Review Article

Endoscopic Carpal Tunnel Release: Techniques, Controversies, and Comparison to Open Techniques

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ABSTRACT

Endoscopic carpal tunnel release (ECTR) continues to rise in popularity as a treatment option for carpal tunnel syndrome. Numerous variations in technique and instrumentation currently exist, broadly classified into two-portal and single-portal techniques with antegrade and retrograde designs. ECTR is equally effective as open carpal tunnel release for alleviating symptoms of carpal tunnel syndrome with no differences in long-term outcomes. ECTR has an increased risk of transient nerve injury, whereas open carpal tunnel release has an increased risk of wound and scar complications. ECTR has higher direct costs but is associated with earlier return to work. ECTR is a safe and effective approach to carpal tunnel release in the hands of experienced surgeons.

Carpal tunnel syndrome is the most common compressive peripheral neuropathy within the United States with an incidence of 1 to 3 cases per 1,000 patients per year and a prevalence as high as 5% in the general population.[1,2] Its diagnosis carries significant disability and economic burden with approximately 500,000 carpal tunnel releases performed annually and economic cost estimates in excess of $2 billion per year within the United States alone.[3] Timely surgical intervention after failure of conservative measures may reduce economic loss and prevent permanent disability and need for reconstructive procedures.[1]

Both open carpal tunnel release (OCTR) and endoscopic carpal tunnel release (ECTR) are popular techniques for surgical treatment of carpal tunnel syndrome. Although there currently is no consensus regarding the choice of one over the other, rates of ECTR continue to rise. Between 2005 and 2012, 14% of all carpal tunnel releases performed in the Medicare database were done endoscopically, with rates of ECTR growing by 5% annually compared with 0.9% annually for OCTR ($P < 0.001$).[4] Recent survey studies of the members of the American Society for Surgery of the Hand have shown as many as 26% to 36% of members using ECTR for most of their cases.[5,6] Looking at young surgeons specifically, a query of the American Board of Orthopaedic Surgery Part II database revealed an increasing proportion of carpal tunnel releases performed endoscopically, with hand fellowship-

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Figure 1

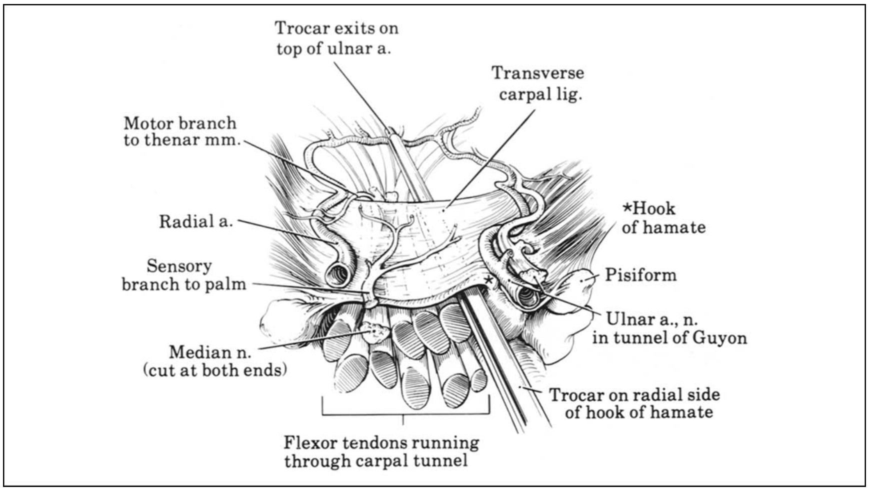


Illustration showing correct placement of trocar through the carpal tunnel into the palm with the two-portal endoscopic technique. The trocar enters on the radial aspect of the hook of the hamate and exits on top of the superficial palmar arch (Reprinted from Arthroscopy, 5(1), Chow JC, Endoscopic release of the carpal ligament: A new technique for carpal tunnel syndrome, 19 to 24, 1989, with permission from Elsevier).

trained surgeons performing 4.5 times as many ECTRs as nonhand fellowship-trained surgeons.[7] In light of the growing popularity of ECTR, it is becoming increasingly important for surgeons to understand the technical aspects and outcomes of this technique.

Surgical Technique

Many modifications to ECTR technique have been made since its original description in 1987 by Okutsu et al,[8] whose technique consisted of placing both an endoscope and an instrument into a single volar incision. Two main techniques exist today—the two-portal technique and the single-portal technique. In reality, the exact steps to perform ECTR are often dictated by the configuration of the specific instrumentation to be used and are not the focus of this review. Cannula design, degrees of freedom, and blade orientation are examples of how individual systems can alter surgical technique. Specifics aside, each technique has several essential surgical steps, which will be reviewed below.

