

Carpal Tunnel Syndrome

Overview

- Ongoing debates exist in the diagnosis and management of carpal tunnel syndrome, including the utility of diagnostic tests, outcome measurement standardization, and cost-effectiveness calculations [3].
- 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 [4].
- The AAOS Appropriate Use Criteria provide guidance on the appropriateness of surgical versus nonsurgical interventions for carpal tunnel syndrome [4].
- The trapeziometacarpal joint osteoarthritis and carpal tunnel syndrome concomitant treatment procedure is not suitable for severe carpal tunnel syndrome [6].
- The trapeziometacarpal joint osteoarthritis and carpal tunnel syndrome concomitant treatment procedure is not suitable when direct visualization of the median nerve and the carpal tunnel is necessary [6].
- 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 [9].
- Carpal tunnel decompression surgery is safe and effective, with 97% of patients experiencing complete or partial relief [10].
- Endoscopic carpal tunnel release is safe and yields predictable long-term results [12].
- More accurate means of selecting patients who will benefit from surgery in the early stages of carpal tunnel syndrome are needed [13].
- Successful treatment of carpal tunnel syndrome is commonly defined based on a patient-reported outcome measure (PROM) [24].
- The AAOS developed Appropriate Use Criteria to help determine the appropriateness of treatments for carpal tunnel syndrome by synthesizing evidence with expert opinion [27].
- The Neurology practice parameter defines standards, guidelines, and options for electrodiagnostic studies of carpal tunnel syndrome based on a critical review of the literature [28].
- Patients in high-allergy cohorts can be expected to benefit from carpal tunnel release [29].
- Surgical decompression of the carpal tunnel is the treatment of choice for carpal tunnel syndrome in children and adolescents with no history of trauma [30].

- Long-term follow-up is recommended for children and adolescents with carpal tunnel syndrome who undergo surgical decompression [30].
- A rational plan of therapy is available for each category of complications of carpal tunnel syndrome [33].
- Given specific clinical criteria for establishing the diagnosis of carpal tunnel syndrome, electrodiagnostic testing does not appear to correlate with improved final symptomatic outcome after carpal tunnel release [50].
- Nonsurgical methods for mild to moderate carpal tunnel syndrome are effective and underused [51].
- Conservative treatment for carpal tunnel syndrome has slight complications compared to surgical risks [51].
- In carpal tunnel syndrome, endoscopic surgery was associated with less postoperative pain than open surgery [55].
- The small size of the benefit and similarity in other outcomes between endoscopic and open surgery make the cost effectiveness of endoscopic surgery uncertain [55].
- Universal acceptance of diagnostic criteria for carpal tunnel syndrome remains elusive without prospective controlled studies verifying improved performance [58].
- The outcome of carpal tunnel decompression syndrome is good in the majority of the cases [60].
- Open and endoscopic techniques provide similar results for carpal tunnel decompression syndrome [60].
- There are no clear indications on how health utilities can be integrated into decision analysis models and economic evaluation regarding carpal tunnel syndrome of various severities [61].
- Evidence available to purchasers and clinicians attempting to manage demand for carpal tunnel decompression is usually sparse and rarely comprehensive [136].
- Universally applied and validated measures for hand surgery outcomes are rarely available [136].
- Clinical symptoms of carpal tunnel syndrome improved in all 55 hands following evaluation of carpal canal pressure [138].
- Postoperative electrophysiologic data remained within normal range in patients who agreed to receive electrophysiologic examinations after carpal canal pressure evaluation [138].
- The outcome of carpal tunnel release in terms of improvement in the symptom and functional scores is sufficient to justify surgery in the elderly [140].
- Surgical outcomes for carpal tunnel release are less predictable in elderly patients than in younger patients [140].
- Surgery should be considered as the initial form of treatment when patients are diagnosed with carpal tunnel syndrome confirmed by nerve conduction studies [144].
- Surgery for carpal tunnel syndrome confirmed by nerve conduction studies provides symptom resolution with a favorable cost analysis [144].

