

Endoscopic carpal surgery in carpal tunnel syndrome: A systematic review

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Abstract

Objective: Endoscopic carpal tunnel release has become increasingly popular and has shown the advantage of early recovery of hand function with minimal morbidity. In this systematic review, we aimed to summarize the currently available data and describe the reported advantages and disadvantages of endoscopic carpal tunnel surgery for treating carpal tunnel syndrome.

Methods: In this study, we followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, which is a set of reporting requirements for systematic reviews and meta-analyses. The search strategy with MeSH terms was “MeSH (carpal tunnel syndrome) AND (endoscopic)” Filters: in the last 5 years, English—on February 27th, 2022. A total of 131 articles fulfilled the first screening criteria. A detailed analysis of those articles identified 39 that matched the criteria, of which 14 were considered appropriate for this analysis after applying the complete inclusion and exclusion criteria.

Results: A total of 14 studies met the eligibility criteria. Analysis of those studies found that all types of portals in endoscopic carpal tunnel release reduced postoperative pain at a short-term follow-up. There was no evidence to suggest the superiority of the single- or two-portal techniques in terms of outcomes. In terms of pain relief, symptom resolution, patient satisfaction, duration to return to work, and adverse events, this early use of endoscopic carpal tunnel release produced satisfactory outcomes. Further studies comparing the number of portals are needed.

Conclusion: Endoscopic carpal tunnel surgery for treating carpal tunnel syndrome is effective and both single- and dual-portal techniques provide advantages in terms of early recovery and minimal morbidity.

Keywords

Carpal tunnel syndrome, endoscopic carpal tunnel release, minimal invasive surgery

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Introduction

One of the most prevalent musculoskeletal diseases of the hand and wrist is carpal tunnel syndrome (CTS).^{1,2} Most evidence supports splinting and medication as first-line therapies.^{2–4} However, surgical treatment, independent of approach, has proven to be superior to nonoperative treatment.⁵

Open carpal tunnel release (OCTR) remains the gold standard procedure for CTS and has evolved into a mini-open procedure with the development of new devices.⁶ There is no clear rule about whether the open approach or the closed approach is better. Although the choice between the endoscopic and the open approach is still controversial, endoscopic carpal tunnel release has recently become increasingly popular in hand surgery practice due to the advantages of early recovery of hand function and minimal morbidity.^{7–11} However, endoscopic carpal tunnel release has

its own imitations.⁶ Since their introduction in the late 1980s, endoscopic techniques have evolved significantly with many different techniques using either a single portal or two portals including the Chow technique and the Agee and Brown technique.¹²

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However, these endoscopic techniques have been associated with a higher risk of nerve injury (neuropraxia) and tendon injury, and depend on the surgeon's experience.¹³ However, there have been no systematic reviews specifically of endoscopic carpal tunnel release.

This study aimed to analyze the currently available data and summarize the reported advantages and disadvantages of only endoscopic carpal tunnel surgery for treating CTS, which has two major goals. The primary goal is to focus on the clinical and functional outcomes after surgery. The secondary goal is additional outcomes, including postoperative imaging and laboratory investigation, to help surgeons choose the appropriate technique for patients in their practice.

Methods

Literature search strategy

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)¹⁴ criteria (Figure 1) were followed in conducting this systematic review. A literature search was performed using the PubMed search engine to collect articles published in PubMed between 2017 and 2022 using the MeSH terms. Only the 5 most recent years of publication were included to focus on the most recent ideas. The search strategy for inclusion in this study was "MeSH (carpal tunnel syndrome) AND (endoscopic)" Filters: in the last 5 years, English—on February 27th, 2022. Additional manual checks of the reference lists were also accomplished. Only articles written in English were considered for inclusion. This systematic review was registered by PROSPERO International Prospective Register of Ongoing Systematic Reviews (Registration number: CRD42023409964). However, ethical and consent approval is not applicable.

Inclusion and exclusion criteria

Randomized controlled trials (RCTs) and observational cohort studies were included in this systematic review. There were no restrictions on the type of study, for example, retrospective or prospective; however, all studies had to be published in English. The search did not include case reports, case studies, or technical notes. All of the identified articles' titles and abstracts were evaluated and reviewed. All articles and journals were thoroughly studied, and essential details were recorded.

Data extraction

The following data on the studies were recorded: (1) author and year of publication, (2) type of study design¹⁵ and the country in which the surgery was conducted, (3) sample size and mean age of patients (mean \pm SD), (4) diagnostic tools used, (5) type of anesthetic and administration technique, (6) endoscopic technique and surgical approach, (7) final outcome, (8) complications, and (9) follow-up period.

Assessment of risk of bias of this systematic review

RevMan (Review Manager, Version 5.4, Cochrane Collaboration, 2020), the Cochrane Collaboration tools for assessing the risk of bias in randomized trials, was used to determine the risk of bias for individual RCTs. The evaluation included selection bias, performance bias, attrition bias, bias in detection, and bias in reporting, each of which was classified as high risk, low risk, or uncertain risk. Two investigators rated the included studies' levels of bias separately before comparing their results. Consensus-based decisions were made in cases of disagreement, and a third author's assessment was sought if necessary. A third reviewer also resolved any remaining disagreements regarding evaluation of the retrieved data.