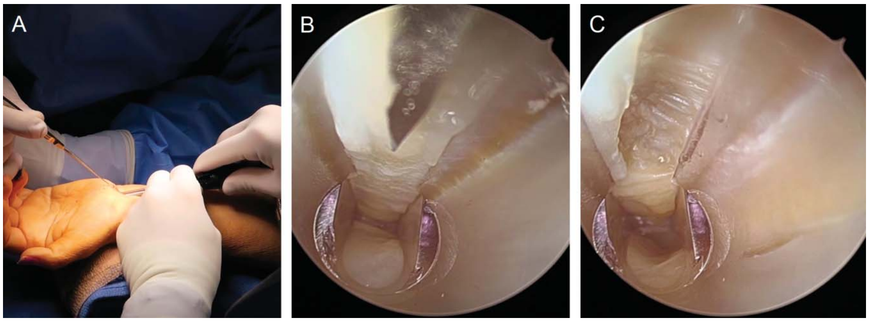
Two-Portal Technique

The two-portal technique was first described in 1989 by Chow.[9] The first portal is made at the wrist flexion crease between the flexor carpi ulnaris and flexor carpi radialis tendons. The fascia is incised, and a trocar-cannula assembly is inserted into the carpal tunnel using the hook of the hamate as a guide (Figure 1). The wrist and fingers are then held in extension with a specialized device, and the assembly is advanced into the palm. The second portal is made in the palm over the tip of the trocar, and the endoscope is placed into the trocar at the proximal portal to visualize the undersurface of the transverse carpal ligament (TCL). A series of blades are then inserted into the distal portal to sequentially release the distal half of the ligament. Finally, the endoscope and blades are switched, and the proximal ligament is divided. The antebrachial fascia is then released through the proximal incision with tenotomy scissors. Although the original description by Chow used several specialized blades, modern systems frequently use one blade for a single pass through the TCL.

Single-Portal Technique

Agee et al[10] introduced the contemporary single-portal technique in 1992, developed in concert with a new blade assembly device, which allowed blade deployment and visualization through a single window. A single incision is made at the wrist flexion crease in a similar fashion as previously mentioned. A distally based flap of antebrachial fascia is raised, and synovial tissue is cleared from the undersurface of the TCL followed by insertion of the blade assembly into the carpal tunnel (Figure 2, A). Once the ligament is properly visualized, the blade is deployed and the ligament is sequentially released in a retrograde fashion. The antebrachial fascia is then released with tenotomy scissors. Although the original description of Agee et al used a blade assembly with retrograde design, current systems offer both antegrade (Figure 2, B and C) and retrograde options.

Figure 2



Intraoperative images demonstrating the single-portal endoscopic technique. **A,** Clinical photograph demonstrating proper placement of a single-portal endoscopic device with the assistant providing exposure. **B,** Endoscopic image with knife deployed releasing the transverse carpal ligament (TCL) in an antegrade fashion. The TCL can be identified by its transverse fibers. The distal margin can be identified by the fat pad visualized distally. **C,** Endoscopic image after TCL release has been completed. Radial and ulnar leaflets of the TCL are visualized, and complete release of the distal margin is confirmed. TCL = transverse carpal ligament

Variations in Contemporary Systems

There are multiple contemporary single-portal endoscopic systems with variations that make each unique. The differences are neither good nor bad, but rather appeal to surgeon preference and familiarity. The three most common variations between modern designs are (1) anterograde versus retrograde knives, (2) linked knife and endoscope versus independent knife and endoscope, and (3) independent cannula systems versus single unit systems.

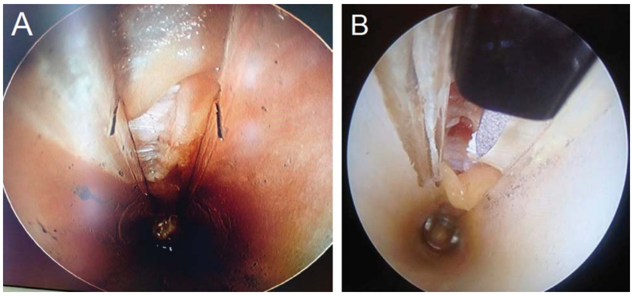
A retrograde system has the theoretical benefit of being less likely to injure the superficial palmar arch as the surgeon is cutting away from the vascular structure rather than toward it. Antegrade systems, on the other hand, have the theoretical benefit of preventing incomplete distal release because the surgeon maintains visibility of the distal aspect of the TCL and has direct visualization once the distal margin has been transected. Having a single unit which houses both the knife and the endoscope allows for simplicity and direct visualization of the blade at all times. The benefit of having the endoscope and knife separate is that the surgeon has a greater degree of control. Finally, the benefit of having an independent cannula is the ability to maintain the surgical field even after release of ligament. The downside of the cannula is that it adds to the number of components within the system and thus can complicate the procedure.

