared using the Mann-Whitney U test, with significant differences being detected at a value of $p < 0.05$.

RESULTS

Demographics

A total of 486 patients undergoing endoscopic carpal tunnel release by a single surgeon (Caplin) during the 13-year period represented in this report met the inclusion criteria. This cohort represents 753 hands. Bilateral procedures were accomplished in 292 patients. There were 332 female patients and 154 male patients. The majority of patients ($n = 438$) were Caucasian, with 47 of African descent and one of Asian descent. Hand dominance was right in 455 and left in 29, with the two remaining patients claiming to be ambidextrous. The mean age of the cohort was 49.5 years (median, 48 years; range, 19 to 87 years). Work status was defined as unemployed in 61, retired in 48, employed in an occupation involving manual labor tasks in 122, and employed in an occupation involving nonmanual labor tasks in 255. Two hundred six patients had filed a worker's compensation claim. Patient demographics are summarized in Table 1.

Medical comorbidities included hypertension in 110 patients, diabetes mellitus in 28, coronary artery disease in 29, prior hand trauma in four, thyroid disease in 13, and cervical spine disease in 18. One hundred fifteen patients claimed to be smokers, and all denied significant alcoholic beverage consumption.

Subjective Complaints

Forty-six patients reported complaints related to only the left hand and 93 reported complaints related to only the right hand. Bilateral symptoms were present in the remainder of the cohort, with

Table 1. Demographics of 486 Patients Undergoing Endoscopic Carpal Tunnel Release

Characteristic	No. of Patients
Sex	
Female	332
Male	154
Race	
Caucasian	438
African American	47
Asian	1
Age, years	
Mean	50
Median	48
Range	19–86
Smoking status	
Smokers	115
Nonsmokers	371
Hand dominance	
Right-handed	455
Left-handed	29
Ambidextrous	2
Worker's compensation status	
Worker's compensation	206
Non–worker's compensation	280
Employment type	
Laborer	122
Nonlaborer	364

91 patients reporting greater symptoms in the left hand, 229 patients reporting greater symptoms in the right hand, and 27 patients reporting equal symptoms bilaterally (Fig. 1).

Symptomatic complaints varied widely. Hand weakness was reported by 347 patients. Hand pain was reported by 223 and clumsiness was noted by 12. Numbness and tingling were the most common presenting complaints, with 470 and 460 patients complaining of them, respectively. Four hundred twenty-eight patients reported that they were awakened from sleep on a routine basis by their symptoms. Three hundred fifty-four patients reported that symptoms were exacerbated by driving. Symptom duration for the cohort before presentation to our clinic was a mean of 3.86 years (median, 2 years; range, 7 days to 30 years).

Prior Interventions

The vast majority of patients had attempted other interventions before their presentation to our clinic. Ninety-five patients had undergone at least one corticosteroid injection into the carpal canal. Splinting at night, during labor, or at all times was attempted by 339. Nonsteroidal anti-inflammatory drugs were used by 311, and 100 patients had attempted therapy with high-dose vitamin B_6. Thirty-five patients had used prior physical or occupational therapy. Of patients using nonoperative therapy, 420 reported that they had either no response (151 patients) or only some response (269 patients) to the therapy.

Twenty-five patients had a prior surgical intervention for carpal tunnel syndrome performed elsewhere. Seven of these patients had an endoscopic release attempted and 18 underwent release by means of a traditional open approach. Nineteen of these patients underwent prior right carpal tunnel release, and three of them required a revision by the senior author. Prior left carpal tunnel release was performed on six patients, two of whom required revision surgery by the senior author. Therefore, the revision group included five patients; three patients had a prior endoscopic procedure and two had a prior open procedure. Eighteen patients with prior open releases underwent endoscopic carpal tunnel release by our group on the contralateral hand and could report