The description of the surgical techniques

As an illustration of the single-portal approach (Agee technique), a video endoscope, a pistol-grip handpiece, and an endoscope-blade assembly that was inserted into the carpal tunnel comprised the system. There was a trigger mechanism incorporated into the pistol-grip hand piece. Through a window located near the assembly's tip, the bottom of the transverse carpal ligament (TCL) could be seen using an endoscope. A 3-cm incision in the wrist flexor crease was created to install the entire device. A trigger-activated mechanism allowed a triangular blade to engage and elevate 3.5 mm above the surface of the assembly. The blade engaged, cutting the TCL, and the complete unit was extracted.¹⁶

In contrast, the proximal portal is formed using the dual-portal approach (Chow technique) by drawing a line 1–1.5 cm radially to the proximal pole of the pisiform bone. 0.5 cm in front of the end of the first line is where the second line is indicated. To represent the entry portal, a third line is drawn about 1 cm radially from the end of the second line. A trocar is inserted, the wrist is stretched, and a specific hand frame holds it in place. A second incision is made 1 cm in front of a line that cuts through the angle produced by the third web space and the distal border of the fully abducted thumb. The trocar, which has a slotted end that sits directly below the TCL, is entered with the endoscope inserted proximally. The distal end is chopped proximally with a probe (forward-facing) knife.¹⁷

Results

A total of 131 articles found in the PubMed database fulfilled the first screening criteria. A detailed analysis discovered 39 articles that matched the criteria of which 14 were considered qualified for inclusion in this analysis after applying the complete inclusion and exclusion criteria (Figure 1). All articles reported on an incidence of endoscopic carpal tunnel surgery with either a single-portal technique or a dual-portal technique. All the studies of carpal tunnel surgery included the diagnosis of carpal tunnel disease and a description of the treatment with endoscopic surgery.

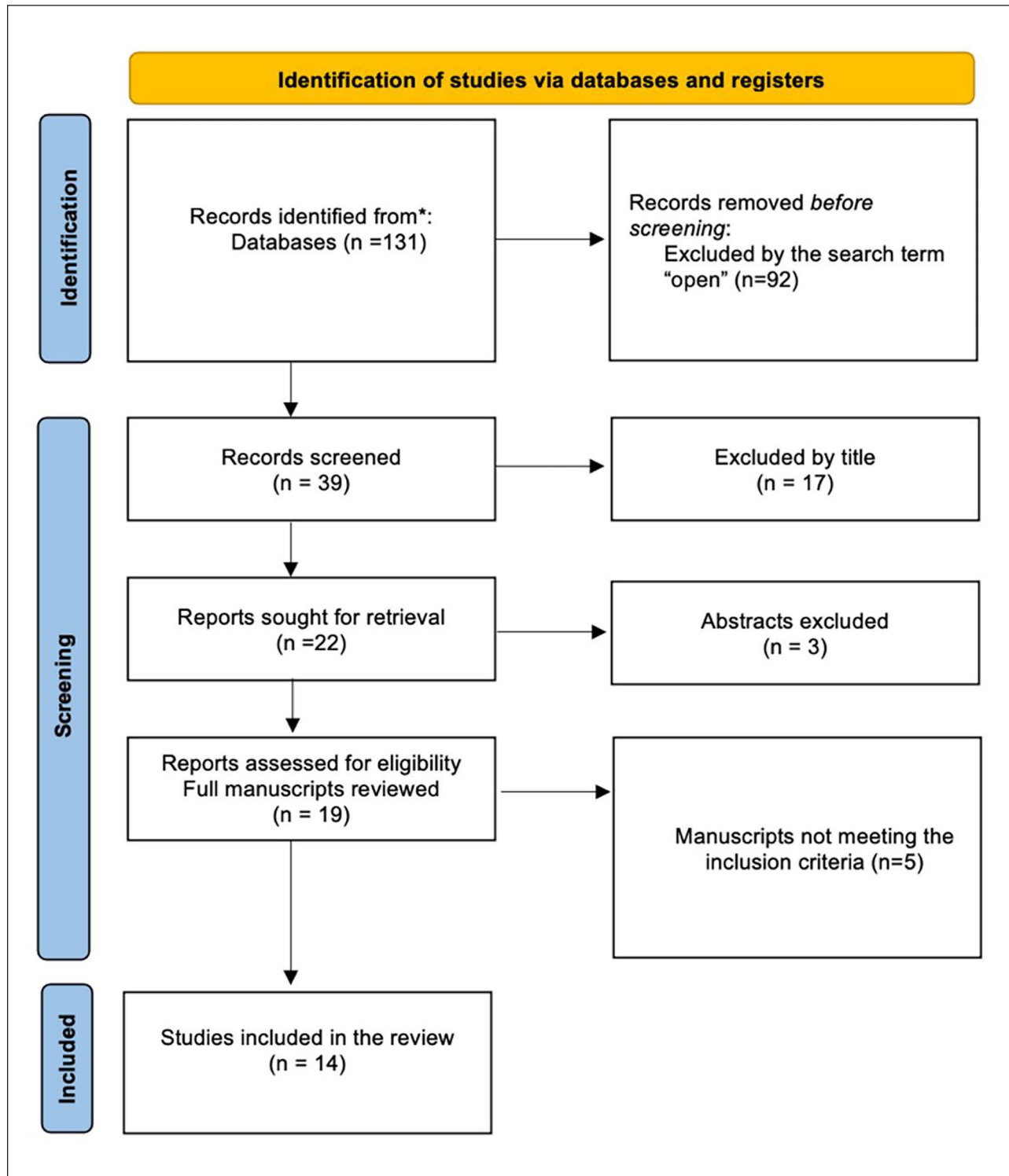


Figure 1. Systematic reviews and meta-analyses (PRISMA) flow diagram of the study.