Concerns

The rise in popularity of ECTR has not been without resistance. Critics have questioned the potential benefits of an alternative treatment to OCTR, a well-established, safe, and simple surgical procedure, leading some to cite ECTR as a triumph of technology over reason.[11] The primary concern of ECTR is damage to anatomic structures secondary to limited visualization of the full surgical field. Fear of damaging major neurovascular structures including the median nerve, the palmar cutaneous branch, the thenar motor branch, the ulnar nerve, and the superficial palmar arch are potentially catastrophic complications which lead many to avoid ECTR altogether. Incomplete release of the TCL is another concern arising from the limited visualization. Gould et al[12] provided a comprehensive list of reasons for their concern with ECTR, which includes anatomic concerns such as motor branch variations, presence of recurrent or bifid nerves, persistent median arteries, and presence of the superficial palmar arch or other extraneous musculotendinous units within the canal, as well as ancillary issues including systemic disease such as amyloidosis, extensive tenosynovitis or calcifications, or mass effect in the form of cysts or schwannomas, the sum of which prompt the authors to favor OCTR.

Clearly, these concerns have not precluded all to avoid ECTR. In direct response to the article by Gould et al, Wagner et al offered a counterargument about the safety of ECTR in the hands of experienced surgeons.[13] The authors cite previous studies demonstrating improved outcomes and fewer complications for procedures performed by higher volume surgeons at higher volume centers, which is the case for complex microsurgical procedures such as free flaps and finger replantation and more common procedures such as hip and knee arthroplasty.[13] Surgeon experience is vital for recognizing anatomic variants and atypical causes both while diagnosing carpal tunnel syndrome and while performing ECTR (Figure 3), allowing the surgeon to take

Figure 3



Intraoperative endoscopic images demonstrating (**A**), transligamentous recurrent motor branch and (**B**) subligamentous recurrent motor branch (Reprinted from Plastic & Reconstructive Surgery Global Open, 5(9), Wolfswinkel EM, Hoang D, Kulber DA, Anatomic Variations of the Median Nerve Identified during Endoscopic Carpal Tunnel Release with STRATOS, 1 to 2, 2017, with permission from Wolters Kluwer Health, Inc).

appropriate safety measures when necessary. Thus, the authors argue that although ECTR may be technically more difficult, it should still be pursued if there is potential for improved outcomes over traditional OCTR. A learning curve certainly exists for ECTR. Although an exact number of cases to master the technique have not been determined, studies have shown a higher rate of conversion to OCTR in the early stages of a surgeon's practice.[14] Some studies have shown a nonsignificant higher incidence of complications in early stages, although other studies have not.[14,15]

Endoscopic versus Open Carpal Tunnel Release

Symptom Relief

The Boston Carpal Tunnel Syndrome Questionnaire (BCTQ) is a validated, two-part patient-reported survey divided into symptom severity (BCTQ-S) and functional status (BCTQ-F) portions, which is frequently used to assess symptom severity in carpal tunnel syndrome.[16] A meta-analysis of seven studies using the BCTQ to compare ECTR and OCTR found no differences at 1 year with either BCTQ-S (mean difference [MD] 0.15; 95% CI [−0.04, 0.35]; n = 592; $P = 0.13$) or BCTQ-F (MD 0.17; 95% CI [−0.02, 0.36]; n = 592; $P = 0.08$).[17] Similarly, there were no differences in pain relief between ECTR and OCTR as measured by the Visual Analogue Scale before or after 3 months postoperatively.[18]

No significant differences were found between ECTR and OCTR with respect to digital sensation with Semmes-Weinstein monofilament testing at 3 months (MD 0.06; 95% CI [−0.09, 0.21]; n = 297; $P = 0.43$) or with two-point discrimination testing at 1 year (MD −0.16; 95% CI [−0.45, 0.12]; n = 402; $P = 0.26$).[17] Other studies using Semmes-Weinstein monofilament testing as a surrogate for paresthesia relief had similar findings with no differences when further stratified into less than 3 months and greater than 3 months.[18]