Anatomy & Pathophysiology

EPIDEMIOLOGY AND RISK FACTORS

- Carpal tunnel syndrome is the most common compression neuropathy of the upper extremity [16].
- The mean age at diagnosis for carpal tunnel syndrome is 50 years [16].
- Carpal tunnel syndrome is more common in women than men by nearly four times [16].
- By the age of 65 years, the prevalence of carpal tunnel syndrome is approximately 5.1% for women and 1.3% for men [16].
- Risk factors for carpal tunnel syndrome include obesity, pregnancy, hypothyroidism, diabetes mellitus, and menopause [16].
- 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 [16].
- Obesity, diabetes, use of hand-held vibratory tools, and repeated forceful movements of the wrist and hand are causes of impaired median nerve function [79].
- 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 [216].
- Wrist ratio was the only significant predictor in the logistic regression analysis for carpal tunnel syndrome risk [182].
- Wrist circumference was not a predictor of the smallest carpal canal area [166].
- The results provide some support for a causative association between wrist morphometry, as measured by the wrist index, and carpal tunnel syndrome, but this difference is too small to be of diagnostic value in clinical or epidemiological practice [162].

PATHOGENESIS AND MECHANISMS

- Acute carpal tunnel syndrome is a compartment syndrome of the carpal tunnel in which there is a rapid rise and sustained increase in the interstitial pressure within the carpal canal [165].
- Chronic carpal tunnel syndrome is a compressive neuropathy in which there is an insidious rise in the carpal tunnel interstitial pressure of a moderate degree [165].
- In chronic carpal tunnel syndrome, the increase in interstitial pressure initially may be intermittent but with time and increased symptoms it is likely to be elevated constantly [165].
- Factors involved in the pathogenesis of carpal tunnel syndrome include bony abnormalities of the carpal bones, acromegaly, and flexion or extension of the wrist [15].
- Factors involved in the pathogenesis of carpal tunnel syndrome include forearm and wrist fractures, dislocations and subluxations, posttraumatic arthritis, musculotendinous variants, aberrant muscles, local tumors, persistent medial artery, hypertrophic synovium, and hematoma [15].

- Neuropathic conditions involved in the pathogenesis of carpal tunnel syndrome include diabetes mellitus, alcoholism, double-crush syndrome, and exposure to industrial solvents [15].
- Inflammatory conditions involved in the pathogenesis of carpal tunnel syndrome include rheumatoid arthritis, gout, nonspecific tenosynovitis, and infection [15].
- 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 [15].
- External forces involved in the pathogenesis of carpal tunnel syndrome include vibration and direct pressure [15].
- Flexion of the wrist and/or fingers produces a palmar rearrangement of the flexor tendons creating potential compression of the median nerve [185].
- Patients suffering from idiopathic carpal tunnel syndrome have high canal pressures, especially at the extremes of wrist positions, with pressures maximal with maximal wrist extension [194].
- Splints that immobilize the wrist in a functional position of extension do not minimize carpal tunnel pressure [210].
- The study suggests an alternative pressure-mediated biomechanical model that could explain why slowing of conduction in the median nerve occurs just distal to the distal edge of the carpal tunnel, even though pressures in the more proximal segments may be greater [206].
- A new animal model demonstrates a temporally unambiguous relationship between exposure to a moderately forceful, repetitive manual task and development of median mononeuropathy at the wrist [75].
- Nerve gliding associated with wrist movements can be considerably increased and nerve strain substantially reduced by simultaneously moving neighboring joints [72].
- Transverse movement of the median nerve is most marked with forearm supination, irrespective of other changes in the kinetic chain [143].
- Reduced longitudinal excursion of the median nerve at the carpal tunnel is observed in carpal tunnel syndrome patients [220].
- The altered hand dynamics in carpal tunnel syndrome patients may have implications for the pathophysiology and clinical evaluation of carpal tunnel syndrome [71].

CLINICAL PRESENTATION AND DIAGNOSIS

- Carpal tunnel syndrome classically presents with nocturnal paresthesias in a median nerve distribution that gradually worsen as nerve injury progresses [16].
- Late in the disease course, carpal tunnel syndrome leads to sensory loss and thenar muscle atrophy [16].
- Symptoms of carpal tunnel syndrome include paresthesia or numbness in the median nerve distribution (thumb, index finger, middle finger, and radial side of the ring finger) [179].
- Nocturnal paresthesias in the radial three digits of the hand is nearly pathognomonic for carpal tunnel syndrome [179].

