

Carpal Tunnel Syndrome

Overview

- Patients with end-stage carpal tunnel syndrome do not have worse long-term patient-reported outcomes after carpal tunnel release compared with the general population [3].
- Ongoing debates in the diagnosis and management of carpal tunnel syndrome include the utility of diagnostic tests, outcome measurement standardization, and cost-effectiveness calculations [7].
- Carpal tunnel decompression surgery is safe and effective, with 97% of patients experiencing complete or partial relief [11].
- The AAOS developed Appropriate Use Criteria to help determine the appropriateness of treatments for carpal tunnel syndrome by synthesizing evidence with expert opinion [14].
- Standards, guidelines, and options for electrodiagnostic studies of carpal tunnel syndrome are defined based on a critical review of the literature [15].
- Patients in high-allergy cohorts can be expected to benefit from carpal tunnel release [16].
- A rational plan of therapy is available for each category of complications of carpal tunnel syndrome [17].
- Successful treatment of carpal tunnel syndrome is commonly defined based on a patient-reported outcome measure (PROM) [27].
- Nonsurgical methods for mild to moderate carpal tunnel syndrome are effective and underused, emphasizing patient choice and the slight complications of conservative treatment compared to surgical risks [28].
- The AAOS Appropriate Use Criteria provide guidance on diagnostic and treatment options for carpal tunnel syndrome, including scenarios where electrodiagnostic studies are or are not necessary and the appropriateness of surgical versus nonsurgical interventions [31].
- Universal acceptance of diagnostic criteria for carpal tunnel syndrome remains elusive without prospective controlled studies verifying improved performance [35].
- Evidence available to purchasers and clinicians attempting to manage demand for carpal tunnel decompression is usually sparse and rarely comprehensive [84].
- Universally applied and validated measures for hand surgery outcomes are rarely available [84].

Anatomy & Pathophysiology

EPIDEMIOLOGY AND RISK FACTORS

- Carpal tunnel syndrome is the most common compression neuropathy of the upper extremity [5].
- The mean age at diagnosis for carpal tunnel syndrome is 50 years [5].
- Carpal tunnel syndrome is more common in women than men by nearly four times [5].
- By the age of 65 years, the prevalence of carpal tunnel syndrome is approximately 5.1% for women and 1.3% for men [5].
- Risk factors for carpal tunnel syndrome include obesity, pregnancy, hypothyroidism, diabetes mellitus, and menopause [5].
- The American Academy of Orthopaedic Surgeons guidelines list body mass index (BMI) and high hand repetition rate as factors with strong evidence of increased risk for development of carpal tunnel syndrome [5].
- Obesity, diabetes, use of hand-held vibratory tools, and repeated forceful movements of the wrist and hand are causes of impaired median nerve function [117].
- Wrist ratio was the only significant predictor in a logistic regression analysis for carpal tunnel syndrome risk [107].
- A quantitative analysis of published scientific evidence indicates that the etiology of carpal tunnel syndrome is largely structural, genetic, and biological, with environmental and occupational factors such as repetitive hand use playing a minor and more debatable role [124].

PATHOGENESIS AND MECHANISMS

- Acute carpal tunnel syndrome is a compartment syndrome of the carpal tunnel characterized by a rapid rise and sustained increase in interstitial pressure within the carpal canal [93].
- Chronic carpal tunnel syndrome is a compressive neuropathy characterized by an insidious rise in carpal tunnel interstitial pressure of a moderate degree [93].
- The increase in interstitial pressure in chronic carpal tunnel syndrome may initially be intermittent but is likely to be elevated constantly with time and increased symptoms [93].
- Factors involved in the pathogenesis of carpal tunnel syndrome include bony abnormalities of the carpal bones, acromegaly, and flexion or extension of the wrist [4].
- Factors increasing the contents of the carpal canal include forearm and wrist fractures, dislocations and subluxations, posttraumatic arthritis, musculotendinous variants, aberrant muscles, local tumors, persistent medial artery, hypertrophic synovium, and hematoma [4].
- Neuropathic conditions involved in the pathogenesis of carpal tunnel syndrome include diabetes mellitus, alcoholism, double-crush syndrome, and exposure to industrial solvents [4].
- Inflammatory conditions involved in the pathogenesis of carpal tunnel syndrome include rheumatoid arthritis, gout, nonspecific tenosynovitis, and infection [4].

- Alterations of fluid balance involved in the pathogenesis of carpal tunnel syndrome include pregnancy, menopause, eclampsia, thyroid disorders, renal failure, long-term hemodialysis, Raynaud disease, obesity, lupus erythematosus, scleroderma, amyloidosis, and Paget disease [4].
- External forces involved in the pathogenesis of carpal tunnel syndrome include vibration and direct pressure [4].
- No consensus has been reached regarding the specific role that risk factors such as hormonal changes or edema play in the pathophysiology of carpal tunnel syndrome [5].