Sleep disturbance is a common manifestation of carpal tunnel syndrome. To study sleep disturbance specifically, Gaspar et al randomized 60 patients to ECTR or OCTR and administered the Pittsburgh Sleep Quality Index (PQSI), the Insomnia Severity Scale, and the Quick Disabilities of the Arm, Shoulder and Hand surveys at three postoperative time points. They found that ECTR provided superior improvement in the PQSI ($P = 0.016$) and Insomnia Severity Scale ($P = 0.006$) at the first postoperative visit (1 to 2 weeks) and PQSI ($P = 0.0038$) at the second postoperative visit (4 to 6 weeks), with no differences at final follow-up (6 to 12 months).[19] Thus, although both ECTR and OCTR can alleviate sleep-related symptoms, ECTR may do so more rapidly.

Strength

A prospective randomized trial by Trumble et al[20] including 192 hands found that patients treated by ECTR had significantly greater grip strength, pinch strength, and hand dexterity during the first 3 months after surgery ($P < 0.05$). One meta-analysis similarly concluded that ECTR results in significantly better pinch strength than OCTR at 3 months postoperatively.[17] Another meta-analysis found similar results initially; however, once the studies were filtered and only long-term data (defined as greater than 6 months postoperatively) were included, there were no differences between ECTR and OCTR with either grip strength (MD 0.90 kg; 95% CI [−1.47, 3.27]; n = 571; $P = 0.46$) or pinch strength (MD 0.37 kg; 95% CI [−0.09, 0.84]; n = 614; $P = 0.12$) at long-term follow-up.[21] These results paralleled those of Trumble et al,[20] who found that the better strength results initially seen with ECTR tapered off and were equivalent to those of OCTR after 3 months. A possible explanation is that smaller skin incisions and less soft-tissue dissection with ECTR result in quicker soft-tissue recovery and earlier confidence to resume activity and begin strengthening.

Return to Work

In line with the reasoning that less soft-tissue violation may lead to earlier improvements in strength and dexterity, ECTR has been theorized to result in quicker return to work times, one of its more impactful proposed advantages. Meta-analyses agree that ECTR results in significantly shorter return to work, the largest of which reviewed 11 studies and found a mean difference of −8.73 days (MD −8.73 days; 95% CI [−12.82, −4.65]; n = 1,234; $P < 0.001$).[21] Other studies have shown mean differences ranging from −7.25 to −9.56 days.[17,18,22] However, these pooled analyses did not make distinctions regarding patient occupation, which is an important distinction as surgeons may have different return to work criteria for manual laborers than for those working desk-based jobs. Accordingly, the authors found a large degree of heterogeneity between studies, which may be attributed to this variability of work and daily activity.[21,22] Despite these limitations, there does seem to be a significant difference in return to work between these techniques, which has broad implications when considering cost-effectiveness of the two procedures. Future studies stratifying results by type of work and functional demand may lead to a deeper understanding of this finding.

Complications

Complications as a whole are difficult to study as they are relatively rare in nature and depend heavily on surgeon reporting, patient follow-up, and even the definition of a complication itself. Early studies on ECTR reported unacceptable complication rates ranging from 2% to as high as 35%.[23] With further experience and advancements in endoscopic technique, more recent studies have reported complication rates similar to those of OCTR, although controversy remains.[24]

Benson et al performed a literature review of 68 articles spanning over 27,000 cases of carpal tunnel release to study rates of complications, which they defined as damage to nerves, arteries, or tendons. The authors found a higher overall complication rate with ECTR compared with OCTR (1.63% vs 0.74%, $P < 0.005$). On further analysis, a large proportion of complications associated with ECTR were transient neurapraxias, which self-resolved. In fact, ECTR was associated with a 1.45% rate of transient neurapraxia versus 0.25% with OCTR ($P < 0.005$). When transient neurapraxias are removed from the analysis, the overall rate of structural complications is actually significantly lower with ECTR compared with OCTR (0.19% vs 0.49%, $P < 0.005$).[25]