Demographic data analysis

Data on the studies, including author, year of publication, country in which the surgery was conducted, study design, average age of the patients, sample size, gender ratio,

diagnostic tools, anesthetic technique, endoscopic technique, surgical approach (single-portal or dual-portal technique), clinical outcome parameter measurement score, complications, and average time of follow-up were reviewed and analyzed (Table 1).

Table 1. Demographic data.

Author	Year	Published year	Method	Country	Average age	Female	Male	Study size (wrist)	Left	Right	Diagnosis	Endoscopic technique	Approach	Anesthetic technique
Single portal (1) Kempton et al. ¹⁸	2017	N/A	A blinded randomized controlled trial	USA	29	9	21	30	N/A	N/A	N/A	Single portal	The surgical module was designed to include the following three distinct learning components: (1) A didactic component consisting of a 20-min video reviewing carpal tunnel; (2) a surgical video; and (3) an interactive physical model simulator	N/A
(2) DeGeorge et al. ²⁰	2018	February 2013 to November 2015	Prospective study	France	60.5	19	11	30	30	30	Class 2 or 3 according to Lundborg's scale, electromyography (EMG), "moderate" to "severe" according to Stevens	Single portal (Agee et al.)	Agee's endoscopic carpal tunnel release (CTR) surgery procedure	Regional bilateral anesthesia using an axillary block
(3) Satteson et al. ²⁷	2018	Between 2011 and 2016	Retrospective study	USA	58.9	355	167	522 (897)	N/A	N/A	Nerve conduction studies (NCS), and history of prior CTR	A proximal, single-portal technique was performed	N/A	N/A
(4) Trung et al. ²¹	2019	N/A	Prospective study	Vietnam	51.7	98	20	118 (150)	N/A	N/A	Clinical diagnosis, ultrasound study results, and positive electrodiagnostic study results	Single portal	Agee's endoscopic CTR surgery procedure	Block and local anesthesia
(5) Hein et al. ²⁸	2020	From 2013 to 2019	Retrospective study	USA	53	49	31	80	N/A	N/A	Symptoms prior to treatment for more than 1 year, of the 80 patients, 76 had a positive EMG-NCS	Single portal	The MicroAire single-portal smart release	Monitored anesthesia care with the administration of local anesthetic
(6) Liu and Wu ²⁹	2020	N/A	Retrospective study	China	60	8	0	8 (9)	N/A	N/A	Clinical	Single-portal technique	Incision on the patient's volar skin. A longitudinal line is drawn along the ulnar border of the middle finger, and Kaplan's line is drawn along the abducted thumb. The intersection between these two lines indicates the location of the distal end of the TCL. A clear, colorless, plastic shield was created from a standard syringe that offered a 360° vision of the carpal tunnel and protection of the median nerve.	Local anesthetics
(7) Truelove et al. ¹⁹	2020	From October 2015 to April 2017	Randomized, double-blind	USA	43–57 (50)	33	11	44	N/A	N/A	N/A	Single-portal ECTR	Single incision endoscopic technique.	Local anesthetics
(8) van Rooij et al. ²⁶	2022	Between December 2015 and July 2019	Prospective study	The Netherlands	51.9	47	34	81	7	56	Clinical diagnosis and positive electrodiagnostic study results	Single-portal technique	Fechner endoscopic CTR surgery procedure	Local anesthesia
(9) Tarfusser et al. ³¹	2022	N/A	Retrospective study	Italy	60.5	26	7	33	N/A	N/A	Clinical and neurological evaluation, including EMG	Single-portal ECTR (transresinacular technique)	After incising the well exposed proximal third of the transverse carpal ligament, transection of the remainder is completed using a pediatric urethrotome. This small caliber instrument is moved in the plane of the TCL, without invading the tunnel	Wide area local anesthesia and without tourniquet (WALANT)

(Continued)

Table 1. (Continued)

Author	Year	Published year	Method	Country	Average age	Female	Male	Study size (wrist)	Left	Right	Diagnosis	Endoscopic technique	Approach	Anesthetic technique
Two portals (10) Li et al. ²¹	2019	From December 2014 to October 2016	Prospective study	China	53.4 ± 6.7	21	10	31 (44)	N/A	N/A	Clinical diagnosis of severe idiopathic CTS who underwent electrodiagnostic testing, high-frequency ultrasonic examination	Two portals	Chow's endoscopic CTR surgery procedure	Local anesthesia
(11) Ng et al. ²⁵	2021	May 2013 to September 2016	Prospective study	Hong Kong	56.7 ± 6.8	27	5	23 (35)	11	24	Diagnosed clinically and confirmed with nerve conduction tests	Two-portal technique	N/A	N/A
(12) Ng et al. ²⁴	2021	Between April 2013 and December 2017	Prospective study	Hong Kong	56.9 ± 6.7	30	5	35	12	25	Diagnosed clinically and confirmed by nerve conduction test (NCT) in all patients.	A two-portal ECTR technique	Divide the flexor retinaculum with a retrograde hook knife	N/A
N/A technique (13) Grandizio et al. ²³	2021	Outpatient visit in 2012	Prospective study	USA	58	6	3	9	4	5	Diagnosed by history and physical examination, with a carpal tunnel syndrome-6 (CTS-6) score of greater than 12 considered diagnostic	3 portals: the 3-4 portal for camera placement, the 6R portal for outflow catheter placement, and the 4-5 portal for instrumentation	Ruch and Poebling et al. (Agee's technique) endoscopic CTR surgery procedure	Bier block anesthesia
(14) Wellington et al. ³⁰	2021	Underwent an ECTR between April 28, 2018, and December 31, 2019	Retrospective study	USA	46-56 (51)	N/A	N/A	132 (172)	N/A	N/A	N/A	N/A	N/A	Monitored anesthesia care with tourniquet, local anesthesia with tourniquet (LT), and WALANT

Table 2. The non-RCT risk of bias in this systematic review.