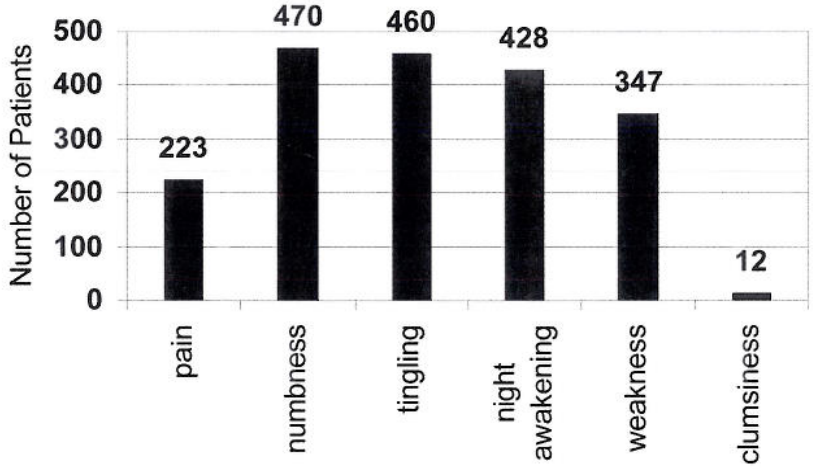

Fig. 1. Subjective complaints on initial presentation by patients with carpal tunnel syndrome (n = 486).

on their perception of comparative outcome at final follow-up.

Examination Findings

Patients underwent an initial physical examination by the senior author during the first clinical visit after subjective complaints were assessed (Fig. 2). Patients were initially subjected to median nerve compression testing and two-point discrimination testing and were also assessed for evidence of thenar atrophy. If positive findings were present during this testing, in conjunction with positive nerve conduction test results, patients were determined to have carpal tunnel syndrome. If patients did not demonstrate a positive median nerve compression test or have sensory changes, they underwent further provocative examinations including assessment of Tinel's sign and Phalen's testing. Therefore, not all patients underwent Tinel's and Phalen's testing.

Scars (not otherwise specified) were noted on the left hand of 11 patients, the right hand of 33 patients, and bilaterally in four patients. Thenar atrophy was present bilaterally in 130 patients, on the left in 21, and on the right in 76. A positive median nerve compression test was noted bilaterally in 303 patients, on the left only in 46, and on the right only in 81. Decreased light touch sensibility was noted bilaterally in 287 patients, on the left in 40, and on the right in 92. Evidence of degenerative arthritis was noted, on physical examination and with review of plain radiographs, bilaterally in 99 patients, on the left only in five, and on the right only in 10.

Nerve Conduction Studies

A total of 472 patients underwent preoperative nerve conduction studies. Of the 14 patients who did not, 12 had a positive median nerve compression test and all 14 had decreased light touch sensitivity on examination; 13 complained of tingling, 12 of numbness, and 11 of weakness. Nine of these patients also had exacerbation of symptoms with driving, and 12 were awakened from sleep by their symptoms on a regular basis. All 14 patients who did not undergo preoperative nerve conduction studies were uninterested in pursuing these studies and met clinical criteria for carpal tunnel syndrome.

Of the 472 patients who underwent nerve conduction studies, only nine (1.9 percent) had results inconsistent with carpal tunnel syndrome ("negative" results), despite physical examination findings consistent with carpal tunnel syndrome. Six of these patients had negative nerve conduction studies bilaterally and yet underwent endoscopic carpal tunnel release (two bilateral procedures, one left-sided, and three right-sided). Two patients with exclusively left-sided symptoms had left side only nerve conduction studies that were negative yet underwent left endoscopic carpal tunnel release, and one patient with exclusively right-sided symptoms with a negative right-sided nerve