CLINICAL PRESENTATION AND DIAGNOSIS

- Carpal tunnel syndrome classically presents with nocturnal paresthesias in a median nerve distribution that gradually worsen as nerve injury progresses [5].
- Late in the disease course, carpal tunnel syndrome leads to sensory loss and thenar muscle atrophy [5].
- Nocturnal paresthesias in the radial three digits of the hand is nearly pathognomonic for carpal tunnel syndrome [104].
- Paresthesias in carpal tunnel syndrome occur characteristically in “fixed wrist activities” such as reading, driving, or use of a computer keyboard or mouse [104].
- Patients with advanced nerve compression in carpal tunnel syndrome may present with weakness and atrophy of the abductor pollicis brevis and opponens pollicis muscles [104].
- A positive Tinel sign at the wrist has a reported specificity ranging from 55% to 100% [5].
- The Phalen test has a reported specificity ranging from 54% to 98% [5].
- Nerve conduction studies assess focal demyelination by delayed conduction velocities of the median nerve at the wrist [5].
- Needle electromyography is considered an optional adjunct to nerve conduction studies and is mostly used to differentiate carpal tunnel syndrome from other possible causes [5].
- Documenting muscle atrophy and fibrillations on needle EMG assists with identifying severity of the disease and prognostication [5].
- Ultrasound sensitivity for carpal tunnel syndrome is reported to be over 97% when the median nerve diameter is greater than 10 mm² at the level of the pisiform [4].
- In patients with negative electrodiagnostic studies but a clinical diagnosis of carpal tunnel syndrome, high-resolution ultrasonography has a sensitivity of 73% if the cutoff of 9.4 mm² at the inlet of the carpal tunnel is used [4].
- The diagnosis of carpal tunnel syndrome should be based on clinical acumen and physical examination in the vast majority of patients, with ancillary tests reserved for patients without clear presentations [4].
- MRI is not routinely used for diagnosis of carpal tunnel syndrome, though reports are promising especially with newer techniques such as diffusion tensor imaging [4].
- Carpal tunnel syndrome impairs the performance of precision pinch movement as indicated by increased variability [123].

- Reduced longitudinal excursion of the median nerve at the carpal tunnel has been observed in carpal tunnel syndrome patients [126].
- Transverse movement of the median nerve is most marked with forearm supination, irrespective of other changes in the kinetic chain [86].

ANATOMICAL CONSIDERATIONS

- The flexor retinaculum includes the distal deep fascia of the forearm proximally, the transverse carpal ligament, and the aponeurosis between the thenar and hypothenar muscles [37].
- A successful carpal tunnel release usually requires division of all components of the flexor retinaculum [37].
- The palmar cutaneous sensory branch of the median nerve lies in the interval between the palmaris longus and the flexor carpi radialis tendons [37].
- The superficial palmar arterial arch is located 5 to 8 mm distal to the distal margin of the transverse carpal ligament [37].
- Fibers of the transverse carpal ligament can extend distally farther than expected [37].
- The median nerve palmar cutaneous branch is located deep to the thenar crease and radial to the palmaris longus [129].
- Splints that immobilize the wrist in a functional position of extension do not minimize carpal tunnel pressure [119].

Classification

- The diagnosis of carpal tunnel syndrome should shift from a dichotomous, all-or-none approach to one that considers probabilities of disease [24].
- Tools such as the hand diagram and CTS 6 are utilized to form baseline probabilities and guide management based on estimated probability and severity [24].
- Grading severity in electrodiagnostic reports involves grading the median neuropathy rather than the syndrome itself [75].
- Grading severity in electrodiagnostic reports fulfills the obligation of electrodiagnostic physicians to provide the referring source with the best possible interpretation and synthesis of physiologic data regarding the degree of nerve pathology [75].
- A retrospective study of 105 wrists classified carpal tunnel syndrome onset after distal radius fracture into acute (< 1 week), subacute (1, < 12 weeks), and delayed (≥ 12 weeks) groups [102].
- In a retrospective study of 105 wrists, the severity of carpal tunnel syndrome after distal radius fracture was classified as Grade 1 (mild) in 47 cases, Grade 2 (moderate) in 45 cases, and Grade 3 (severe) in 13 cases [102].
- In a retrospective study of 105 wrists, distal motor latency was classified as within normal in 13 cases, prolonged in 60 cases, and not examined in 32 cases [102].

- In a retrospective study of 105 wrists, distal radius fractures were classified using the AO classification system as A 1-3 (61 cases), B 1-3 (6 cases), C 1-3 (32 cases), and not classified (6 cases) [102].
- In a retrospective study of 105 wrists, fracture reduction was classified as unacceptable in 69 cases and acceptable in 36 cases [102].
- In a retrospective study of 105 wrists, acute onset carpal tunnel syndrome was associated with C-type fractures, while subacute and delayed onset groups were predominantly associated with A-type fractures [102].
- In a study of 90 subjects, EM grading for carpal tunnel syndrome was distributed as 18.9% at grade 1, 26.7% at grade 2, 42.2% at grade 3, and 12.2% at grade 4 or more [128].
- Existing anatomical classifications of the median nerve in the carpal tunnel cannot be relied upon entirely [69].

Clinical Presentation

EPIDEMIOLOGY AND RISK FACTORS

- Carpal tunnel syndrome is the commonest peripheral nerve problem in the United Kingdom [56].

SYMPTOMS AND SIGNS

- Classically, carpal tunnel syndrome presents with nocturnal paresthesias in a median nerve distribution that gradually worsens as nerve injury progresses [5].
- As nerve injury progresses in carpal tunnel syndrome, it leads to sensory loss and thenar muscle atrophy late in the disease course [5].
- Many patients with carpal tunnel syndrome report pain in the hand and may report symptoms that are not directly referable to the median nerve [5].
- A positive Tinel sign at the wrist can aid in the diagnosis of carpal tunnel syndrome [5].
- Development of symptoms after a provocative Phalen maneuver can aid in the diagnosis of carpal tunnel syndrome [5].
- The reported specificity of the Tinel sign at the wrist for carpal tunnel syndrome varies from 55% to 100% [5].
- The reported specificity of the Phalen test for carpal tunnel syndrome varies from 54% to 98% [5].
- Provocative tests for carpal tunnel syndrome are based on enhancing or inducing the symptoms of a damaged median nerve as it passes through the carpal tunnel [12].
- Specialists do not consider pain without paresthesia or a noncharacteristic symptom distribution as characteristic of carpal tunnel syndrome [21].
- Symptoms and signs characteristic of carpal tunnel syndrome significantly, but incompletely coincided with electrophysiological testing [50].