Vasiliadis et al performed a meta-analysis explicitly focused on safety and complication risk, stratified into major and minor complications. Major complications included permanent structural injury, complex regional pain syndrome, and moderate or severe pain at greater than 1 year follow-up. Minor complications included any postoperative issues, which resolved at final follow-up (ie, scar issues, pillar pain, and transient neurapraxia) and delayed recovery continuing up to the latest follow-up reported. The authors reported no differences between ECTR and OCTR with respect to major complications (odds ratio [OR] 1.00; 95% CI [0.44, 2.27]; n = 2,565; $P > 0.05$), with a very low overall major complication rate (0.9%). On the other hand, ECTR was associated with 50% decrease in odds of minor complications compared with OCTR (OR 0.50; 95% CI [0.31, 0.82]; n = 2,442; $P < 0.05$). Specifically, ECTR carried a 76% decrease in odds for wound or scar issues compared with OCTR (OR 0.24; 95% CI [0.15, 0.40]; n = 1,943; $P < 0.05$) but 2.42 times the odds for transient neurapraxia (OR 2.42; 95% CI [1.22, 4.80]; n = 2,182; $P < 0.05$).[22] These results were mirrored in several other meta-analyses.[17,18,21]

One hypothesis for the increased rates of transient neurapraxia with ECTR is the brief increase in tunnel pressure, and thus pressure exerted on the median nerve, associated with insertion of instrumentation before ligament release. Uchiyama et al used an intraoperative pressure transducer while performing two-portal ECTR and found that tunnel pressure was greatest immediately before the cannula was withdrawn from the exit portal. However, no conclusion can be made regarding the relationship of tunnel pressure to postoperative neurapraxia as the transducer was only accurate to 300 mmHg (nearly all maximum pressures were >300 mmHg) and no cases of postoperative neurapraxia were reported.[26] In addition, single-portal and two-portal techniques may be subjected to different pressure environments as the wrist is suspended in hyperextension in the latter. Additional studies are necessary to determine whether this is truly the etiology of transient neurapraxias. Increased rates of wound and scar-related issues with OCTR can be explained by the larger surgical incisions made directly over the base of the volar palm.

Incomplete release of the TCL is sometimes defined as a complication of carpal tunnel release and is an inherent concern of ECTR due to potential limitations with endoscopic visualization. Incomplete release is difficult to measure directly. Failure to relieve symptoms due to persistent compression is a proxy measurement, which was previously explored in this discussion and shown to have no differences between the two techniques. Rate of revision surgery is another proxy measurement, although less reliable as revision surgery can be performed for a variety of reasons not limited to incomplete release. Chen et al[18] analyzed seven trials and found no significant increase in risk of revision surgery following either procedure (relative risk 1.18; 95% CI [0.53, 2.63]; n = 1,031; $P = 0.68$). Other meta-analyses also found no significant increase in risk or difference in incidence of revision surgery.[21,22]

The methodology through which complications are assessed must be considered. As previously mentioned, a large proportion of data are based on surgeon reporting. Take for example, a study conducted by Devana et al using the PearlDiver database to investigate the billing records of over 60,000 patients. The authors found a lower rate of median nerve injury after ECTR versus OCTR in both private payer (0.59 vs 1.69 per 1,000 patients) and Medicare (1.96 vs 3.72 per 1,000 patients) groups.[1] However, these conclusions were made based on *International Classification of Diseases, Ninth Revision* codes and are heavily dependent on proper and appropriate coding.

On the other hand, Trehan et al used a New York State database to investigate rate of subsequent nerve repair specifically, rather than all-cause revision surgeries, by searching for Common Procedural Terminology codes for nerve repair procedures following carpal tunnel release. Their study had the benefit of a state-wide registry, which was able to capture data by patient rather than by provider, including patients who received revision surgery by another provider or at another institution. The authors found that although low overall, the rate of subsequent nerve repair after ECTR was significantly higher than OCTR (0.09% vs 0.04%, $P = 0.01$) and carried a hazard ratio of 2.40 (HR 2.40, 95% CI [1.02, 5.27]).[27] Their study was limited by state boundaries and accurate procedural coding, but nonetheless introduces the idea that the true incidence of nerve injury may not be so simple to measure.

Direct Cost

On the surface, it seems obvious that ECTR would be more expensive than OCTR. Koehler et al[28] used a time-driven activity-based costing technique to characterize costs and found that total procedural costs of ECTR were 43.9% greater than OCTR ($2,759.70 vs $1,918.06), largely related to disposables, direct operating room costs for procedural duration, and physician labor. Other studies using different accounting methods all generally agree that the immediate procedural costs of ECTR exceed those of OCTR, some estimates by as much as $2,000 per case.[29,30]

Direct costs are not limited to the choice of procedure, but also encompass surgical setting (procedure room versus operating room) and anesthesia choice (local, monitored anesthesia care, Bier block, and general). Kazmers et al used their institutional data to calculate total direct costs of carpal tunnel release surgical encounters and found that performing OCTR in the procedure room under local anesthesia was the least costly technique. Performing OCTR in the operating room under monitored anesthesia care was approximately 11 times as costly, whereas ECTR in the same setting was more than 15 times as costly.[31] Certainly, the exact surgical environment is limited by the inability of some patients to tolerate local anesthesia alone or by the availability of equipment and anesthesia options in some settings, but these factors must all be considered together when discussing direct costs.