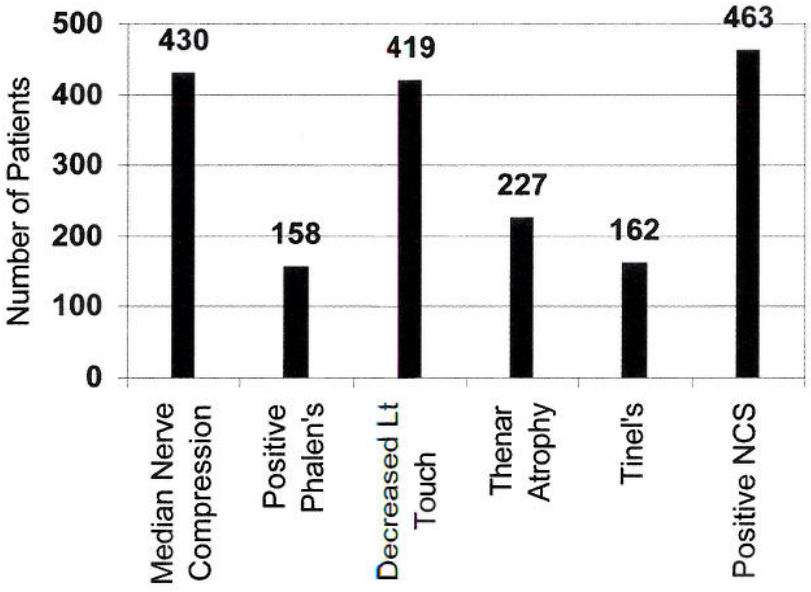

Fig. 2. Objective findings on initial physical examination for patients with carpal tunnel syndrome (n = 486).

conduction study underwent right endoscopic carpal tunnel release.

Results of Endoscopic Carpal Tunnel Release

All patients were evaluated at a single, independently owned and operated occupational therapy clinic by a certified hand therapist. Final follow-up was accomplished at a mean of 226 days (median, 63 days; range, 1 to 2553 days). At final follow-up, all 486 patients reported significant or complete relief of symptoms in all 753 hands. Worker's compensation patients were allowed to return to work with one-handed duty restrictions 1 to 2 days after surgery when such restricted duty was available at their place of employment. They returned to light-duty work at a median of 21 days (right) and 20 days (left) postoperatively, and non–worker's compensation patients returned to light-duty work at a median of 21 days (right) and 20 days (left). There was no difference noted between these two groups with regard to return to light-duty work ($p > 0.05$). Worker's compensation patients returned to work full-duty at a median of 43 days (right) and 42 days (left) postoperatively, and non–worker's compensation patients returned to work full-duty at a median of 42 days (right) and 40 days (left). There was no difference noted between these two groups with regard to return to regular-duty work ($p > 0.05$). Of 209 patients for whom postoperative work status was available, 188 (90 percent) were able to return to their original occupation.

Complications

There were eight complications not related to scar. These included one case of transient postoperative hand numbness in the median nerve distribution, six cases of residual hand pain similar in nature but milder in intensity to the pain before surgical release, and one case of hand hypersensitivity. These eight complaints correspond to an overall complication rate of 1.1 percent. Eighty-seven patients (12 percent) complained of occasional scar tenderness, and four (0.8 percent) complained of hypersensitivity of the scar to touch, cold, and/or heat. We report annual complication rates with a range of 0 to 8 percent, which primarily include postoperative scar complications, with overall long-term complications approximating 1 percent (Fig. 3). One patient had a recurrence (0.13 percent) and underwent a subsequent open carpal tunnel release by the senior surgeon. Of the 25 patients with prior carpal tunnel releases, 18 had previously undergone open carpal tunnel release at an outside institution. These 18 patients subsequently underwent endoscopic carpal tunnel release on the contralateral extremity by our group and uniformly reported greater satisfaction with their outcome after the endoscopic approach.