DIAGNOSTIC MODALITIES AND LIMITATIONS

- The diagnosis of carpal tunnel syndrome is made by clinical history, physical examination, and supportive diagnostic testing with exclusion of other possible disorders [5].
- Nerve conduction studies are a useful diagnostic tool for carpal tunnel syndrome because focal demyelination can be assessed by delayed conduction velocities of the median nerve at the wrist [5].
- Documenting muscle atrophy and fibrillations on needle EMG can assist with identifying severity of carpal tunnel syndrome and help with prognostication [5].
- Ultrasonography can diagnose carpal tunnel syndrome by identification of enlarged, hypoechoic median nerve fascicles proximal to the carpal tunnel [5].
- There is no universally agreed-upon reference standard test for diagnosing carpal tunnel syndrome [49].
- No standardized diagnostic criteria have been established for carpal tunnel syndrome [51].
- Electrophysiological testing has been reported to have 13% false-negative and 18% false-positive rates [51].
- Ultrasound sensitivity for carpal tunnel syndrome has been reported to be over 97% when the median nerve diameter is greater than 10 mm² at the level of the pisiform [4].
- There is a severe discordance between the estimated prevalence of mild-to-moderate carpal tunnel syndrome based on clinical signs and symptoms (73%) versus electrodiagnostic studies and ultrasound (51%) [54].
- Ultrasonography is capable of discovering the cause of median nerve compression, especially in cases with an atypical clinical presentation [25].
- MRI and/or ultrasonography imaging should be considered in patients who have new, persistent, or recurrent symptoms after surgery to delineate the etiology of the symptoms [5].

PATHOGENESIS AND ETIOLOGY

- Carpal tunnel syndrome can be an early manifestation of systemic amyloidosis [23].
- An elongated muscle belly of the flexor digitorum superficialis can cause carpal tunnel syndrome [25].
- An interosseous ganglion of the lunate can cause carpal tunnel syndrome [55].

Investigations

CLINICAL DIAGNOSIS AND PROVOCATIVE TESTS

- The American Academy of Orthopaedic Surgeons guidelines list body mass index and high hand repetition rate as factors with strong evidence of increased risk for development of carpal tunnel syndrome [5].
- Late in the disease course of carpal tunnel syndrome, sensory loss and thenar muscle atrophy occur [5].
- A positive Tinel sign at the wrist or development of symptoms after provocative Phalen maneuver can aid in the diagnosis of carpal tunnel syndrome [5].
- Tinel sign and Phalen maneuver are most reliable as adjuncts to other diagnostic tests for carpal tunnel syndrome [5].

CQ HAND + UPPER LIMB

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- The diagnosis of carpal tunnel syndrome should be based on clinical acumen and physical examination in the vast majority of patients [4].
- Ancillary tests for carpal tunnel syndrome should be reserved for patients without clear presentations [4].

ELECTRODIAGNOSTIC TESTING

- Nerve conduction studies remain a useful diagnostic tool in carpal tunnel syndrome as focal demyelination can be assessed by delayed conduction velocities of the median nerve at the wrist [5].
- Needle electromyography is currently considered an optional adjunct to nerve conduction studies and is mostly used to differentiate carpal tunnel syndrome from other possible causes [5].
- Documenting muscle atrophy and fibrillations on needle electromyography can assist with identifying severity of carpal tunnel syndrome and help with prognostication [5].
- Thenar atrophy and abductor pollicis brevis weakness can often be detected on physical examination for carpal tunnel syndrome [5].
- Pre-operative electrodiagnostic testing predicts time to resolution of symptoms after carpal tunnel release [1].
- Postoperative electrodiagnostic testing may be helpful in assessing recurrent symptoms after carpal tunnel release [4].
- The false-negative rate of electrodiagnostic testing for carpal tunnel syndrome is reported to be 10% [4].
- Electrodiagnostic testing does not increase the diagnostic value of the four commonly used clinical tests for carpal tunnel syndrome (abnormal hand diagram, abnormal Semmes-Weinstein, positive Durkan compression, and night pain) [4].
- Electrodiagnostic testing does not predict the degree of functional recovery or reemployment after carpal tunnel release [4].
- With clinical evaluation as the reference standard, electrodiagnostic testing is not helpful in making a diagnosis of pronator syndrome concurrent with carpal tunnel syndrome [96].

ULTRASONOGRAPHY

- Advances in ultrasonography technology have allowed rapid diagnosis of carpal tunnel syndrome by identification of enlarged, hypoechoic median nerve fascicles proximal to the carpal tunnel [5].
- Controversy remains as to whether ultrasonography evaluation could replace electrophysiology in the diagnosis of carpal tunnel syndrome [5].
- There is sufficient evidence for orthopaedic and hand surgeons to seriously consider using ultrasound as the first-line confirmatory diagnostic tool for carpal tunnel syndrome [81].
- High resolution ultrasound is a valid and accurate diagnostic modality in carpal tunnel syndrome and correlates with carpal tunnel syndrome severity [90].
- Ultrasonography is a useful method in the diagnostic evaluation of carpal tunnel syndrome, capable of discovering the cause of median nerve compression, especially in cases with an atypical clinical presentation [25].

- When carpal tunnel syndrome is suspected, an ultrasound examination can confirm the diagnosis and uncover the underlying etiology [99].
- Nerve conduction studies may still be required even when ultrasound confirms carpal tunnel syndrome and uncovers the underlying etiology [99].
- The study demonstrates the value of routine sonographic assessment when evaluating patients with carpal tunnel syndrome [100].
- Space occupying lesions of the carpal tunnel may be easily missed, and a carpal tunnel view and ultrasound scanning in suspected cases is mandatory [95].