Cost-Effectiveness

The differences are less clear, however, when looking at cost-effectiveness rather than direct upfront cost. To fully understand the idea of cost-effectiveness, it is important to realize the societal cost of carpal tunnel syndrome and its surgical treatment. Data reported by the US Bureau of Labor Statistics show that carpal tunnel syndrome leads to a median of 30 days away from work.[32] A 5-year analysis of workers' compensation trends in Washington State estimated $310 million in claims related to carpal tunnel syndrome, of which $149 million was allocated to temporary disability.[33] Thus, when considering cost-effectiveness, the cost to society from loss of productivity and opportunity cost from missed work must be considered.

Barnes et al used a Markov model to perform the most recent comprehensive cost-effectiveness analysis of ECTR versus OCTR. With the assumption that patients undergoing ECTR were able to return to work 8.21 days earlier than those undergoing OCTR, they found that ECTR was actually more cost-effective than OCTR from the societal perspective.[34] ECTR was also more cost-effective from the payor perspective when using a willingness-to-pay threshold of $100,000/quality-adjusted life year, a common threshold used in healthcare cost-effectiveness studies.[34,35] Specifically, ECTR in the office setting is the most cost-effective measure, followed by ECTR in the operating room, OCTR in the office setting, and OCTR in the operating room. Cost-effectiveness studies have many inherent limitations including numerous variables and assumptions gathered from other studies, but are still frequently used to justify reimbursement of procedures. As the United States continues to transition toward value-based delivery of health care, the cost-effectiveness of procedures performed will undergo continued scrutiny.

Compensation

One last cost-related factor to consider is physician compensation. Currently, distinct Common Procedural Terminology codes exist for both OCTR (64721—neuroplasty and/or transposition; median nerve at carpal tunnel) and ECTR (29848—endoscopy, wrist, surgical, with release of transverse carpal ligament), each with its own assigned work relative value units (wRVU). OCTR is currently valued at 4.97 wRVU, whereas ECTR is currently valued at 6.39 wRVU, a 29% increase.[27] Along these lines, a surgeon's salary structure (ie, incorporating wRVU or not) and any ownership or stake in facilities may sway individual decision making. This should be kept in mind when interpreting studies or opinions of others.

Patient Satisfaction

A handful of studies have reported on patient satisfaction following ECTR versus OCTR. As there are virtually no validated tools for measuring patient satisfaction, these results can be subjective and should be interpreted accordingly.[21] Using a scale of 0 to 100 points with a higher score corresponding to increased satisfaction, analysis of these studies has shown that patients tend to be more satisfied with ECTR than OCTR (MD 3.13; 95% CI [1.43, 4.82]; n = 303; $P = 0.0003$).[17] Michelotti et al followed a cohort of patients who underwent staged bilateral carpal tunnel release randomized to either ECTR or OCTR on the first side followed by the other technique on the contralateral side. They found no statistically significant differences in patient satisfaction with either procedure.[36]

Surgical Time

Studies are divided as to the surgical time of ECTR versus OCTR. Studies have been published showing that ECTR is significantly faster than, equivalent to, and significantly slower than OCTR.[17,21,28] In reality, surgical time is highly variable and difficult to measure due to discrepancies in location of procedure, type of anesthesia, familiarity of surgical staff with setup, presence of trainees, surgeon skill and experience level, etc. The exact difference in procedural time is likely irrelevant and would not affect cost-effectiveness studies in a significant manner.[34]

Opioid Use

Opioid use after carpal tunnel release has also been studied. A retrospective review analyzed trends in postoperative analgesic use and found that patients who underwent OCTR were significantly more likely to fill opioid prescriptions (62% vs 60%, $P = 0.034$), more likely to refill earlier (16% vs 14%, $P = 0.008$), and filled higher quantities (411 ± 96 vs 379 ± 82 oral morphine equivalents, $P < 0.001$).[37] Although statistically significant, these differences were small and their applicability is unclear as other studies have shown no differences in pain scores, coping skills, or symptoms with opioid versus nonopioid analgesic postoperative regimens after carpal tunnel release.[38] Postoperative analgesic use after carpal tunnel release is likely correlated more with individual prescriber patterns rather than chosen technique. A summary of results from all meta-analyses comparing ECTR with OCTR, which included 15 or more randomized trials from 2014 to present, is presented in Table 1.