- Paresthesias occur characteristically in “fixed wrist activities” such as reading a book or a newspaper, driving, or use of a computer keyboard or mouse [179].
- With advanced nerve compression, patients experience weakness and atrophy of the abductor pollicis brevis and opponens pollicis muscles [179].
- Because of the slow onset of thenar weakness, patients typically adapt to this loss without functional impairments [179].
- A positive Tinel sign at the wrist or development of symptoms after provocative Phalen maneuver can aid in the diagnosis of carpal tunnel syndrome [16].
- The reported specificity of Tinel sign at the wrist varies from 55% to 100% [16].
- The reported specificity of the Phalen test varies from 54% to 98% [16].
- The diagnosis of carpal tunnel syndrome should be based on clinical acumen and physical examination in the vast majority of patients [15].
- 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 [16].
- 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 [16].
- Documenting muscle atrophy and fibrillations on needle EMG can assist with identifying severity of the disease and help with prognostication [16].
- 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 [15].
- In patients with negative electrodiagnostic studies but a clinical diagnosis of carpal tunnel syndrome, high-resolution ultrasonography has been used to diagnose carpal tunnel with a sensitivity of 73% if the cutoff of 9.4 mm² at the inlet of the carpal tunnel is used [15].
- MRI is not routinely used for diagnosis of carpal tunnel syndrome [15].
- A major advantage of MRI is its high soft-tissue contrast, which gives detailed images of bones and soft tissues [15].
- We found a very low incidence of lesions occurring proximal to the tunnel at the axis of wrist motion in patients with carpal tunnel syndrome [152].
- Carpal tunnel syndrome impairs the ability to perform precision pinch across the movement and at digit-contact [170].
- Carpal tunnel syndrome impairs the performance of precision pinch movement as indicated by the increased variability [214].

ANATOMICAL STRUCTURES AND SURGICAL 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 [62].
- A successful carpal tunnel release usually requires division of all components of the flexor retinaculum [62].

- The palmar cutaneous branch of the median nerve lies in the interval between the palmaris longus and the flexor carpi radialis tendons [62].
- The superficial palmar arterial arch is 5 to 8 mm distal to the distal margin of the transverse carpal ligament [62].
- Fibers of the transverse carpal ligament can extend distally farther than expected [62].
- The thenar crease takes a variable course, and palmar incisions should be well ulnar to it to avoid the median nerve palmar cutaneous branch [62].
- The incision is marked about 6 mm ulnar to the thenar crease to ensure that any scarring is away from the median nerve and that the incision is well ulnar to the palmar cutaneous branch of the median nerve [227].
- The palmar cutaneous branch of the median nerve is located deep to the thenar crease and radial to the palmaris longus [227].
- About 15% of the time, a crossing cutaneous branch from the ulnar nerve will be identified in a distal portion of the incision and protected [227].
- The recurrent motor branch of the median nerve may perforate the ligament and leave the median nerve on the volar side [62].
- In patients with deep, aching thenar pain or thenar muscle wasting, the recurrent motor branch will often enter the thenar musculature through its own tendinous tunnel [227].
- In these patients, the thenar motor branch may come off the ulnar side of the median nerve and directly under the ligament [227].
- The subsynovial connective tissue is an anatomical structure that contributes to the carpal tunnel and has a relation with the surrounding tendons and nerve [211].
- The supraretinacular fat pad lies in the path of the normal carpal tunnel approach [215].

Classification

- Carpal tunnel syndrome is the most frequently diagnosed, best understood, and most easily treated entrapment neuropathy [2].
- There is no universally agreed-upon reference standard test for diagnosing carpal tunnel syndrome [21].
- Clinicians diagnose carpal tunnel syndrome using symptoms and signs alone, electrodiagnostic testing, or both [21].
- The diagnosis of carpal tunnel syndrome should shift from a dichotomous, all-or-none approach to one that considers probabilities of disease [41].
- Tools such as the hand diagram and CTS 6 are utilized to form baseline probabilities and guide management based on estimated probability and severity [41].
- A management model based on a questionnaire score for symptoms and signs was developed to select patients with a high probability of carpal tunnel syndrome for carpal tunnel release without nerve conduction studies [145].