MAGNETIC RESONANCE IMAGING

- Reports of MRI in carpal tunnel syndrome are promising, especially with newer techniques such as diffusion tensor imaging [4].
- MRI is not routinely used for diagnosis of carpal tunnel syndrome [4].
- A major advantage of MRI for carpal tunnel syndrome is its high soft-tissue contrast, which gives detailed images of bones and soft tissues [4].
- The physician should not routinely evaluate patients suspected of having carpal tunnel syndrome with magnetic resonance imaging [68].
- Imaging can be used to help evaluate any other lesions of concern and can simultaneously add support for the diagnosis of carpal tunnel syndrome by demonstrating changes in the cross-sectional area of the median nerve at the level of the inlet [79].
- MRI-based measurements of median nerve cross-sectional area, particularly at the inlet level, suggest that relying solely on cross-sectional area measurements may not be an optimal diagnostic strategy for carpal tunnel syndrome in patients with equivocal clinical symptoms [108].
- MRI of patients 3 months after successful endoscopic carpal tunnel release does not demonstrate a discrete gap or separation in the flexor retinaculum overlying the median nerve [88].
- MRI may be useful for evaluating median nerve morphology after endoscopic carpal tunnel release [88].
- In cases with swelling or tenderness on the area of wrist flexion creases, it is important to obtain a carpal tunnel view, and MRI and/or CT should be supplemented in order to rule out space occupying lesions around the carpal tunnel if necessary [105].
- With clinical evaluation as the reference standard, MRI is not helpful in making a diagnosis of pronator syndrome concurrent with carpal tunnel syndrome [96].

OTHER IMAGING AND DIAGNOSTIC CONSIDERATIONS

- The physician should not routinely evaluate patients suspected of having carpal tunnel syndrome with computed tomography [68].
- The physician should not routinely evaluate patients suspected of having carpal tunnel syndrome with pressure-specified sensorimotor devices in the wrist and hand [68].

- Carpal tunnel syndrome caused by a space occupying lesion is rare and more complicated than idiopathic carpal tunnel syndrome [110].
- Amyloidosis diagnosis after carpal tunnel release is rare but is associated with poor outcomes [98].

Treatment

NON-OPERATIVE MANAGEMENT

- Initial conservative management via hand therapy, activity modification with splinting, and corticosteroid injection is supported by strong evidence for mild and/or moderate carpal tunnel syndrome symptoms [5].
- Splinting is a basic, easily implemented, inexpensive, and effective intervention for carpal tunnel syndrome [85].
- Steroid injection into the carpal tunnel is effective and may be superior to splinting alone when combined with splinting [85].
- A short pulse of systemic steroid treatment might be effective for carpal tunnel syndrome, although the risk of long-term complications from even short systemic exposure is not fully known [85].
- Systemic steroid treatment is superior to placebo but is not as effective as local steroid injection for carpal tunnel syndrome [85].
- In people with carpal tunnel syndrome, steroid injection combined with splinting resulted in modestly greater reduction of symptoms, functional recovery, and improvement of nerve function at 12-week follow-up compared to steroid injection alone [65].
- Local steroid injection for carpal tunnel syndrome has an overall success rate of 45% after a mean follow-up of 16 months [66].
- Nonsurgical methods for mild to moderate carpal tunnel syndrome are effective and underused, with slight complications compared to surgical risks [28].
- Both surgical and conservative interventions had treatment benefit in carpal tunnel syndrome [64].
- Patients with early carpal tunnel syndrome can be managed with conservative treatment, but carpal tunnel release should be recommended to patients who have failed nonsurgical treatment [13].
- The AAOS Appropriate Use Criteria provide guidance on diagnostic and treatment options for carpal tunnel syndrome, including the appropriateness of surgical versus nonsurgical interventions [31].

OPERATIVE MANAGEMENT

- Surgical decompression of the transverse carpal ligament is the benchmark procedure for the treatment of carpal tunnel syndrome [5].
- There has been no definitive difference in long-term functional outcome between open and endoscopic carpal tunnel release [5].
- Patients undergoing endoscopic carpal tunnel release often have a more abbreviated recovery with less incisional pain compared to open release [5].

- Endoscopic carpal tunnel release is associated with an increased cost of the procedure and a slightly higher rate of iatrogenic transient neurapraxia compared to open release [5].
- Postoperative complications of carpal tunnel release include nerve, arterial, or tendon injury with a 0.5% incidence and complex regional pain syndrome with a 2.1% to 5% incidence [5].
- Mini-open carpal tunnel release is performed with a limited, targeted incision of 1.5 to 2 cm, with low complication rates and high rates of patient satisfaction [5].
- No approach has yet demonstrated superiority over other techniques currently in use in large, randomized controlled surgical trials [5].
- Open and endoscopic carpal tunnel release procedures provided similar symptom relief and hand strength and sensibility recovery, and were safe for patients with carpal tunnel syndrome [61].
- Both open and endoscopic methods have equal efficacy in relieving symptoms of carpal tunnel syndrome [67].
- Carpal tunnel release surgery continues to evolve with new diagnostic techniques and less-invasive surgical methods [38].

RECURRENT OR UNRELIEVED SYMPTOMS

- The recurrence rate after primary carpal tunnel release is approximately 2% [46].
- Complications and failures after primary carpal tunnel release are estimated to be 3% to 19% [46].
- Unrelieved symptoms may lead to repeat operation in 12% of patients [46].
- Findings reported at reoperation for recurrent carpal tunnel syndrome include incomplete release of the transverse carpal ligament, re-formation of the flexor retinaculum, scarring in the carpal tunnel, median or palmar cutaneous neuroma, palmar cutaneous nerve entrapment, recurrent granulomatous or inflammatory tenosynovitis, and hypertrophic scar in the skin [46].
- Procedures for incomplete ligament release include reexploration, rerelease of the transverse carpal ligament, excision, and release of re-formed retinaculum [46].
- Procedures for fibrosis or painful scar include epineurolysis, local muscle flaps, local or remote free fat or radial forearm fascial grafts, excision, Z-plasty of painful scar, nerve wrapping, or interposition materials [46].
- Procedures for recurrent tenosynovitis include tenosynovectomy and appropriate medical management, such as antibiotics for infectious granulomatous tenosynovitis from fungi or mycobacteria [46].
- Patients with normal preoperative electrodiagnostic studies, patients who had filed for compensation, and patients with ulnar nerve symptoms have been reported to have results significantly worse than patients without these findings [46].
- Temporary relief following a corticosteroid injection is a good prognostic sign when considering reoperation for recurrent carpal tunnel syndrome [46].
- Recurrent carpal tunnel syndrome was demonstrated more often in patients with diabetes [46].
- Incomplete release of the flexor retinaculum and scarring of the median nerve were common intraoperative findings in all patients with recurrent carpal tunnel syndrome [46].