Study	Selection of participants	Confounding variables	Measurement of exposure	Blinding of outcome assessment	Incomplete outcome data	Selection outcome reporting
(1) Degeorge et al. ²⁰	Low	Low	Low	Low	Low	Low
(2) Satteson et al. ²⁷	Low	High	Low	Low	Low	Low
(3) Trung et al. ²²	Low	Low	Low	Low	Low	Low
(4) Hein et al. ²⁸	Low	Low	Low	Low	Low	Low
(5) Liu and Wu ²⁹	High	Low	High	Low	Low	Low
(6) van Rooij et al. ²⁶	Low	Low	Low	Low	Low	Low
(7) Tarfusser et al. ³¹	Low	Low	Low	Low	Low	Low
(8) Li et al. ²¹	High	Low	High	Low	Low	Low
(9) Ng et al. ²⁵	Low	Low	Low	Low	Low	Low
(10) Ng et al. ²⁴	Low	Low	Low	Low	Low	Low
(11) Grandizio et al. ²³	High	Low	Low	Low	Low	Low
(12) Wellington et al. ³⁰	Low	Low	Low	Low	Low	Low

Table 3. The RCT risk of bias in this systematic review.

Study	Randomization	Deviation from intended intervention	Missing outcome data	Measurement of the outcome	Selection of the report results	Overall
(1) Kempton et al. ¹⁸	Low	Some	Low	Low	Low	Some
(2) Truelove et al. ¹⁹	Low	Low	Low	Low	Low	Low

Risk of bias analysis

A summary of the non-RCT risk of bias is shown in Table 2. Three studies had a high risk of bias in the selection of participants, of which two were at high risk of measurement of exposure and one had a high risk of confounding variables. All studies had a low risk of performance bias for blinding of outcome assessment, incomplete outcome data, and selection outcome reporting. Most of the RCT risk of bias included studies with a lower risk of reporting bias (Table 3).

Study design and publication information

In this review, we found blinded RCT studies, prospective studies, and retrospective studies. Two studies were RCT studies by Kempton et al.¹⁸ and Truelove et al.¹⁹. Seven studies were prospective studies, the most prevalent research design, including studies by Degeorge et al.,²⁰ Li et al.,²¹ Trung et al.,²² Grandizio et al.,²³ Ng et al.,^{24,25} and Rooij et al.²⁶ Only five retrospective studies were identified, by Satteson et al.,²⁷ Hein et al.,²⁸ Liu and Wu,²⁹ Wellington et al.,³⁰ and Tarfusser et al.³¹

Nationality

The number of publications on endoscopic carpal tunnel surgery increased between 2015 and 2021 as the trend toward this surgical technique grew. The studies included six articles from the United States, two articles each from the China and Hong Kong, and one article each from France, Vietnam, the Netherlands, and Italy.

Samples size

A 2018 retrospective study conducted in the United States between 2011 and 2016 by Satteson et al. had the largest sample size with 522 patients and 897 wrists using endoscopic surgery, whereas a retrospective review by Liu and Wu²⁹ in China had the smallest sample size of eight patients. A prospective study in Vietnam by Trung et al.²² had the largest sample size of 150 patients. Two RCT articles reported sample sizes of 30 patients (Kempton et al.¹⁸) and 44 patients (Truelove et al.¹⁹), both from the United States.

Gender ratio and average age

In 14 studies, the average age was 53.6 years (range 29–60.5 years). The maximum average age, 60.5 years, was in the studies by Degeorge et al.²⁰ and Tarfusser et al.,³¹ while the minimum average age was 29 years in the study by Kempton et al.,¹⁸ which studied surgical learning modules. Twelve studies had a predominance of females over males. Only Kempton et al.¹⁸ included more males than females, and one study by Wellington et al.³⁰ did not demonstrate the sex aspect.

Diagnostic tools and parameter scores

Eleven studies included information on the tools used for diagnosis, including clinical and neurological evaluation Liu and Wu,²⁹ electrodiagnostic study results (EMG), and NCS. The parameters varied depending on the objectives of the study. Pain outcome measurement included the 11-point pain

scale of the Boston Carpal Tunnel Questionnaire (BCTQ),³² and a six-point CTS-6 score.³³ Clinical and functional outcomes included the visual analog scale (VAS),^{34,35} Quick Disabilities of the Arm, Shoulder, and Hand (DASH) score,³⁶ Activities of Daily Living (ADL) scale,³⁷ the DASH score,³⁸ pinch and grip strength,^{39,40} two-point discrimination,^{41,42} and the number of days until self-reliance.²⁶ Secondary outcomes included imaging and postoperative investigations: motor NCSs, sensory nerve conduction velocities (SNCV) and sensory nerve action potential (SNAPS), cross-sectional area (CSA), edema length (EL), anteroposterior diameter of median nerve (D), as well as median nerve CSA, width, height, TCL width, and anteroposterior dimension of the carpal tunnel. Some studies evaluated surgical timing using a five-point scoring system based on a written multiple-choice test, for example, Wellington et al.³⁰ and Kempton et al.¹⁸

Anesthetic and endoscopic technique

Anesthetic and endoscopic technique of the 12 publications that reported on anesthetic aspects, most reported the use of regional or local anesthesia. A monitored anesthesia care technique was added by Hein et al.,²⁸ while Tarfusser et al.³¹ used only the wide-awake, local anesthesia, no tourniquet (WALANT) technique in all samples. Wellington et al.³⁰ compared the outcome of monitored anesthesia care with tourniquet, (MT)⁴³ local anesthesia with tourniquet (LT), and WALANT. That study reported that WALANT was favored over MT and LT for average operating room time.

