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A Comparative Study of Endoscopic Carpal Tunnel Release and Open Carpal Tunnel Release for Carpal Tunnel Syndrome

Zhiqi Zhang
Yichang Central People's Hospital
Yulong Liu
Yichang Central People's Hospital
Huarui Yang
Yichang Central People's Hospital
Bihui Song
Yichang Central People's Hospital
Kangquan Shou
jimmyreborn@outlook.com

Yichang Central People's Hospital

Research Article

Keywords: carpal tunnel syndrome, endoscope, neurolysis, neuroelectrophysiology

Posted Date: March 20th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9123689/v1

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Additional Declarations: No competing interests reported.

Abstract

Purpose

To compare the efficacy of endoscopic carpal tunnel release and open carpal tunnel release in the treatment of carpal tunnel syndrome.

Methods

A retrospective analysis was performed on clinical data of 112 patients with carpal tunnel syndrome admitted from January 2022 to December 2024. The BCTQ-SSS, BCTQ-FSS, pain VAS, median nerve electrophysiological indices (SNCV, SNAP amplitude, DML, CMAP amplitude), and complications were assessed and documented.

Results

According to the predefined inclusion and exclusion criteria, 82 of 112 patients were included, with a median follow-up of 34 months (range 13–48 months). 35 patients underwent ECTR and 47 underwent OCTR. At the final follow-up, both groups achieved significant improvements in VAS score, BCTQ-SSS, BCTQ-FSS, and all electrophysiological parameters (SNCV, SNAP, DML, CMAP) versus preoperative baseline. No significant intergroup differences were found in these postoperative outcomes (all $P > 0.05$). The ECTR group had significantly shorter operative time and lower hospitalization cost than the OCTR group (both $P < 0.001$).

Conclusion

This single-center retrospective study with short-term follow-up has inherent limitations, yet our results confirm favorable clinical efficacy for both surgical approaches. Endoscopic carpal tunnel release provides minimal invasiveness and less scarring, whereas open release features shorter operation time and lower inpatient costs.

Level of evidence

Level IV retrospective case series.

Introduction

Carpal tunnel syndrome (CTS) is the most prevalent upper extremity peripheral nerve entrapment neuropathy worldwide, with a prevalence of 3.8% in the general population. In the United States alone, over 600,000 patients undergo carpal tunnel release (CTR) annually, imposing a substantial burden on healthcare systems and societal workforce productivity[1–3]. As the leading cause of hand dysfunction secondary to nerve entrapment, the standardized surgical management of CTS has long been a key research focus and clinical hotspot in the field of hand surgery.

The core pathological change of CTS is compression of the median nerve within the carpal tunnel, which can lead to progressive pain, paresthesia, and motor dysfunction of the hand, severely impairing patients' quality of life and work capacity[4]. For patients with moderate-to-severe CTS who show no response to conservative management, surgical division of the transverse carpal ligament (TCL) to achieve median nerve decompression is currently a well-recognized definitive treatment strategy[5]. Conventional open carpal tunnel release (OCTR) has long been regarded as the gold standard procedure for CTR, with the advantages of adequate surgical field exposure, a low technical threshold, and broad clinical indications[6, 7]. As a minimally invasive alternative, endoscopic carpal tunnel release (ECTR) has seen a continuous rise in clinical adoption since its introduction. Its core benefits include minimal soft tissue trauma and a more cosmetically favorable postoperative scar, theoretically enabling a more rapid postoperative recovery[4, 8–10].

Previous comparative studies and systematic reviews evaluating these two surgical approaches have yielded inconsistent conclusions[11]. In a randomized controlled trial, MacDermid et al.[8] found that ECTR conferred a short-term advantage in grip strength recovery and pain relief at 1 and 6 weeks postoperatively, but this difference was completely abolished by 12 weeks after surgery. The latest meta-analysis by Boutros et al.[6], which enrolled 44 comparative studies, revealed no statistically significant differences between the two techniques in terms of long-term pain relief, functional recovery, muscle strength improvement, and overall complication rates, while the ECTR group had a significantly lower postoperative revision rate.

To further clarify the clinical application value of different CTR surgical techniques, we conducted a single-center retrospective study. We collected the clinical data and follow-up information of patients with CTS who underwent surgical treatment at our institution, and performed a comparative analysis of the clinical efficacy, complications, and prognostic outcomes between OCTR and ECTR. This study aims to provide real-world data to support clinical decision-making in the selection of surgical approaches for CTS.