DISCUSSION

Since the 1950s, when Phalen popularized the open approach in the treatment of carpal tunnel syndrome, open carpal tunnel release has been the standard treatment for surgical decompression of the median nerve at the carpal canal.[4] It has proven to be effective, with an acceptably low rate of recurrence and complications. The advent of minimally invasive techniques in surgery has spawned interest in methods of implementing such techniques in approaching surgical problems involving the upper extremity. In the late 1980s, several authors offered different ap-

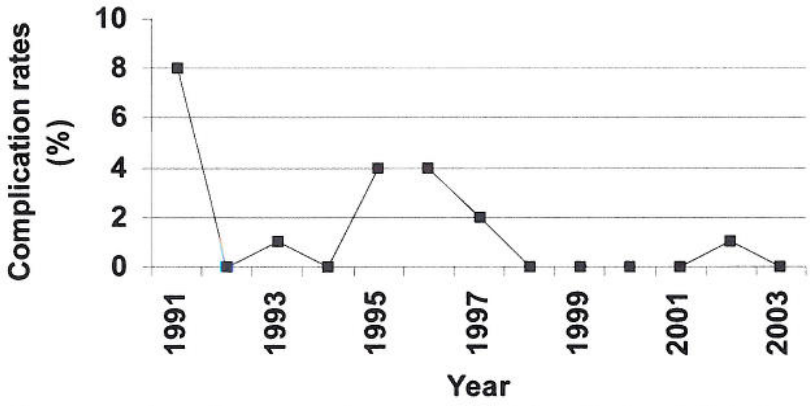

Fig. 3. Annual complication rates ($n = 486$ patients). Complications included transient hand numbness in the median nerve distribution, residual mild generalized hand pain, and hand hypersensitivity.

proaches using endoscopic techniques to address carpal tunnel syndrome.[8–10] Open procedures have been shown to result in hypertrophic and often painful scars with prolonged limitations in return to full work duty. Therefore, minimally invasive approaches were implemented in an effort to address these concerns. There have been both retrospective and prospective evaluations comparing open carpal tunnel release to endoscopic carpal tunnel release.[11,18–23] In short, both procedures have been shown to be effective; differences between outcomes have varied with regard to time to return to full work status, scar pain, cosmesis, subsequent pillar pain, long-term satisfaction, and complication rates.

Comparative studies have demonstrated earlier recovery of pinch and grip strength, earlier return to full work status, less postoperative pain, and less scarring in those treated with endoscopic carpal tunnel release.[17,18,24–26] Controversy exists as to the safety of the endoscopic approach, with some authors citing increased risk of tendon laceration, incomplete release, and damage to neurovascular structures.[2,27–31] These risks appear to be somewhat dependent on the experience of the surgeon, as several clinical studies have shown that decreased complication rates correlate with increased surgical experience.[11,28,32–34]

In an effort to address this controversy, we have retrospectively reviewed our experience with a large cohort of patients over a 13-year period with confirmed carpal tunnel syndrome. Our study details one surgeon's experience and demonstrates reproducible successful results, both subjectively and objectively, with an acceptably low complication rate. Our complication rate was 1.1 percent, and no serious complications involving laceration of nerves, vessels, or tendons were noted. Endoscopic carpal tunnel release provided relief of preoperative symptoms in 100 percent of patients. Mean follow-up was 226 days (median, 63 days; range, 1 to 2553 days). Follow-up evaluations were subjective (regarding strength, sensitivity, pain, and cosmesis) and objective; an independent hand therapist performed all evaluations. Our results suggest that endoscopic carpal tunnel release is an effective and safe approach to the patient with carpal tunnel syndrome, when performed by an experienced surgeon.

Immediate postoperative pain after endoscopic carpal tunnel release was minimal. Patients were offered a limited prescription of oxycodone or propoxyphene postoperatively and a cyclooxygenase-2–selective nonsteroidal anti-inflammatory drug within the first 2 weeks. Most patients, however, reported using little or no postoperative analgesic or only acetaminophen for pain.