Regarding endoscopic techniques, nine studies used a single-portal endoscopic technique with different approaches. DeGeorge et al.,²⁰ Trung et al.,²² and Grandizio et al.²³ demonstrated the Agee technique in a single-portal endoscopic technique which incised the wrist crease from proximal to distal and then inserted a clear plastic cannula with an angled endoscope. Van Rooij et al.²⁶ following Fechner et al. (2013)⁴⁴ used a single-portal technique, claiming that it will can better prevent accidental injury to the median nerve. Liu and Wu²⁹ used a new technique using a plastic shield created from a standard syringe that offers a 360° view of the carpal tunnel and provides protection for the median nerve in single-portal endoscopic techniques. Another single-portal method using a transretinacular technique was demonstrated in a study by Tarfusser et al.³¹

A two-portal endoscope method was used by Li et al.²¹ via the Chow technique, a transbursal approach, while both of Ng et al.'s^{24,25} studies used the portal to divide the flexor retinaculum with a retrograde hook knife. Grandizio et al.²³ and Wellington et al.³⁰ did not report the number of endoscopic portals.

Final outcome and complications

This systematic review classified surgical outcomes into two groups: primary and secondary outcomes (Table 4). The

primary outcome was determined by an evaluation of the clinical and functional results postoperatively, while the secondary outcome included the imaging parameter and other factors that could not be classified as primary outcomes.

We found that most of the endoscopic studies reported satisfaction with the primary outcome. Studies using the Agee technique with a single-portal endoscopic procedure included DeGeorge et al.²⁰ which reported that 97% of patients were satisfied or very satisfied with the outcome and that mean pain had statistically significantly decreased. Trung et al.²² reported that 98% of hands showed improvement in numbness, paresthesia, and pain reduction at the 1-month follow-up, and 92% had full recovery of muscle function at the 6-month follow-up. Grandizio et al.²³ claimed that all operations resulted in complete symptom resolution postoperatively. Those using the Agee technique did not report any complications, although a single case of superficial infection of the operated site (1.7% of patients) was reported by DeGeorge et al.²⁰

Another single-portal technique used in the study by van Rooij et al.²⁶ which employed the technique described by Fechner et al. (2013)⁴⁴ and stated that postoperative functional status increased significantly on a daily basis, and that the mean BCTQ score decreased gradually from intense difficulty to little difficulty in daily tasks over a period of 7 days. Tarfusser et al.³¹ using another single-portal via transretinacular technique stated that all patients reported rapid recovery, pain subsidence, and return to daily activity within a few days, although one patient did not experience measurable improvement of grip strength or sensory function, but only disappearance of pain and discomfort at 2 weeks after surgery. Liu and Wu²⁹ used a new plastic shield portal technique and reported that DASH, BCTQ, and VAS were statistically significantly decreased compared to preoperation.

Two studies of the single-portal technique did not report details of the specific technique or the approach used in the surgery. Satteson et al.²⁷ reported a significant difference only in incidence of neuropraxia, with higher rates occurring in the mild neuropraxia group. Hein et al.,²⁸ using a MicroAire single-portal smart release set, reported that their patients used narcotic pain medication for only 2 days following the operation and returned to ADL in an average of 5 days. The rate of use of narcotic pain medications was higher in females than in males. One superficial infection was treated with oral antibiotics and one patient had persistent CTS symptoms requiring return to the operating room. An anesthetic comparison study by Truelove et al.¹⁹ stated that patients in the IV acetaminophen group reported less pain than both those in the IV ketorolac group ($p < 0.001$) and those in the combination group ($p = 0.03$), but there was no difference in mean pain scores between the IV acetaminophen and placebo groups ($p = 0.99$). The authors suggested that further study was needed to increase the power of their results.

Two-portal endoscope technique studies by Ng et al.^{24,25} which used the portal to divide the flexor retinaculum with a

Table 4. Surgical outcomes and complications.