1. Methods & methods

This study was approved by the Ethics Committee of Yichang Central People's Hospital and performed in accordance with the Declaration of Helsinki (2026-021-01).

1.1 Inclusion and exclusion criteria

The inclusion criteria for this study are as follows: (1) a clinical diagnosis of CTS based on symptoms and physical examination findings; (2) electrophysiological findings consistent with the diagnostic criteria for CTS, characterized by prolonged motor latency, reduced amplitude of the median nerve at the wrist, prolonged sensory latency, reduced amplitude, slowed conduction velocity, and, in severe cases, absence of both motor and sensory potentials[12];(3) Failure of a 2-month conservative treatment

regimen; (4) Patients with unilateral disease; (5) Follow-up period exceeding 6 months, with a comprehensive dataset.

The exclusion criteria were as follows: (1) Patients with CTS who did not undergo surgical treatment in accordance with the study protocol;(2) Patients with a mass within the carpal tunnel detected via ultrasonographic examination;(3) Patients with bony or articular abnormalities of the carpal tunnel indicated by plain radiography;(4) Patients with a concurrent diagnosis of osteoarthritis, rheumatoid arthritis, or gouty arthritis involving the wrist joint;(5) Patients with a follow-up period of less than 6 months or incomplete clinical datasets.

1.2 Clinical data

Between January 2022 and December 2024, a total of 112 patients were diagnosed with CTS. Of these, 82 patients who met the aforementioned inclusion criteria were enrolled in this study (Fig. 1). A comprehensive retrospective review was performed on the clinical data and electrophysiological characteristics of the enrolled patients.

Baseline clinical data included age, sex, and body mass index (BMI). The outcome measures included the symptom severity score (SSS) and functional status score (FSS) of the Boston Carpal Tunnel Questionnaire (BCTQ), the Visual Analogue Scale (VAS), as well as electrophysiological parameters of the median nerve: sensory nerve conduction velocity (SNCV), sensory nerve action potential (SNAP) amplitude, distal motor latency (DML), and compound muscle action potential (CMAP) amplitude. Long-term complications and reoperation rates were recorded. All questionnaires were completed independently by each patient.

1.3 Boston Carpal Tunnel Questionnaire

The Boston Carpal Tunnel Questionnaire (BCTQ) was developed by David W. Levine from Brigham and Women's Hospital in Boston, USA, in 1993. It consists of two core domains: the Symptom Severity Score (SSS) and the Functional Status Score (FSS). The SSS evaluates the frequency and severity of core CTS symptoms, while the FSS assesses the impact of CTS on patients' ability to perform activities of daily living (ADLs). The clinically recognized thresholds for the Patient Acceptable Symptom State (PASS) are an SSS ≤ 1.82 and an FSS ≤ 1.50; scores below these thresholds indicate that the patient has achieved clinically satisfactory recovery of symptoms and functional status[13, 14].

1.4 Neuroelectrophysiology examination

The summary of the 2024 Clinical Practice Guideline for CTS issued by the American Academy of Orthopaedic Surgeons (AAOS) has repeatedly highlighted neuroelectrophysiological assessment and identified it as a core reference modality for CTS diagnosis[15]. SNCV, SNAP, DML, and CMAP of the median nerve play a critical role in the diagnosis, severity stratification, and prognostic assessment of CTS[16].

1.5 Statistical analysis

Statistical analyses were performed using SPSS version 25.0 software (SPSS Inc., Chicago, IL, USA). Categorical variables were presented as frequencies and percentages, and intergroup comparisons were conducted using the chi-square test. Continuous variables were expressed as mean ± standard deviation (SD). The Shapiro-Wilk test was used to verify the normality of data distribution, and Levene's test was applied to assess the homogeneity of variances between groups. For intergroup comparisons of continuous variables, the independent samples t-test was used when data were normally distributed with homogeneous variances, while Welch's corrected t-test was adopted in cases of heterogeneous variances. The Mann-Whitney U test was performed for data with a non-normal distribution. A P-value < 0.05 was considered to indicate a statistically significant difference.

2. Surgical Procedure

OCTR was performed using the mini-palm open release technique, which was first described by G.S. Bromley[17]. ECTR was conducted with a specialized technique using a transparent, colorless plastic protective sheath fabricated from a syringe, which was first reported by Bo Liu[18].