- Persistent symptoms and more than one prior carpal tunnel syndrome had higher odds of not changing or worsening postoperative pain [46].
- Higher preoperative pain, use of pain medication, and workers' compensation were significant predictors of higher postoperative average pain [46].
- The transverse carpal ligament that reforms is indistinguishable from the native ligament, making determination of incomplete release not possible [46].
- Neural adhesion lysis and early nerve gliding exercises are essential in the management of problematic recurrent carpal tunnel cases [46].
- Synovial or hypothenar fat pad flaps are rarely necessary in the management of problematic recurrent carpal tunnel cases [46].
- Recurrent symptoms after carpal tunnel release can occur and are thought to be due to scarring, tenosynovitis, and/or adhesive tethering [5].
- Rates of recurrent symptoms after carpal tunnel release may be as high as 4.5% [5].
- Recurrent symptoms should be differentiated from persistent symptoms, which may be due to an incompletely divided ligament during the index procedure or incorrect diagnosis [5].
- Repeat open median nerve neurolysis is often performed when symptoms recur, either by itself or in conjunction with local tissue flaps or wraps [5].
- Neither repeat open median nerve neurolysis alone nor in conjunction with local tissue flaps or wraps has demonstrated superiority for treatment of recurrent carpal tunnel symptoms [5].
- Effective management of recalcitrant carpal tunnel syndrome requires an accurate diagnosis and a comprehensive treatment strategy [62].
- Revision carpal tunnel release is less successful than primary release, with up to 40% of patients having unfavorable outcomes [62].

PROGNOSIS AND RECOVERY

- Timing of recovery after carpal tunnel decompression is related to preoperative electrodiagnostic studies [47].
- Reinnervation in patients with decreased conduction velocity and increased latency will take just a few months [47].
- Axonal regeneration, indicated by decreased compound muscle action potential, will take much longer than reinnervation [47].
- Following carpal tunnel decompression for mild or moderate nerve compression, there will be return of "painless" sensation to the digits innervated by the median nerve [47].
- Reinnervation of the thenar muscles will occur following carpal tunnel decompression, although it takes longer than sensory recovery [47].
- Return of motor function may not be complete in patients with severe carpal tunnel syndrome [47].
- Patients can expect restoration of full range of motion at the wrist after carpal tunnel decompression [47].

- Patients with severe carpal tunnel syndrome and thenar atrophy have been described to experience a postoperative flare with complaints of pain, stiffness, and swelling likely caused by a reinnervation hypersensitivity [47].
- Postoperative flare in patients with severe carpal tunnel syndrome and thenar atrophy is treated with hand therapy and occasionally a short burst of oral steroids [47].
- Patients can experience pillar pain after carpal tunnel release, which is likely microneuroma related [47].
- The risk of pillar pain can be minimized by placing the incision in the watershed area between the median and ulnar palmar cutaneous nerves, approximately 6 mm ulnar to the thenar crease [47].
- If pillar pain develops after carpal tunnel release, patients are referred to hand therapy for scar massage and desensitization [47].

Complications

- The long-term outcome of carpal tunnel release is favourable with a rate of recurrence of 2.5% and a rate of persistence of 3.75% [30].
- At an average follow-up of 4.5 years, 28% of hands had persistent symptoms after carpal tunnel release by the Agee endoscopic technique [40].
- In a long-term follow-up study of dual-portal endoscopic release, 91.1% of patients reported being pain-free in the operated hand [97].
- In a long-term follow-up study of dual-portal endoscopic release, 83.3% of patients reported the absence of hypesthesia [97].
- In a long-term follow-up study of dual-portal endoscopic release, 81.1% of patients reported no paresthesia [97].
- In a long-term follow-up study of dual-portal endoscopic release, 4 cases reported hypesthesia worse than preoperatively [97].
- Transection of the motor branch of the ulnar nerve is a complication of two-portal endoscopic carpal tunnel release [2].
- Poor outcome for neural surgery (epineurotomy or neurolysis) for carpal tunnel syndrome compared with carpal tunnel release alone has been demonstrated in a meta-analysis of global outcomes [2].
- Carpal tunnel syndrome can be an early manifestation of systemic amyloidosis, and implementation of a straightforward algorithm using biopsy samples during carpal tunnel release will allow for early diagnosis of these progressive and lethal diseases [23].
- An infectious etiology should be considered in atypical carpal tunnel syndrome presentations or when symptoms persist after surgery [94].
- Delayed carpal tunnel syndrome is typically due to alterations in carpal tunnel anatomy and requires etiology-specific treatment [45].
- Patients with a history of ulnar nerve lesions are at a significantly increased risk of developing carpal tunnel syndrome, especially within the first 2 years [32].