Author	Year	Endoscopic technique	Follow-up times	Parameter	Clinical and functional outcomes	Secondary outcome (ex: Imaging, etc)	Complications	Conclusion	Cost
Single portal (1) Kempson et al. ¹⁸	2017	Single portal	N/A	Five-point scoring system based on a written multiple-choice test to evaluate their knowledge of the pathophysiology of CTS, the indications for surgery, and steps of the ECTR procedure	N/A	The average operation performance scores for the surgical module group and nonmodule group were 96% and 82%, respectively.	N/A	The use of an ECTR surgical education module demonstrates a significant benefit in ECTR-native subjects.	The added cost of module and simulator development may limit the widespread application of similar training methodologies.
(2) Degeorge et al. ²⁰	2018	Agee et al. single portal	After 1 and 3 postoperative months.	VAS, QuickDASH score (Disabilities of the Arm, Shoulder, and Hand), and ADL scale	Overall, 97% of patients were satisfied or very satisfied with the outcome. Mean pain had decreased by 3.6 (1–10) on the right side, and 5.7 (2–9) on the left side ($p < 0.001$). The QuickDASH score decreased by 45.6 (7–73) on average ($p < 0.001$).	N/A	Single case of superficial infection of the operated site (1.7%), no further surgery was needed	Bilateral simultaneous endoscopic carpal tunnel surgery results in fast resumption of daily living activities and fast functional recovery. It allows for a fast return to work and appears to be more cost-effective than bilateral delayed surgery.	N/A
(3) Sarteson et al. ²⁷	2018	A proximal, uniportal technique was performed	N/A	Symptom	Significant difference only in neuropraxia rates, with higher rates occurring in the mild group	N/A	Only 8 patients (10 hands, 0.8%) had recurrent symptoms at an average of 8 months postoperatively. Seven hands resolved without intervention, one with open CTR.	Patients with severe CTS should expect relief of symptoms after an endoscopic release of the carpal tunnel.	N/A
(4) Trung et al. ²²	2019	Single portal	1-, 3-, and 6-month follow-up	Boston questionnaire (BQ), electromyography, and ultrasound	At 1-month follow-up, 98% of the hands had improved numbness, paresthesia, and discomfort, while 2% had no change. At 3 months, 32% of the hands had fully recovered muscle function, while 68% still had difficulties. At 6-month follow-up, 92% of hands had full muscle function recovery, whereas 8% had partial recovery.	EMG findings start showing significant improvement at 3-month follow-up onward. At the 1-month follow-up, electromyographic values do not change significantly due to a big negative preoperative difference in sensory latencies.	Intraoperative complications did not occur.	The endoscopic release using the MicroAire single-portal system happened to be a safe and efficacious option for ECTR, especially in moderate cases (2-stage by R. Szabo)	N/A
(5) Hein et al. ²⁶	2020	Single portal	Two-week and an average 4-week clinical follow-up	Return to work was recorded in business days. Return to recreational activities was subjective and based on the nine-item Quick Disabilities of the Arm, Shoulder, and Hand (QuickDASH-9) questionnaire	Patients reported an average of 7.2 days of use of postoperative narcotic pain medication and an average of 5.7, and 19 days of return to ADL, work, and recreational activities, respectively. Female patients reported more days of narcotic pain medications (1 day versus 3 days, $p = 0.0483$) and an average of longer time return to work than men (9 days versus 5 days, $p = 0.0477$).	N/A	One superficial infection treated with oral antibiotics and one patient with persistent CTS symptoms requiring return to the operating room.	Simultaneous bilateral ECTR is a successful procedure with shorter recovery times than reported previously.	N/A
(6) Liu and Wu ²⁹	2020	Single-portal technique	Six-month follow-up	The DASH score, the BCTQ, and a VAS	All patients improved clinically after ECTR. The DASH, BCTQ, VAS showed statistically significant decreases compared to preoperation (< 0.05)	N/A	No peri- or postoperative complications were encountered.	At the 6-month follow-up, DASH and VAS ratings improved in all patients. All patients were satisfied with the surgery and said that they would repeat it if they had the same problems on the other hand.	Our cost-effective ECTR method can be performed by any operating room team trained in small joint arthroscopy using standard reusable hand surgery instruments.
(7) Truelove et al. ¹⁹	2020	Single-portal ECTR	Every 8 h for 7 days after surgery	11-point pain scale	Patients in the IV acetaminophen group reported less pain than those in the IV ketorolac group ($p < .001$) and combination group ($p = 0.03$). There was no difference in mean pain scores between the IV acetaminophen and placebo groups ($p = 0.99$).	N/A	N/A	The differences were small, but they are supportive of using IV acetaminophen for perioperative pain control following an ECTR	N/A
(8) van Rooij et al. ²⁶	2022	Single-portal technique	1 and 2 weeks	BCTQ and the number of days until self-reliance	Postoperative functional status improved everyday, and mean BCTQ ratings declined from great difficulty to minimal difficulty in daily tasks over 7 days. Preoperative BCTQ symptoms decreased from medium to moderate.	N/A	N/A	Bilateral ECTR may save society money by reducing recovery time and self-reliance, especially for patients who need speedy recovery. Simultaneous, bilateral ECTR allows self-reliance in 4–5 days and a progressive and significant rise in hand function in the postoperative days. On postoperative days 1 and 2, bilateral patients had more trouble with various everyday functions.	Bilateral ECTR saves substantial costs to society compared to single CTR. (costs for ECTR are known to be higher than for OCTR)
(9) Tarfusser et al. ³¹	2022	Single-portal ECTR (transneurovascular technique)	2 weeks and 6 months	BCTQ, pinch and grip strength, and two-point discrimination	All patients reported rapid recovery and return to daily activity within a few days. Pain subsided in all patients within the first few days after surgery. The BCTQ score showed consistent improvement with the symptom severity score dropping from 2.79 ± 0.26 , preoperatively, to 1.17 ± 0.11 , 2 weeks after surgery, and the functional status score from 1.83 ± 0.20 to 1.38 ± 0.20 . At 6 months, all patients but one had recovered full sensibility and grip strength.	N/A	One patient did not experience measurable improvement of grip strength or sensory function, but only disappearance of pain and discomfort at 2 weeks from surgery.	Obtaining the desired results, in particular a very swift recovery, with a procedure designed to be less traumatic and technically more accurate than any other ECTR procedures.	N/A

(Continued)

Table 4. (Continued)