3. Results

Between January 2022 and December 2024, a total of 112 patients were diagnosed with CTS. Of these, 82 patients (55 females and 27 males) met the inclusion criteria and were enrolled in this study. The median follow-up duration of all patients was 34 months (range, 13–48 months), and no vascular or neurological complications occurred in any patient during the follow-up period. Among the enrolled patients, 47 cases underwent OCTR, and the remaining 35 cases received ECTR.

We first compared the preoperative baseline characteristics between the two groups of patients. There were no statistically significant differences in age, sex distribution, and body mass index (BMI) between the two groups (all $P > 0.05$), indicating that the demographic characteristics of the two groups were comparable (Table 1). No statistically significant differences were observed in the preoperative VAS score, BCTQ-SSS, and BCTQ-FSS between the OCTR group and the ECTR group (all $P > 0.05$). For the preoperative neuroelectrophysiological parameters, including SNCV, SNAP amplitude, DML, and CMAP amplitude, no significant differences were detected between the two groups (all $P > 0.05$, Table 2). These results confirmed that the baseline characteristics of the two groups were well-balanced and comparable.

Table 1
Patient demographics characteristics.

Variables	Open(n = 47)	Endoscopic(n = 35)	*P* Value
Age (years)	53.33 ± 8.66	53.42 ± 9.67	0.9647
Sex (M/F)	15(31.91)/32(68.08%)	12(35.29%)/23(65.71%)	0.8212
BMI (kg/m^2)	24.38 ± 3.12	24.29 ± 2.77	0.8926
Left/Right	19(40.43%)/28(59.57%)	13(37.14%)/22(62.86%)	0.7633
BMI, body mass index;			

At the final follow-up, both groups achieved remarkable improvements in clinical symptom scores and nerve electrophysiological indicators relative to their preoperative baseline levels. In the intergroup comparison, no statistically significant differences were found in the VAS scores (0.38 ± 0.49 vs 0.34 ± 0.48, $P = 0.7132$), BCTQ-SSS scores (12.38 ± 1.13 vs 12.51 ± 1.15, $P = 0.6103$), and BCTQ-FSS scores (9.43 ± 1.85 vs 9.49 ± 1.29, $P = 0.8630$) between the OCTR and ECTR groups. Consistently, the final follow-up nerve electrophysiological outcomes, including SNCV (46.51 ± 2.57 m/s vs 45.71 ± 3.22 m/s, $P = 0.2146$), SNAP (15.30 ± 3.51 μV vs 16.40 ± 2.79 μV, $P = 0.1304$), DML (4.77 ± 0.44 ms vs 4.68 ± 0.42 ms, $P = 0.3530$), and CMAP (12.23 ± 1.31 mV vs 12.51 ± 1.12 mV, $P = 0.3121$), showed no significant differences between the two groups (all $P > 0.05$, Table 2).

Table 2
Preoperative and postoperative VAS scores, BCTQ scores, and nerve electrophysiological examination outcomes of patients

Variables	Prior to surgery			Final follow-up		
	Open (n = 47)	Endoscopic (n = 35)	*P* value	Open (n = 47)	Endoscopic (n = 35)	*P* value
VAS	2.77 ± 0.91	2.66 ± 0.97	0.5999	0.38 ± 0.49	0.34 ± 0.48	0.7132
BCTQ-SSS	22.06 ± 5.91	21.77 ± 5.59	0.8224	12.38 ± 1.13	12.51 ± 1.15	0.6103
BCTQ-FSS	12.30 ± 3.54	12.63 + 2.10	0.5998	9.43 ± 1.85	9.49 ± 1.29	0.8630
SNCV *(m/s)*	38.77 ± 3.82	39.57 ± 3.23	0.3202	46.51 ± 2.57	45.71 ± 3.22	0.2146
SNAP *(μV)*	12.38 ± 1.81	12.31 ± 1.64	0.8575	15.30 ± 3.51	16.40 ± 2.79	0.1304
DML *(ms)*	5.02 ± 0.33	5.14 ± 0.35	0.1163	4.77 ± 0.44	4.68 ± 0.42	0.3530
CMAP *(mV)*	9.43 ± 1.21	9.51 ± 1.18	0.7656	12.23 ± 1.31	12.51 ± 1.12	0.3121

BCTQ-SSS: the symptom severity scale of Boston carpal tunnel questionnaire; BCTQ-FSS: the functional status scale of Boston carpal tunnel questionnaire; CMAP: compound muscle action potential; DML: distal motor latency; SNAP: sensory nerve action potential; SNCV: sensory nerve conduction velocity.