Summary

ECTR is becoming increasingly popular as an alternative technique to traditional OCTR for surgical treatment of carpal tunnel syndrome. Both are effective techniques for alleviating symptoms of carpal tunnel syndrome. ECTR is associated with accelerated recovery, quicker return of strength postoperatively, and earlier return to work, although long-term results are equivalent to OCTR. Despite numerous anatomic concerns, ECTR and OCTR have similar rates of overall complications, although ECTR has an increased risk of transient nerve injury, whereas OCTR has an increased risk of wound and scar complications. ECTR has higher direct costs than OCTR. The difference is less clear as to which procedure is more cost-effective when societal costs are factored in. Choosing between the two procedures is also potentially biased by surgeon reimbursement and salary structure due to the differences in wRVU assignments. Because ECTR is associated with a steeper learning curve, surgeons who choose to perform it should do so frequently rather than occasionally, as experience and familiarity reduce the risk of potentially devastating complications. Both OCTR and ECTR are acceptable techniques for surgical management of carpal tunnel syndrome. Regardless of choice of technique, a thorough understanding of relevant anatomy and possible variants is vital when performing carpal tunnel release.

Table 1. Summary of Recent Meta-analysis Results Comparing ECTR With OCTR

Author(s)	Chen et al[18]	Sayegh et al[21]	Vasiliadis et al[22]	Li et al[17]
Year	2014	2015	2015	2020
No. of studies	15	21	27	28
Symptom relief	Pain relief by VAS at < 3 mo: RR = 1.13 (U) [0.98, 1.31]; *P* = 0.10; n = 470 Pain relief by VAS at > 3 mo: RR 1.02 (U) [0.92, 1.14]; *P* = 0.71; n = 340	BCTQ-S: SMD = 0.04 (O) [−0.11, 0.18]; *P* = 0.64; n = 715 BCTQ-F: SMD = −0.06 (E) [−0.30, 0.19]; *P* = 0.65; n = 592 VAS: MD = −0.13 (E) [−0.55, 0.28]; *P* = 0.53; n = 455	Recurrence: OR = 1.02 (O) [0.55, 1.90]; *P* > 0.05; n = 1,684	BCTQ-S at 1 yr: MD = 0.15 (E) [−0.04, 0.35]; *P* = 0.13; n = 592 BCTQ-F at 1 yr: MD = 0.17 (E) [−0.02, 0.36]; *P* = 0.08; n = 592
Grip strength	At 3 mo: MD = 1.96 kg (E) [−0.47, 4.38]; *P* = 0.11; n = 297	**All time points:** **MD = 3.03 kg (E)** **[0.08, 6]; *P* = 0.04; n = 1,196** Long term (>6 mo): MD = 0.90 kg (E) [−1.47, 3.27]; *P* = 0.46; n = 571	Not analyzed	At 3 mo: MD = 1.99 kg (O) [−0.43, 4.42]; *P* = 0.11; n = 297
Key pinch strength	**At 3 mo:** **MD = 0.83 kg (E)** **[0.31, 1.35]; *P* = 0.002; n = 297**	**All time points:** **MD = 0.77 kg (E)** **[0.33, 1]; *P* = 0.001; n = 290** Long term (>6 mo): MD = 0.37 kg (E) [−0.09, 0.84]; *P* = 0.12; n = 614	Not analyzed	**At 3 mo:** **MD = 0.79 kg (E)** **[0.27, 1.32]; *P* = 0.003; n = 297**
Sensation	Paresthesia relief by Semmes-Weinstein at < 3 mo: RR = 0.94 (U) [0.85, 1.04]; *P* = 0.21; n = 552 Paresthesia relief by Semmes-Weinstein at > 3 mo: RR = 1.07 (U) [0.98, 1.17]; *P* = 0.12; n = 296	Semmes-Weinstein: MD = −0.02 (O) [−0.16, 0.12]; *P* = 0.76; n = 589 Static two-point discrimination: MD = 0.04 mm (E) [−0.35, 0.43]; *P* = 0.84; n = 579 Static two-point sensory threshold: MD = 0.13 mm (E) [−0.67, 0.94]; *P* = 0.75; n = 143	Not analyzed	Semmes-Weinstein at 3 mo: MD = 0.06 (O) [−0.09, 0.21]; *P* = 0.43; n = 297 Two-point discrimination at 1 yr: MD = −0.16 mm (E) [−0.45, 0.12]; *P* = 0.26; n = 402
Return to work	**MD = −8.21 d (E)** **[−9.79, −6.63]; *P* < 0.001; n = 362**	**MD = −8.73 d (E)** **[−12.82, −4.65]; *P* < 0.001; n = 1,234**	**MD = −9.56 d (E)** **[−12.51, −.60]; *P* < 0.05; n = 1,115**	**MD = −7.25 d (E)** **[−14.31, −0.19]; *P* = 0.04; n = 357**
Complications	Permanent nerve injury: RR = 0.31 (E) [0.05, 1.91]; *P* = 0.21; n = 302 **Transient neurapraxia:** **RR = 2.90 (O)**	**Nerve injury (all):** **RR = 2.84 (O)** **[1.08, 7.46]; *P* = 0.03; n = 1,573** **Scar tenderness:** **RR = 0.53 (E)**	All complications: OR = 0.82 (E) [0.52, 1.51]; *P* > 0.05; n = 2,442 Major complications: OR = 1.00 (NA)	All complications: OR = 1.06 (O) [0.69, 1.64]; *P* = 0.78; n = 2,320 Permanent nerve injury: OR = 1.93 (O)