Author	Year	Endoscopic technique	Follow-up times	Parameter	Clinical and functional outcomes	Secondary outcome (ex: imaging, etc.)	Complications	Conclusion	Cost
(10) Li et al. ²¹	2019	Two portals	At 2 weeks, 4 weeks, 3 months, 6 months, and 12 months after surgery.	Motor NCSs, SNCV and SNAIS, CSA, the EL, and anteroposterior diameter of median nerve (D)	N/A	The 2-week postoperative (1.94 ± 0.998 cm in EL, 0.28 ± 0.039 cm in D, and 0.18 ± 0.015 cm ² in CSA) and 3-day postoperative (P-EL = 0.250 ; P-D = 0.125 ; P-CSA = 0.712) parameters did not differ significantly. After surgery, the metrics improved quickly. The EL (0.715 ± 0.209 cm), D (0.225 ± 0.017 cm), and CSA (0.117 ± 0.012 cm ²) at 3 months postoperatively were lower than at 4 weeks (P-EL < 0.001 ; P-D = 0.038 ; P-CSA = 0.014). Neurological and anatomical parameters steadily restored. Three measures were neuroanatomically normal at 12 months postoperative. Compared to the control group in D (0.213 ± 0.005 cm), there was no difference at 12 months (0.214 ± 0.009 cm, $p = 0.939$). At the 12-month time period, sick and healthy volunteers still differed in EL (0.098 ± 0.030 cm versus 0.016 ± 0.011 cm) and CSA (0.103 ± 0.008 cm ² versus 0.073 ± 0.005 cm ²).	N/A	N/A	N/A
(11) Ng et al. ²⁵	2021	Two-portals technique	3 and 12 months after ECTR	In-house scoring system (0–4) and paired t test	Mean clinical improvement scores of 2.94 ± 1.0 at 3 months and 3.49 ± 0.56 at 12 months.	Even 12 months after ECTR, the median nerve remained enlarged (> 15 mm ³) and flattened. Median nerve caliber-change ratio, relative signal intensity, and carpal tunnel CSA changed. After ECTR, 33 (94%) wrists had a retinacular gap, and 6 (17%) had increased retinacular bending.	N/A	Undue swelling and flattening of the median nerve persist for as long as 12 months after surgery, even in patients with a good surgical outcome.	N/A
(12) Ng et al. ²⁴	2021	A two-portals ECTR technique	At 2 weeks, 3 months, and 12 months post-ECTR	In-house developed scoring system, the circumferential surface area, the flattening ratio, neural vascularity, neural fasciculation, retinacular bowing, carpal tunnel CSA, and retinaculum gap	All patients improved clinically after ECTR. The average clinical improvement score \pm SD at 12 months post-ECTR was 2.2 ± 0.7 .	The median nerve CSA proximal and distal to the tunnel decreased post-ECTR but remained inflamed. After ECTR, median nerve diameter and retinacular bowing changed more at the tunnel outlet than at the inlet. A total of 25 (68%) of the 37 wrists demonstrated flexor retinaculum regrowth after 12 months.	N/A	Postoperative changes in median nerve and retinaculum parameters were mostly pronounced at the tunnel outlet. Even in patients with clinical improvement after ECTR.	N/A
(13) Grandizio et al. ²³	2021	The 3 portals: the 3–4 portal for camera placement, the 6R portal for outflow catheter placement, and the 4 CSA 5 portal for instrumentation	6 weeks and 6 years	CTS-6 score, median nerve CSA, width, height, ratio, TCL width, and anteroposterior dimension of the carpal tunnel	All complete symptom resolution postoperatively	The median nerve CSA and the anteroposterior dimension of the carpal tunnel at the level of the hamate increased immediately after surgery and these changes were maintained at 6 years.	No postoperative complications	The median nerve and carpal tunnel in patients with continued symptom resolution 6 years after ECTR. Changes in median nerve and carpal tunnel morphology that occur immediately after surgery remain unchanged at midterm follow-up in asymptomatic patients.	N/A
(14) Wellington et al. ²⁰	2021	N/A	N/A	Surgical timing	N/A	Trends favored WALANT over MT and LT for average operating room time (20 min, SD: 3 versus 32 min, SD: 6 versus 23 min, SD: 3, respectively, $F(2, 153) = 101.1$, $p < .001$), post-anesthesia care unit time (12 min, SD: 7 versus 1:12 min, SD: 26 versus 20 min, SD: 22, respectively, $F(2, 153) = 171.1$, $p < .001$), and door-to-door time (1:37 min, SD: 21 versus 2:51 min, SD: 40 versus 1:46 min, SD: 33, respectively, $F(2, 153) = 109.3$, $p < .0001$).	Two superficial infections in the LT group, one in the WALANT group, and two aseptic flexor tenosynovitis ("other consequence") in the MT group. No group had neuropraxia, nerve damage, deep infection, or ischemia.	Our data suggest favorable trends for patients undergoing eCTR via WALANT versus MT versus LT	N/A

retrograde hook knife showed mean clinical improvement scores of 3.49 ± 0.56 and 2.2 ± 0.7 at 12 months. Grandizio et al.²³ reported on changes in median nerve and carpal tunnel morphology that occurred immediately after surgery and which remain unchanged at the midterm follow-up. All patients reported complete symptom resolution postoperatively without complications.

In regard to the secondary outcomes, Kempton et al.¹⁸ reported that the surgical module for doctors reported an average operation performance score of 96%. Li et al.²¹ NCSs after two-portal ECTS using Chow's technique reported that neuroanatomical parameters gradually improved after ECTR surgery and that the best time for ultrasound follow-up is at the 3-month postoperative time point for patients who do not show clinical improvement.

Wellington et al.'s³⁰ study of surgical timing with different anesthetic techniques did not report the surgical technique used, but favored WALANT over MT and LT for average operating room time (20 min, SD: 3; 32 min, SD: 6; and 23 min, SD: 3, respectively).