The perioperative outcomes of the two groups are summarized in Table 3. The mean operative time was significantly longer in the ECTR group than in the OCTR group (46.91 ± 6.22 min vs 35.11 ± 4.40 min, $P < 0.001$). In addition, the total hospitalization cost of the ECTR group was significantly higher than that of the OCTR group (8059.85 Yuan vs 6995.57 Yuan, $P < 0.001$).

Table 3
Perioperative Outcomes of the Two Groups.

Variables	Open(n = 47)	Endoscopic(n = 35)	*P* Value
Surgery time (min)	35.11 ± 4.40	46.91 ± 6.22	P < 0.001
Costs (Yuan)	6995.57 (5898.34, 7436.60)	8059.85 (6715.24, 8739.40)	P < 0.001

4. Discussion

In this single-center retrospective analysis enrolling 82 patients with CTS, we compared the clinical efficacy, perioperative parameters, and long-term follow-up outcomes between ECTR and OCTR. The core finding was that there were no statistically significant differences between the two surgical approaches in terms of postoperative pain relief, functional recovery, and neuroelectrophysiological improvement, whereas OCTR exhibited significant advantages of shorter operative time and lower hospitalization costs. These findings not only fulfill the study objective of clarifying the clinical application value of the two CTR modalities stated in the Introduction but also provide real-world evidence-based support for clinical surgical decision-making in CTS. Meanwhile, the clinical implications and scientific value of these results warrant in-depth interpretation in the context of the existing research landscape and the inherent limitations of the present study.

CTR serves as the first-line definitive treatment for moderate to severe CTS following failure of conservative treatment, and the optimization of its surgical modalities has long been a key research focus in the field of hand surgery[19]. The results of this study demonstrated that postoperative VAS scores, BCTQ-SSS and BCTQ-FSS scores, as well as median nerve electrophysiological parameters (including SNCV, SNAP amplitude, DML, and CMAP amplitude) were all significantly improved relative to the preoperative baseline in both groups, with no statistically significant differences detected between the two groups. This finding is consistent with the conclusions of the meta-analysis published by Masri et al.[20], which confirmed no significant differences between the two surgical modalities in long-term pain relief, functional recovery, and the incidence of complications. Collectively, these data further verify the robust clinical efficacy of both CTR procedures. The randomized controlled trial (RCT) conducted by Joy C et al.[8] also demonstrated that although ECTR had short-term advantages in grip strength recovery and pain relief at 1 to 6 weeks postoperatively, this difference completely disappeared by 12 weeks after surgery. This finding aligns well with the long-term follow-up results (median follow-up duration of 34 months) of the present study, indicating consistent long-term efficacy between the two surgical modalities. Furthermore, neuroelectrophysiological parameters are recognized as the core benchmarks for evaluating postoperative recovery in CTS. Significant improvements in these parameters directly reflect the efficacy of median nerve decompression [21], which provides a solid theoretical foundation for the efficacy assessment framework employed in the present study.

About perioperative parameters, the present study revealed that OCTR was associated with a significantly shorter operative time (35.11 ± 4.40 min vs. 46.91 ± 6.22 min, $P < 0.001$) and significantly lower hospitalization costs (6995.57 Yuan vs. 8059.85 Yuan, $P < 0.001$) compared with ECTR. This finding aligns with the conclusions of a portion of prior studies, while conflicting with those reported in other published investigations. Studies by Teng et al.[22] and Zheng et al.[23] reported that endoscopic carpal tunnel release had a shorter operative time compared with open surgery. Such discrepancies in study findings may be attributed to variations in surgical modality selection, surgeon operative proficiency, and the severity of patients' CTS. Notably, in the present study, the ECTR procedure was performed using a novel endoscopic technique, which required preparation of a transparent, colorless plastic protective sheath fabricated from a standard syringe. In contrast, the modified mini-palm open release technique adopted for OCTR provided adequate surgical field exposure and a simplified

operative workflow, thus resulting in a shorter operative duration. A 2024 study by Thomas et al.[24] also reported that conventional ECTR generally required a longer operative time than conventional open surgery, as it necessitated the establishment of an endoscopic working channel and precise anatomical localization of carpal tunnel structures. Meanwhile, the utilization of endoscopic equipment was associated with increased hospitalization costs, which is consistent with the finding of higher hospitalization costs for ECTR in the present study.