In reporting success, it is important to temper results by preoperative assessment. As noted by previous authors, patients with more advanced disease, presenting with weakness and muscular atrophy, are associated with less favorable surgical outcomes.[28,35] Our patients are not excluded based on an advanced state of disease. They are simply cautioned to expect longer and possibly incomplete neurologic recovery. In comparing overall satisfaction between the two surgical approaches, there have been several prospective randomized trials directly comparing endoscopic carpal tunnel release versus open carpal tunnel release. Although they exhibit variability in reports of efficacy and complication rates, there are uniformly higher patient satisfaction rates in the endoscopic carpal tunnel release group.[11,22,25,26,36]

Patients with postoperative scar hypersensitivity or tenderness numbered 87 (12 percent) and all fell under the worker's compensation group. Brown et al. reported that a blinded examiner found significant difference in postoperative scar tenderness between open carpal tunnel release and endoscopic carpal tunnel release.[34] On postoperative day 84, 61 percent of open carpal tunnel release patients had painful scars, whereas only 36 percent of endoscopic carpal tunnel release patients had similar complaints. Disregarding any potential for secondary gain in the worker's compensation group, our 12 percent scar complaint appears acceptable.

Reports of unrelieved or recurrent symptoms after carpal tunnel release may result from incomplete release of transverse carpal ligament, fibrous proliferation, scarring within the tunnel, entrapped palmar cutaneous nerve, reflex sympathetic dystrophy, painful scars, and psychological or legal motivation. Recurrence is defined as documented carpal tunnel syndrome after resolution from prior surgical release. Recent reports show a similar incidence of incomplete release of the transverse carpal ligament between the endoscopic carpal tunnel release and open carpal tunnel release groups, being approximately 1 percent.[37] In Langloh and Linscheid's study of 2053 open carpal tunnel release procedures, 1.6 percent required reexploration for recurrence.[23] Concannon et al. report a 7 percent recurrence rate after endoscopic carpal tunnel release,[1] whereas Chow reports one (0.96 percent) recurrence in 104 wrists treated endoscopically.[38] Most often, these recurrences requiring rerelease are attributed to inadequate exposure of the distal

aspect of the ligament, resulting in incomplete release of the transverse carpal ligament.[23,39,40] Our study had one patient (0.13 percent) whose condition recurred within 1 year. This patient underwent rerelease by an open minimal incision technique. Fibroproliferative scarring without evidence of incomplete transverse carpal ligament release or neurovascular injury was noted at the time of rerelease.

High complication rates are the pivotal argument for those against minimally invasive approaches to the carpal tunnel. Detractors argue that limited visibility through the endoscope predisposes the surgeon to iatrogenic injuries. Some reported complications of endoscopic carpal tunnel release consist of partial or complete transection of ulnar or median nerves proper or their branches, neurapraxia, digital nerve injury, laceration of the superficial palmar arch, laceration of flexor tendons, reflex sympathetic dystrophy, hematoma, and inadvertent Guyon's canal release.[2,7,10–12,15,17,21,22] Although proponents of open carpal tunnel release argue that it is safe, it is not without risk. Similar complications result from either approach.

Palmer and Toivonen's study is often cited when comparing the complications between endoscopic carpal tunnel release and open carpal tunnel release[17] (Table 2). This study demonstrates that endoscopic carpal tunnel release has a lower rate of median palmar cutaneous nerve injury and neuroma formation but a higher rate of ulnar nerve and superficial palmer arch and flexor tendon injuries. Moreover, their data demonstrate similar rates of median nerve laceration. This elucidated the fact that both surgical approaches have the potential for complications but clearly demonstrated that the open approach is not a more benign procedure.

Table 2. Complications of Endoscopic versus Open Carpal Tunnel Release*

Complication	Endoscopic Approach	Open Approach
Median nerve laceration	100	147
Palmar cutaneous branch laceration	17	117
Ulnar nerve laceration	88	29
Digital nerve laceration	77	54
Tendon laceration	69	19
Superficial arch laceration	86	21
Ulnar artery laceration	34	11
Total complications	455	283
Total respondents	708	616

*Data from Palmer, A. K., and Toivonen, D. A. Complications of endoscopic and open carpal tunnel release. *J. Hand Surg. (Am.)* 24: 561, 1999.