Recovery

SURGICAL OUTCOMES AND PROGNOSIS

- At an average follow-up of 4.5 years, 28% of hands had persistent symptoms after carpal tunnel release by the Agee endoscopic technique, but results were scarcely different from the conventional technique with no patient requiring reoperation [40].
- Clinical severity of carpal tunnel syndrome at intake is the most important factor in estimating symptom relief after surgical treatment [133].
- Patients with mild or moderate carpal tunnel syndrome experience a faster time to resolution of daytime numbness and tingling when compared with patients with severe carpal tunnel syndrome [130].
- Symptoms experienced outside of the median nerve distribution had a high likelihood of resolution after carpal tunnel release, with over 85% of symptoms in each of the anatomic zones studied resolving [136].
- A significant correlation was found between patients with an incomplete release and lack of a symptom-free period after carpal tunnel release [135].
- Patients undergoing revision open carpal tunnel decompression for recurrent carpal tunnel syndrome experience a significant improvement in function and health-related quality of life [78].
- Long-term improvement in patients with diabetes remained after carpal tunnel release to the same extent as for patients without diabetes [33].

NON-OPERATIVE AND NATURAL HISTORY

- The symptoms of carpal tunnel syndrome may improve without surgery, but further studies are needed to understand the natural history of the disorder [9].
- One-third of patients with carpal tunnel syndrome had a long-term beneficial effect from corticosteroid injection, especially when they had a good initial response [36].

MINIMALLY INVASIVE TECHNIQUES

- Ultrasound-guided carpal tunnel release quickly improves hand function and reduces hand discomfort; improvement persisted beyond one year [39].

DISEASE PROGRESSION AND CONTEXT

- Idiopathic median neuropathy at the carpal tunnel acts more like a steadily and inevitably progressive disease than a self-limiting one [43].
- Carpal tunnel syndrome is a condition that requires attention to service delivery, awareness of systemic disease, and long-term nerve biology, rather than just surgical competence [10].

Key Evidence

- [L4] Patients with end-stage carpal tunnel syndrome do not have worse long-term patient-reported outcomes after carpal tunnel release compared with the general population. [3] ([10.1177/1558944719857815](#))
- [L5] The article highlights ongoing debates in the diagnosis and management of carpal tunnel syndrome, including the utility of diagnostic tests, outcome measurement standardization, and cost-effectiveness calculations, while encouraging high-quality research to resolve these issues. [7] ([10.1177/17531934221080631](#))
- [L3] The symptoms of carpal tunnel syndrome may improve without surgery, but further studies are needed to understand the natural history of the disorder. [9] ([10.1177/1753193411410155](#))
- [L5] Carpal tunnel syndrome is a condition that requires attention to service delivery, awareness of systemic disease, and long-term nerve biology, rather than just surgical competence. [10] ([10.1177/17531934261433793](#))
- [L3] Carpal tunnel decompression surgery is safe and effective, with 97% of patients experiencing complete or partial relief. [11] ([10.1054/jhsb.2001.0616](#))
- [L4] [12] ([10.1038/ncpneuro0216](#))
- [Paper] Patients with early carpal tunnel syndrome can be managed with conservative treatment, but carpal tunnel release should be recommended to patients who have failed nonsurgical treatment. [13] ([10.1016/b978-0-12-385157-4.00652-7](#))
- [L5] The AAOS developed Appropriate Use Criteria to help determine the appropriateness of treatments for carpal tunnel syndrome by synthesizing evidence with expert opinion. [14] ([10.5435/jaaos-d-17-00451](#))
- [L1] The document defines standards, guidelines, and options for EDX studies of carpal tunnel syndrome based on a critical review of the literature. [15] ([10.1212/wnl.58.11.1589](#))
- [L4] Consequently, patients in high-allergy cohorts can be expected to benefit from carpal tunnel release. [16] ([10.1177/15589447241284304](#))
- [L5] A rational plan of therapy is available for each category of complications of carpal tunnel syndrome. [17] ([10.1016/s0749-0712\(21\)00316-4](#))
- [L4] Specialists do not consider pain without paresthesia or a noncharacteristic symptom distribution as characteristic of carpal tunnel syndrome. [21] ([10.1016/j.jhsa.2024.07.004](#))
- [L5] Carpal tunnel syndrome can be an early manifestation of systemic amyloidosis, and implementation of a straightforward algorithm using biopsy samples during carpal tunnel release will allow for early diagnosis of these progressive and lethal diseases. [23] ([10.1016/j.jhsa.2025.07.017](#))
- [L5] The diagnosis of carpal tunnel syndrome should shift from a dichotomous, all-or-none approach to one that considers probabilities of disease, utilizing tools like the hand diagram and CTS 6 to form baseline probabilities and guide management based on estimated probability and severity. [24] ([10.1016/j.jhsa.2009.12.034](#))