From a pathophysiological perspective, both surgical procedures effectively improve clinical symptoms and neuroelectrophysiological parameters in patients with CTS. The core mechanism underlying these improvements is the release of the transverse carpal ligament (TCL), which relieves mechanical compression on the median nerve and restores its blood supply and conduction function[4]. The 2025 updated Clinical Practice Guideline for CTS issued by the AAOS[15] explicitly states that median nerve SNCV, SNAP, DML, and CMAP are core parameters for evaluating the severity of CTS and postoperative recovery, and the degree of their improvement directly reflects the efficacy of median nerve decompression. Preclinical animal studies have demonstrated that release of the TCL can significantly reduce median nerve thickness, improve nerve conduction function, and downregulate the levels of inflammatory cytokines within the carpal tunnel, which constitutes the key pathophysiological basis underlying the clinical efficacy of both surgical procedures[25]. In the present study, significant elevations in SNCV, SNAP amplitude and CMAP amplitude, alongside significant shortening of DML, were observed postoperatively in both patient groups. These findings indicate that both surgical modalities can effectively achieve adequate decompression of the median nerve, which is consistent with the conclusions of the 2024 CTS review by Alrayes et al.[26]. The review confirmed that complete release of the TCL, whether performed via an open or endoscopic surgical approach, can effectively restore median nerve function. Furthermore, the study on the application of the BCTQ scale in Chinese populations conducted by Lue et al.[27] found that the Chinese version of the BCTQ is a reliable and valid instrument for evaluating symptom severity and functional status in patients with CTS. In the present study, the significant postoperative improvement in BCTQ scores in both groups further verified the efficacy of the two surgical modalities in alleviating symptoms and restoring hand function, which is fully consistent with the conclusions of the study.

The clinical value of the present study mainly lies in providing precise evidence-based reference for surgical decision-making of CTS in real-world clinical settings. As the most prevalent upper extremity peripheral nerve entrapment disorder worldwide, CTS has a prevalence rate of 9.6% among office workers in China, has been included in China's statutory list of occupational diseases, and a large number of patients undergo CTR annually[28]. Selecting a more cost-effective and efficient surgical modality while ensuring consistent therapeutic efficacy is of great clinical and socioeconomic significance for alleviating the healthcare burden and improving patients' healthcare experience. The present study demonstrated that OCTR and ECTR achieved comparable clinical efficacy, whereas OCTR exhibited distinct advantages in operative time and medical costs, making it particularly suitable for primary healthcare institutions and cost-sensitive patients. As a minimally invasive surgical modality, ECTR offers the benefits of minimal surgical trauma and inconspicuous postoperative scarring, and can

be prioritized for younger patients with high cosmetic demands. These findings are consistent with the results reported by Rajapandian et al.[29], which stated that the cosmetic advantage of ECTR represents a core value for its clinical application, while the high efficiency and cost-effectiveness of OCTR are more favorable for large-scale clinical implementation.

Several limitations of the present study should be objectively acknowledged. First, this study was a single-center retrospective analysis with a limited enrolled sample size of 82 patients. Furthermore, only patients with unilateral CTS were included, which inevitably restricts the generalizability of the findings. The results cannot be extrapolated to complex clinical scenarios, including patients with bilateral CTS or those complicated with other joint disorders. Second, the median follow-up duration of this study was 34 months. Although this meets the standard for medium-to-long-term follow-up, it remains insufficient to evaluate the long-term efficacy and complication risk of the two surgical modalities beyond 5 years postoperatively. Previous studies have indicated that a minimum follow-up period of 5 years is required for patients after CTS surgery to assess the long-term stability of median nerve function and the risk of reoperation[30]. Furthermore, no standardized and unified postoperative rehabilitation protocol was implemented for the enrolled patients in the present study, while rehabilitation interventions have a well-recognized critical impact on postoperative functional recovery after CTS surgery[31]. This may act as a potential confounding factor influencing the differences in functional recovery between the two groups. Finally, no blinded assessment of outcome measures was performed in the present study, which may introduce subjective bias; this is a well-recognized common limitation inherent to retrospective study designs. Multicenter, large-sample, prospective randomized controlled trials (RCTs) are warranted in the future to further validate the findings and conclusions of the present study.

5. Conclusion

This study confirms that both ECTR and OCTR yield good mid-term outcomes in the treatment of CTS, and there is no significant difference in efficacy between the two procedures. However, OCTR offers the advantages of shorter operative time and lower hospitalization costs, while ECTR is characterized by minimal trauma and a cosmetically pleasing postoperative scar. In clinical practice, the choice of surgical approach can be tailored to the patient’s specific needs, the technical capabilities of the medical institution, and the surgeon’s experience.