In an effort to better answer the question of complication rates, Boeckstyn and Sorensen performed a meta-analysis, reviewing a total of 9516 cases of endoscopic carpal tunnel release and 1203 cases of open carpal tunnel release. They found nerve injury rates to be 0.3 percent for endoscopic carpal tunnel release and 0.2 percent for open carpal tunnel release. Moreover, they found similar rates between the two groups for other complications, including tendon and arterial injuries.[21] This large analysis of 54 publications demonstrates that open carpal tunnel release and endoscopic carpal tunnel release have similar rates of complications.

If similarly low complication rates and similarly high rates of successful decompression of the transverse carpal ligament can be achieved using both approaches, then what factors confer an advantage to one over the other? This answer seems to be addressed in studies that compare endoscopic carpal tunnel release and open carpal tunnel release in patients who each underwent release by both approaches in bilateral disease. In a review by Friol et al. of 1400 patients undergoing endoscopic carpal tunnel release, 63 underwent an open carpal tunnel release on one side and endoscopic carpal tunnel release on the other. Of these, 54 (86 percent) preferred endoscopic carpal tunnel release, six had no opinion, and three (5 percent) preferred open carpal tunnel release.[41] Others have compared open carpal tunnel release to endoscopic carpal tunnel release, both retrospectively and prospectively, and the trend of higher patient satisfaction in the endoscopic carpal tunnel release group persists.[11,22,25,26,36] Likewise, in our study, all patients with bilateral disease who underwent both surgical techniques were uniform in their reported preference for the endoscopic release.

Limitations of our study include performance of all procedures by a single surgeon and lack of consistent long-term follow-up. However, strengths of our study include large cohort size and objective postoperative evaluation by an independently managed hand therapy practice. Long-term follow-up can prove difficult and is more likely when patients feel they have obtained a satisfactory result and therefore do not return for clinical assessment. However, worker's compensation groups generally have better follow-up, as it is frequently required for evaluation of return-to-work status.

Our overall complication rates were low (1 percent). Transient scar discomfort, not included in our definition of procedural complications, accounted for another 12 percent of patient-reported complaints. Using this definition, annual complication rates ranged from 0 to 8 percent, with the initial year (1991) having the highest rate. This may be somewhat misleading, however, because the number of patients initially undergoing this procedure in 1991 was 13, comprising 17 operations, with one complication. In 2002, 54 patients underwent 73 procedures, and only one complication was noted. Thus, with a lower total number of patients undergoing endoscopic carpal tunnel release in 1991, the complication rates may appear higher than in other years, which often had manyfold the number of patients while maintaining a similar number of total annual complications. In summation, complication rates in our cohort do not seem to demonstrate a dramatic learning curve, as per annum, the number of patients with a complication was essentially constant.

CONCLUSIONS

In our study of 753 hands decompressed by the endoscopic approach for carpal tunnel syndrome, all patients (100 percent) reported significant or complete relief of initial symptoms. There were no nerve, vascular, or tendon injuries. We report eight patients (1.1 percent) with complications that included transient neurapraxia, hand or thumb soreness, and hypersensitivity. One patient underwent subsequent open carpal tunnel release for recurrence secondary to scar formation. We report 87 patients (12 percent) with scar complaints at the time of their last follow-up. There was no statistical difference in return-to-work status for light and heavy labor between the worker's compensation group and those without worker's compensation claims.

Our results suggest that endoscopic carpal tunnel release using the uniportal Agee/Micro-Aire technique is a safe approach for decompressing the carpal tunnel. There is likely a learning curve, as the surgeon must become familiar with the endoscopic equipment and gain a familiarity with the endoscopic carpal tunnel anatomy before performing this procedure. However, in the hands of a surgeon experienced with this technique, this approach proves to be effective, having consistent and safe outcomes.