The study by Grandizio et al.²³ stated that the median nerve CSA and the anteroposterior dimension of the carpal tunnel at the level of the hamate increased immediately after surgery using three portals and that those changes were maintained for 6 years postoperatively.

Discussion

The most frequent individual's awareness of the hands is CTS. Clinical relevance in the general population is 3.8%.⁴⁵ Patients with CTS who have sustained numbness, discomfort for longer than 6 months, or who did not receive sufficient conservative therapy require surgical treatment.⁴⁶ Surgery is performed on between 31% and 40% of CTS patients, a noteworthy percentage. If the patient has significant compression and thenar muscle atrophy, urgent decompression is required to enable a potential full recovery. Prior to surgery, patients should be informed of the nature of the proposed treatment plan. Advanced surgical procedures have seen ongoing improvement in terms of minimally invasive surgery. There has been a significant paradigm shift from traditional big-open surgery to minimally invasive surgery such as ECTR, resulting in improved patient benefits and quicker recovery. ECTR is one of the advances, with the small incision allowing for faster recovery and earlier return to normal activity.¹¹

For this analysis, 14 studies conducted in the past 5 years met the inclusion criteria. The endoscopic techniques used can be classified into two main types: single portal and dual portal. Within each of these two main types, there are many different approaches. Results indicate that with all types of portals, ECTR decreased postoperative discomfort during close follow-up. Among the studies that satisfied the inclusion requirements, six studies investigated imaging parameters at short-term follow-up, whereas eight studies analyzed

pain and function as a primary endpoint. The majority of studies used the BCTQ for evaluation, and they found short-term pain reduction after ECTR at intervals of between 1 day and 2 weeks (van Rooij et al.²⁶; Tarfusser et al.³¹; Liu and Wu²⁹; Trung et al.²²; Degeorge et al.²⁰). Several studies additionally reported imaging parameters at long-term follow-up ranging from 2 weeks to 6 years (Grandizio et al.²³; Ng et al.^{24,25}). Following ECTR, no study reported inferior pain outcomes.

Selecting the right patients is crucial to a successful outcome. Candidates should only be patients with classic CTS. Patients with recognized anomalies of the anatomy, ganglion or synovial cysts, neuromas, a fracture history, septic or inflammatory tenosynovitis, and CTR failures in the past, among other conditions, are contraindicated. Large, bulky hands can be challenging to work on technically.⁴⁷

Clinical patients' outcome evaluations following all endoscopic surgeries showed impressive outcomes, but, single-portal operations were reported to have had more complications due to superficial infection than dual portals. However, several studies did not provide information on the complications.

Although there is no proof that one over two-portal approaches produce better results, with a single-portal system, the blade and camera are combined into a single device. Instead of a little off-center image, the severed ligament may be directly seen, thanks to that combination. However, the two-portal system allows for direct viewing when rasping or probing, which may increase safety and is not feasible with the single-portal method. The single or uniportal technique has been recommended because of the lack of persistent pain and dysesthesia in the palmar area attributable to the second incision performed in the dual-portal technique, but the limited visual information is a disadvantage of the single-portal technique. Ulnar neurapraxia and damage to sensible nerves have been reported with the single-portal technique but are very rarely reported with the dual-portal technique.

Brown's two-portal technique was evaluated by Piccirilli et al., who concluded that when the right steps are rigorously followed, it looks to be a safe and reliable ECTR technique. The partial release of the TCL in three cases and one incidence of moderate neuropraxia indicate that there is a learning curve with this treatment. However, we discovered that the technique was simple to understand and apply.⁴⁸

For the limitations of this systematic review, the number of ECTR randomized and non-randomized controlled trials was still limited studies. This study was a detailed analysis of those 39 articles identified from MEDLINE (Scopus database) that matched the criteria, of which 14 were considered appropriate for this analysis because they were not compared with OCTR. However, our next research would compare ECTR and OCTR in a systematic review and meta-analysis of future clinical studies. Furthermore, the purpose of the study of Truelove et al.¹⁹ was to determine if perioperative administration of intravenous NSAIDs decreases

postoperative pain and opioid consumption after ECTR, which does not completely match the aim of the study. However, Truelove et al. still provides some essential information about the ECTR, especially, in postoperative pain management. Another limitation issue is that only the 5 most recent years of publication, from 2017 to 2022, were included to focus on the most recent ideas. However, this could limit some beneficial information in the past.

In conclusion, CTS is a common condition that is readily treated and healed. Conventional or mini-open surgery could be the future standard for CTS treatment, but in moderate to severe situations, surgery is required. It is crucial to release the transverse carpal ligament under the arthroscope the entire time, regardless of whether there are one or two portals. To guarantee safety, it is advised that the operation be carried out while always being visible. One of the most cutting-edge minimally invasive carpal tunnel release procedures, the ECTR with single- and two-portal approaches, has demonstrated good results in terms of lowering complications and ensuring a safe and successful operation.⁹

Conclusions

Overall, literature from randomized and non-RCTs demonstrates that endoscopic surgery is the minimally invasive surgery and that ECTR technique promotes faster recovery of return to work, high satisfaction, improved hand grip strengths, and fewer scar-related problems. This systematic review implies that ECTR can be used effectively to treat patients with CTS. Both the single- and two-portal approaches to endoscopic surgery for carpal tunnel release are employed, and good clinical results and patient satisfaction are obtained more rapidly. Both techniques are safe, effective, and optional minimally invasive treatments for CTS.

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Author contribution

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Availability of data and material

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Supplemental material

Supplemental material for this article is available online.

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