Declarations

Conflicts of interest

The authors declare that they have no conflicts of interest.

Consent for publication

Written informed consent for publication was obtained from all participants.

Informed consent

Informed consent was obtained from all individual participants included in the study.

Ethics approval

This study was approved by the Ethics Committee of Yichang Central People's Hospital and performed in accordance with the Declaration of Helsinki (2026-021-01).

Funding

There is no funding source.

Author Contribution

ZZ: Manuscript writing and data collection YL: Data collection, HY: Performer of surgery, SB and KS: Supervision of the research process and revision of the manuscript.

Data Availability

The datasets used during the current study are available from the corresponding author upon reasonable request.

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Figures

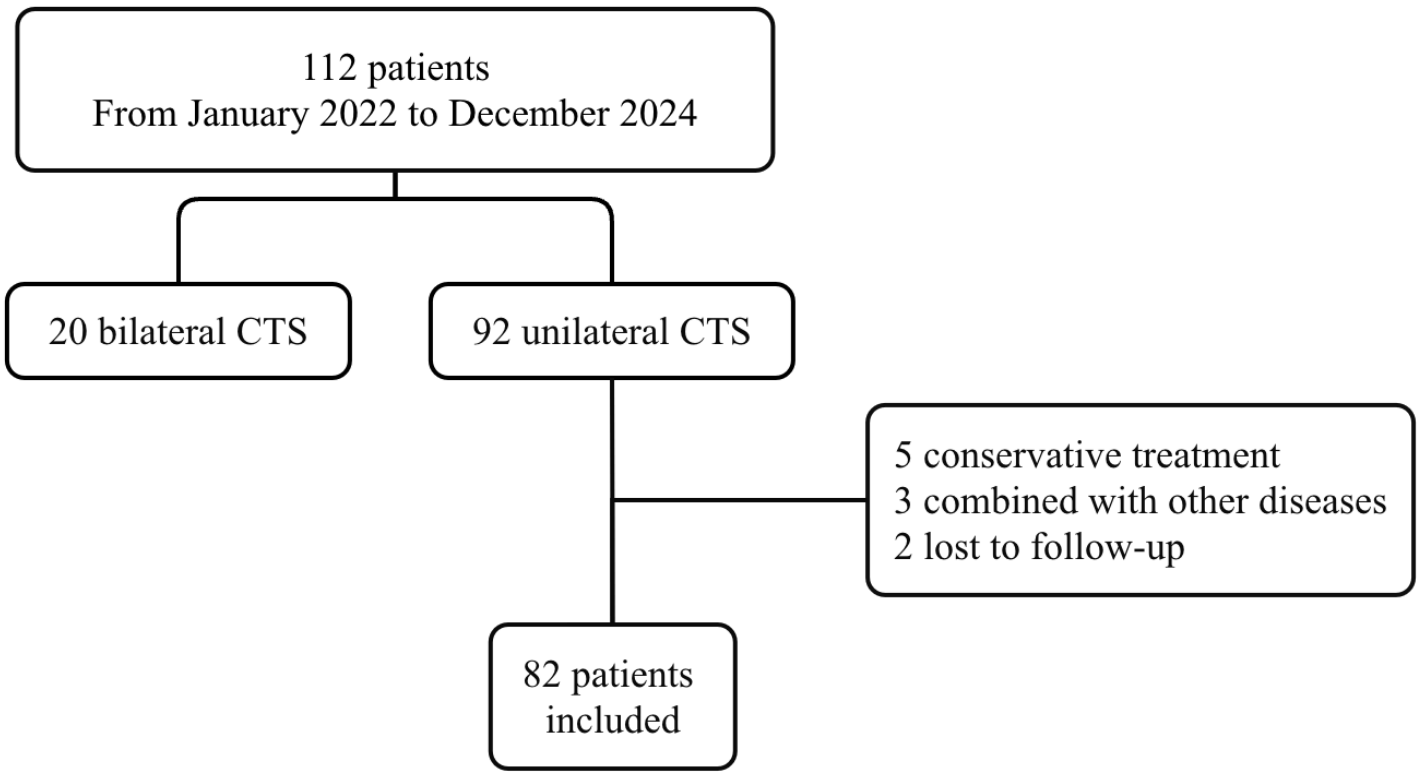


Figure 1

Flow chart showing patient cohort inclusion