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REFERENCES

1. Concannon, M. J., Gainor, B., Petroski, G. F., and Puckett, C. L. The predictive value of electrodiagnostic studies in carpal tunnel syndrome. *Plast. Reconstr. Surg.* 100: 1452, 1997.
2. Deune, E. G., and Mackinnon, S. E. Endoscopic carpal tunnel release: The voice of polite dissent. *Clin. Plast. Surg.* 23: 487, 1996.
3. Phalen, G. S., Gardner, W. J., and La Londe, A. A. Neuropathy of the median nerve due to compression beneath the carpal ligament. *J. Bone Joint Surg. (Am.)* 32: 109, 1950.
4. Phalen, G. S. The carpal tunnel syndrome: Clinical evaluation of 598 hands. *Clin. Orthop.* 83: 29, 1972.
5. Semple, J. C., and Cargill, A. O. Carpal tunnel syndrome: Results of surgical decompression. *Lancet* 1: 918, 1969.
6. Louis, D. S., Green, T. L., and Noellert, R. T. Complications of carpal tunnel surgery. *J. Neurosurg.* 62: 352, 1985.
7. Kuschner, S. H., Brien, W. W., Johnson, D., and Gellmann, H. Complications associated with carpal tunnel release. *Orthop. Rev.* 20: 346, 1991.
8. Okutsu, I., Ninomiya, S., Takatori, Y., and Ugawa, Y. Endoscopic management of carpal tunnel syndrome. *Arthroscopy* 5: 11, 1989.
9. Chow, J. C. Y. Endoscopic release of the carpal ligament for carpal tunnel syndrome: 22-month clinical result. *Arthroscopy* 6: 288, 1990.
10. Agee, J. M., McCarroll, H. R., Jr., Tortosa, R. D., Berry, D. A., Szabo, R. M., and Peimer, C. A. Endoscopic release of the carpal tunnel: A randomized prospective multicenter study. *J. Hand Surg. (Am.)* 17: 987, 1992.
11. Brown, R. A., Gelberman, R. H., Seiler, J. G., et al. Carpal tunnel release: A prospective randomized assessment of open and endoscopic methods. *J. Bone Joint Surg. (Am.)* 75: 1265, 1993.
12. Palmer, D. H., Paulson, J. C., Lane-Larsen, C. L., Peulen, V. K., and Olson, J. D. Endoscopic carpal tunnel release: A comparison of two techniques with open release. *Arthroscopy* 9: 498, 1993.
13. Agee, J. M., Peimer, C. H., Pyrek, J. D., and Walsh, W. E. Endoscopic carpal tunnel release: A prospective study of complications and surgical experience. *J. Hand Surg. (Am.)* 20: 165, 1995.
14. Murphy, R. X., Jr., Jennings, J. F., and Wukich, D. K. Major neurovascular complications of endoscopic carpal tunnel release. *J. Hand Surg. (Am.)* 19: 114, 1994.
15. Nath, R. K., Mackinnon, S. E., and Weeks, P. M. Ulnar nerve transection as a complication of a two-portal endoscopic carpal tunnel release: A case report. *J. Hand Surg. (Am.)* 18: 896, 1993.
16. Evans, D. Endoscopic carpal tunnel release: The hand doctor's dilemma. *J. Hand Surg. (Br.)* 19: 3, 1994.
17. Palmer, A. K., and Toivonen, D. A. Complications of endoscopic and open carpal tunnel release. *J. Hand Surg. (Am.)* 24: 561, 1999.
18. Nagle, D. J., Fischer, T., Harris, G. D., et al. A multi-center prospective review of 640 endoscopic carpal tunnel releases using the Chow technique. *Arthroscopy* 12: 139, 1996.
19. Kerr, C. D., Gittins, M. E., and Sybert, D. R. Endoscopic versus open carpal tunnel release: Clinical results. *Arthroscopy* 10: 266, 1994.
20. Chow, J. C. Y., and Hantes, M. E. Endoscopic carpal tunnel release: Thirteen years experience with the Chow technique. *J. Hand Surg. (Am.)* 27: 1011, 2002.
21. Boeckstyns, M. E. H., and Sorensen, A. I. Does endoscopic carpal tunnel release have a higher rate of complications than open carpal tunnel release? *J. Hand Surg. (Br.)* 24: 9, 1999.
22. Trumble, T. T., Diao, E., Abrams, R., and Gilbert, M. Single-portal endoscopic carpal tunnel release compared with open carpal tunnel release: A prospective randomized trial. *J. Bone Joint Surg. (Am.)* 84: 1107, 2002.
23. Langloh, N. D., and Linschied, R. L. Recurrent unrelieved carpal tunnel syndrome. *Clin. Orthop.* 83: 41, 1972.