(*continued*)

Table 1. *(continued)*

Author(s)	Chen et al[18]	Sayegh et al[21]	Vasiliadis et al[22]	Li et al[17]
	[1.14, 7.36]; $P = 0.02$; n = 746 **Wound/scar complications:** **RR = 0.34 (E)** **[0.12, 0.96]; $P = 0.04$; n = 733** CRPS: RR = 0.35 (E) [0.10, 1.24]; $P = 0.10$; n = 396 Revision surgery: RR = 1.18 (O) [0.53, 2.63]; $P = 0.68$; n = 1,031	**[0.35, 0.82]; $P = 0.005$; n = 581)** Pillar pain: RR = 0.93 (E) [0.45, 2]; $P = 0.85$; n = 449 Revision surgery: RR = 1.77 (O) [0.64, 5]; $P = 0.27$; n = 957	[0.44, 2.27; $P > 0.05$; n = 2,565 **Minor complications:** **OR = 0.50 (E)** **[0.31, 0.82]; $P < 0.05$; n = 2,442** **Transient neurapraxia:** **OR = 2.42 (O)** **[1.22, 4.80]; $P < 0.05$; n = 2,182** **Wound/scar complications** **OR = 0.24 (E)** **[0.15, 0.40]; $P < 0.05$; n = 1,943** Revision surgery: OR = 1.36 (O) [0.61, 3.00]; $P > 0.05$; n = 1,596	[0.58, 6.40]; $P = 0.28$; n = 2,320 **Transient neurapraxia:** **OR = 4.87 (O)** **[1.37, 17.25]; $P = 0.01$; n = 2,320** **Wound/scar complications:** **OR = 0.20 (E)** **[0.07, 0.59]; $P = 0.004$; n = 2,320**
Surgical time	Not analyzed	**MD = −5 min (E)** **[−9, 0]; $P = 0.03$; n = 695**	Not analyzed	MD = −5.81 min (E) [−17.85, 6.23]; $P = 0.34$; n = 261
Satisfaction rate	Not analyzed	Omitted due to lack of validated measure	Not analyzed	**Scale from 0 to 100:** **MD = 3.13 (E)** **[1.43, 4.82]; $P < 0.001$; n = 303**

BCTQ-F = BCTQ functional status score, CRPS = complex regional pain syndrome, ECTR = endoscopic carpal tunnel release, MD = mean difference, NA = not analyzed, OCTR = open carpal tunnel release, OR = odds ratio, RR = relative risk, SMD = standardized mean difference, VAS = Visual Analogue Scale

Meta-analyses from 2014 to present analyzing 15 or more randomized trials were included. Results presented as [95% confidence ratio lower bound, upper bound]; *P* value; number of samples. Statistically significant results ($P < 0.05$) presented in bold. (E) = favors endoscopic carpal tunnel release (ECTR) (ie, greater relief of symptoms, lower rate/risk of complications, faster return to work, and faster procedure). (O) = favors open carpal tunnel release (OCTR). (NA) = does not favor either ECTR or OCTR. (U) = unclear from study description whether ECTR or OCTR is favored. BCTQ-S = Boston Carpal Tunnel Questionnaire (BCTQ) symptom severity score.

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