- [L5] Ultrasonography is a very useful method in the diagnostic evaluation of carpal tunnel syndrome, capable of discovering the cause of median nerve compression, especially in cases with an atypical clinical presentation. [25] ([10.1007/s11552-012-9435-z](#))
- [L1] Successful treatment of carpal tunnel syndrome is commonly defined based on a patient-reported outcome measure (PROM), highlighting recent efforts to measure outcomes from the patient's perspective. [27] ([10.1177/1558944720949951](#))
- [L5] The authors argue that nonsurgical methods for mild to moderate carpal tunnel syndrome are effective and underused, emphasizing patient choice and the slight complications of conservative treatment compared to surgical risks. [28] ([10.1016/j.jhsa.2009.05.009](#))
- [L3] The long-term outcome of carpal tunnel release is favourable with a rate of recurrence of 2.5% and a rate of persistence of 3.75%. [30] ([10.1302/0301-620x.99b10.bjj-2016-0587.r2](#))
- [L5] The AAOS Appropriate Use Criteria provide guidance on diagnostic and treatment options for carpal tunnel syndrome, including scenarios where electrodiagnostic studies are or are not necessary and the appropriateness of surgical versus nonsurgical interventions. [31] ([10.5435/jaaos-d-17-00454](#))
- [L2] Patients with a history of ulnar nerve lesions are at a significantly increased risk of developing carpal tunnel syndrome, especially within the first 2 years. [32] ([10.1016/j.jhsg.2026.100970](#))
- [L2] Long-term improvement in patients with diabetes remained after carpal tunnel release to the same extent as for patients without diabetes. [33] ([10.1016/j.jhsa.2014.01.012](#))
- [L5] Universal acceptance of diagnostic criteria for carpal tunnel syndrome remains elusive without prospective controlled studies verifying improved performance. [35] ([10.1016/j.jhsa.2012.07.041](#))
- [L3] One-third of patients with carpal tunnel syndrome had a long-term beneficial effect from corticosteroid injection, especially when they had a good initial response. [36] ([10.1177/1753193412469580](#))
- [L4] Carpal tunnel release surgery continues to evolve with new diagnostic techniques and less-invasive surgical methods. [38] ([10.1097/gox.0000000000002692](#))
- [L4] Ultrasound-guided carpal tunnel release quickly improves hand function and reduces hand discomfort; improvement persisted beyond one year. [39] ([10.2214/ajr.20.24383](#))
- [L4] At an average follow-up of 4.5 years, 28% of hands had persistent symptoms, but results were scarcely different from the conventional technique with no patient requiring reoperation. [40] ([10.1054/jhsb.1999.0226](#))
- [L5] The authors state that idiopathic median neuropathy at the carpal tunnel acts more like a steadily and inevitably progressive disease than a self-limiting one, and that hand surgeons are at their best when treating objective pathophysiology with evidence-based disease modifying treatments. [43] ([10.1177/1753193414526674](#))
- [L5] Delayed carpal tunnel syndrome is typically due to alterations in carpal tunnel anatomy and requires etiology-specific treatment. [45] ([10.1016/j.hcl.2017.09.003](#))
- [L2] There is no universally agreed-upon reference standard test for diagnosing carpal tunnel syndrome, and clinicians use symptoms and signs alone, electrodiagnostic testing, or both. [49] ([10.1016/j.jhsa.2014.03.039](#))

- [L2] Symptoms and signs characteristic of carpal tunnel syndrome significantly, but incompletely coincided with electrophysiological testing. [50] ([10.1177/1753193412461860](https://doi.org/10.1177/1753193412461860))
- [L3] [51] ([10.1016/j.jhsa.2010.05.020](https://doi.org/10.1016/j.jhsa.2010.05.020))
- [L5] There is a severe discordance between the estimated prevalence of mild-to-moderate carpal tunnel syndrome based on clinical signs and symptoms (73%) versus electrodiagnostic studies and ultrasound (51%), calling into question whether clinicians can confidently diagnose patients with mild-to-moderate CTS. [54] ([10.1097/corr.0000000000002822](https://doi.org/10.1097/corr.0000000000002822))
- [L4] This case highlights the importance of considering uncommon aetiologies in patients with atypical symptoms of carpal tunnel syndrome. [55] ([10.1177/17531934241227809](https://doi.org/10.1177/17531934241227809))
- [L4] Carpal tunnel syndrome is the commonest peripheral nerve problem in the United Kingdom and is readily treatable if recognised early. [56] ([10.1136/bmj.39282.623553.ad](https://doi.org/10.1136/bmj.39282.623553.ad))
- [L1] The procedures provided similar symptom relief and hand strength and sensibility recovery, and were safe for patients with carpal tunnel syndrome. [61] ([10.1002/brb3.439](https://doi.org/10.1002/brb3.439))
- [L5] Effective management of recalcitrant carpal tunnel syndrome requires an accurate diagnosis and a comprehensive treatment strategy, as revision carpal tunnel release is less successful than primary release with up to 40% of patients having unfavorable outcomes. [62] ([10.5435/jaaos-d-18-00004](https://doi.org/10.5435/jaaos-d-18-00004))
- [L1] Both surgical and conservative interventions had treatment benefit in carpal tunnel syndrome. [64] ([10.1186/1749-799x-6-17](https://doi.org/10.1186/1749-799x-6-17))
- [L1] In people with carpal tunnel syndrome, steroid injection combined with splinting resulted in modestly greater reduction of symptoms, functional recovery, and improvement of nerve function at 12-week follow-up compared to steroid injection alone. [65] ([10.1016/j.apmr.2017.01.018](https://doi.org/10.1016/j.apmr.2017.01.018))
- [L4] Local steroid injection for carpal tunnel syndrome has an overall success rate of 45% after a mean follow-up of 16 months. [66] ([10.1016/j.jhsa.2021.09.022](https://doi.org/10.1016/j.jhsa.2021.09.022))
- [L1] Both methods have equal efficacy in relieving symptoms of carpal tunnel syndrome. [67] ([10.1136/bmj.38863.632789.1f](https://doi.org/10.1136/bmj.38863.632789.1f))
- [L4] One cannot rely entirely on the existing anatomical classifications of the MN in the carpal tunnel. [69] ([10.1016/j.injury.2020.03.024](https://doi.org/10.1016/j.injury.2020.03.024))
- [L5] Grading severity of carpal tunnel syndrome in the electrodiagnostic report, with the understanding that it is the median neuropathy being graded and not the syndrome, fulfills the obligation of electrodiagnostic physicians to provide the referring source with the best possible interpretation and synthesis of physiologic data regarding the degree of nerve pathology. [75] ([10.1002/mus.23824](https://doi.org/10.1002/mus.23824))
- [L4] This study confirms that patients undergoing revision open carpal tunnel decompression for recurrent carpal tunnel syndrome experience a significant improvement in function and health-related quality of life. [78] ([10.1177/1753193419875945](https://doi.org/10.1177/1753193419875945))
- [Paper] Imaging can be used to help evaluate any other lesions of concern and can also simultaneously add support for the diagnosis of CTS by demonstrating changes in the CSA of the median nerve at the level of the inlet. [79] ([10.2106/jbjs.25.01685](https://doi.org/10.2106/jbjs.25.01685))
- [L5] There is sufficient evidence for orthopaedic and hand surgeons to seriously consider using ultrasound as the first-line confirmatory diagnostic tool for carpal tunnel syndrome. [81] ([10.2106/jbjs.o.01067](https://doi.org/10.2106/jbjs.o.01067))