24. Sennwald, G. R., and Benedetti, R. The value of one-portal endoscopic carpal tunnel release: A prospective randomized study. *Knee Surg. Sports Traumatol. Arthrosc.* 3: 114, 1995.
25. Ferdinand, R. D., and Maclean, J. G. B. Endoscopic versus open carpal tunnel release in bilateral carpal tunnel syndrome: A prospective randomized, blinded assessment. *J. Bone Joint Surg. (Br.)* 84: 375, 2002.
26. Chow, J. C. Y. Endoscopic release of the carpal ligament for carpal tunnel syndrome: 22-month clinical result. *Arthroscopy* 6: 288, 1990.
27. Tung, T. H. H., and Mackinnon, S. E. Secondary carpal tunnel surgery. *Plast. Reconstr. Surg.* 107: 1830, 2001.
28. Serra, L., Panagiotopoulos, K., Bucciero, A., et al. Endoscopic release in carpal tunnel syndrome: Analysis of clinical results in 200 cases. *Minim. Invas. Neurosurg.* 46: 11, 2003.
29. Adams, B. D. Endoscopic carpal tunnel release. *J. Am. Acad. Orthop. Surg.* 2: 179, 1994.
30. Rowland, E. B., and Kleinert, J. M. Endoscopic carpal tunnel release in cadavera: An investigation of the results of twelve surgeons with this training model. *J. Bone Joint Surg. (Am.)* 76: 266, 1994.
31. Lee, D. H., Masear, V. R., Meyer, R. D., Stevens, D. N., and Colgin, S. Endoscopic carpal tunnel release: A cadaveric study. *J. Hand Surg. (Am.)* 17: 1003, 1992.
32. Feinstein, P. A. Endoscopic carpal tunnel release in a community-based series. *J. Hand Surg. (Am.)* 18: 451, 1993.
33. VanHeest, A., Waters, P., Simmons, B., and Schwartz, J. T. A cadaveric study of the single-portal endoscopic carpal tunnel release. *J. Hand Surg. (Am.)* 20: 363, 1995.
34. Brown, M. G., Keyser, B., and Rothenberg, E. S. Endoscopic carpal tunnel release. *J. Hand Surg. (Am.)* 17: 1009, 1992.
35. Straub, T. A. Endoscopic carpal tunnel release: A prospective analysis of factors associated with unsatisfactory results. *Arthroscopy* 15: 269, 1999.
36. MacDermid, J. C., Richards, R. S., Roth, J. H., Ross, D. C., and King, G. J. W. Endoscopic versus open carpal tunnel release: A randomized trial. *J. Hand Surg. (Am.)* 28: 475, 2003.
37. Botte, M. J., von Schroeder, H. P., Abrams, R. A., and Gellman, H. Recurrent carpal tunnel syndrome. *Hand Clin.* 12: 731, 1996.
38. Chow, J. C. Y. Endoscopic carpal tunnel release. *Clin. Sports Med.* 15: 769, 1996.
39. Hudson, A. R., Kline, D., and Mackinnon, S. E. Entrapment neuropathies. In N. H. Horwitz and H. V. Rizoli (Eds.), *Postoperative Complications of Extracranial Neurological Surgery.* Baltimore: Williams & Wilkins, 1987. Pp. 260–282.
40. Patrick, J. Carpal tunnel syndrome. *Br. Med. J.* 1: 1377, 1965.
41. Friol, J. P., Chaise, F., Gaisne, E., and Bellemere, P. Decompression endoscopique du nerf median au canal carpien: A propos de 1400 cas. *Ann. Chir. Main Memb. Super.* 13: 162, 1994.