- [L5] The paper argues that evidence available to purchasers and clinicians attempting to manage demand for carpal tunnel decompression is usually sparse and rarely comprehensive, and that universally applied and validated measures for hand surgery outcomes are rarely available. [84] ([10.1054/jhsb.1999.0328](#))
- [L5] [85] ([10.1016/j.jhsa.2009.01.010](#))
- [L4] Transverse movement of the median nerve is most marked with forearm supination, irrespective of other changes in the kinetic chain. [86] ([10.1258/ht.2011.011017](#))
- [L2] MRI of patients 3 months after successful endoscopic carpal tunnel release does not demonstrate a discrete gap or separation in the flexor retinaculum overlying the median nerve but may be useful for evaluating median nerve morphology. [88] ([10.1016/j.jhsa.2012.11.013](#))
- [L3] High resolution ultrasound is a valid and accurate diagnostic modality in carpal tunnel syndrome and correlated to CTS severity. [90] ([10.1186/s12891-019-3010-5](#))
- [L5] [93] ([10.1016/s0749-0712\(21\)00307-3](#))
- [L4] The authors suggest considering an infectious etiology in atypical carpal tunnel syndrome presentations or when symptoms persist after surgery. [94] ([10.1016/j.jhsa.2017.05.027](#))
- [L5] Space occupying lesions of the carpal tunnel may be easily missed, and a carpal tunnel view and ultrasound scanning in suspected cases is mandatory. [95] ([10.1007/s12593-012-0076-9](#))
- [L4] With clinical evaluation as the reference standard, electrodiagnostic, ultrasound, and MRI are not helpful in making a diagnosis of pronator syndrome concurrent with carpal tunnel syndrome. [96] ([10.1016/j.jhsa.2020.06.006](#))
- [L4] [97] ([10.1227/01.neu.0000335784.90217.9d](#))
- [L4] Amyloidosis diagnosis after carpal tunnel release is rare but is associated with poor outcomes. [98] ([10.2106/jbjs.20.02093](#))
- [L5] When carpal tunnel syndrome is suspected an ultrasound examination can confirm the diagnosis and uncover the underlying etiology, but nerve conduction studies may still be required. [99] ([10.1177/0883073810387299](#))
- [L4] The study demonstrates the value of routine sonographic assessment when evaluating patients with carpal tunnel syndrome. [100] ([10.1016/j.jhsg.2025.100903](#))
- [L4] [102] ([10.1007/s00776-010-1496-7](#))
- [L4] In cases with swelling or tenderness on the area of wrist flexion creases, it is important to obtain a carpal tunnel view, and MRI and/or CT should be supplemented in order to rule out SOLs around the carpal tunnel, if necessary. [105] ([10.3349/ymj.2009.50.2.257](#))
- [L4] Wrist ratio was the only significant predictor in the logistic regression analysis. [107] ([10.1002/ca.23198](#))
- [L3] MRI-based measurements of median nerve CSA, particularly at the inlet level, suggest that relying solely on CSA measurements may not be an optimal diagnostic strategy for CTS in patients with equivocal clinical symptoms. [108] ([10.2106/jbjs.25.00787](#))
- [L4] Carpal tunnel syndrome caused by a space occupying lesion is rare and more complicated than idiopathic carpal tunnel syndrome. [110] ([10.1177/1753193411414352](#))

- [L3] Obesity, diabetes, use of hand-held vibratory tools, and repeated forceful movements of the wrist and hand are causes of impaired median nerve function. [117] ([10.1186/1471-2474-14-240](#))
- [L4] Splints that immobilize the wrist in a functional position of extension do not minimize carpal tunnel pressure. [119] ([10.2106/00004623-199511000-00008](#))
- [L3] Carpal tunnel syndrome impairs the performance of precision pinch movement as indicated by the increased variability. [123] ([10.1016/j.jhsa.2008.02.030](#))
- [L3] According to a quantitative analysis of published scientific evidence, the etiology of carpal tunnel syndrome is largely structural, genetic, and biological, with environmental and occupational factors such as repetitive hand use playing a minor and more debatable role. [124] ([10.1016/j.jhsa.2008.01.004](#))
- [L3] Further studies are merited to determine if reduced median nerve excursion at the carpal tunnel is clinically relevant in CTS, and can be influenced by movement-based interventions. [126] ([10.1016/j.apmr.2007.02.015](#))
- [L4] [128] ([10.1177/1558944717725379](#))
- [L4] Patients with mild or moderate carpal tunnel syndrome experience a faster time to resolution of daytime numbness and tingling when compared with patients with severe carpal tunnel syndrome. [130] ([10.1177/1753193415576248](#))
- [L2] Clinical severity of carpal tunnel syndrome at intake is the most important factor in estimating symptom relief after surgical treatment. [133] ([10.1016/j.jhsa.2018.05.017](#))
- [L4] A significant correlation was found between patients with an incomplete release and lack of a symptom-free period after carpal tunnel release. [135] ([10.1016/s0749-0712\(21\)00315-2](#))
- [L4] Symptoms experienced outside of the median nerve distribution had a high likelihood of resolution after carpal tunnel release, with over 85% of symptoms in each of the anatomic zones studied resolving. [136] ([10.1016/j.jhsa.2009.04.024](#))

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