- Carpal tunnel syndrome can occur in an acute, subacute, or delayed form following traumatic wrist injuries [219].
- In a retrospective study of 105 wrists with carpal tunnel syndrome after distal radius fracture, 28 wrists were classified as acute onset, 47 as subacute onset, and 30 as delayed onset [176].
- In the same cohort of 105 wrists, CTS severity was graded as mild in 47 wrists, moderate in 45 wrists, and severe in 13 wrists [176].
- Among the acute onset group in the distal radius fracture cohort, 19 of 28 wrists were classified as C-type fractures according to the AO classification [176].
- Among the subacute onset group in the distal radius fracture cohort, 37 of 47 wrists were classified as A-type fractures according to the AO classification [176].
- Among the delayed onset group in the distal radius fracture cohort, 19 of 30 wrists were classified as A-type fractures according to the AO classification [176].
- In a study of 147 persons undergoing carpal tunnel release for idiopathic carpal tunnel syndrome, wrists were separated into mild, moderate, and severe categories based on the severity of symptoms [230].
- The “mild” category in that study represented intermittent symptoms of low intensity, usually nocturnal, which were not functionally limiting [230].
- The “moderate” category in that study represented intermittent and troublesome symptoms that were still not considered by the patient to be functionally limiting [230].
- The “severe” category in that study represented constant or nearly constant symptoms that interfered with function [230].
- Median neuropathy severity is quantified as mild, moderate, or severe based on the categorization of electrodiagnostic findings [226].
- A grading system for carpal tunnel syndrome identifies the degree of nerve injury and allows the referring physician to utilize the electrodiagnostic report to manage the patient [65].
- Patients with problematic class II carpal tunnel syndrome or failed carpal tunnel median neuropathy class III are likely to do poorly with a simple surgical release [118].
- Among large groups of carpal tunnel syndromes, it is possible to distinguish two distinct entities related to a persistent median artery [121].
- Carpal tunnel syndrome is a condition that requires attention to service delivery, awareness of systemic disease, and long-term nerve biology [8].

Clinical Presentation

EPIDEMIOLOGY AND DEMOGRAPHICS

- Carpal tunnel syndrome affects 3% to 6% of American adults [95].
- Carpal tunnel syndrome is the commonest peripheral nerve problem in the United Kingdom [92].

RISK FACTORS AND ETIOLOGY

- The American Academy of Orthopaedic Surgeons (AAOS) 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 [16].
- Proposed mechanisms for the association of carpal tunnel syndrome with risk factors range from hormonal changes to edema, but no consensus has been reached regarding their role in pathophysiology [16].
- 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 [15].
- Alterations of fluid balance involved in the pathogenesis of carpal tunnel syndrome include pregnancy, menopause, eclampsia, thyroid disorders (especially hypothyroidism), renal failure, long-term hemodialysis, Raynaud disease, obesity, lupus erythematosus, scleroderma, amyloidosis, and Paget disease [15].
- Carpal tunnel syndrome can be an early manifestation of systemic amyloidosis [40].
- Carpal tunnel syndrome can be the initial manifestation of scleroderma (systemic sclerosis) [87].

SYMPTOMS AND SIGNS

- Classically, carpal tunnel syndrome presents with nocturnal paresthesias in a median nerve distribution that gradually worsen as nerve injury progresses [16].
- Many patients report pain in the hand and may report symptoms that are not directly referable to the median nerve [16].
- Specialists do not consider pain without paresthesia or a noncharacteristic symptom distribution as characteristic of carpal tunnel syndrome [37].
- Symptoms and signs characteristic of carpal tunnel syndrome significantly, but incompletely coincided with electrophysiological testing [84].
- Even when the patient presents with a typical clinical presentation of carpal tunnel syndrome, the diagnosis is only confirmed electrophysiologically in 61% of cases [18].
- 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%) [90].
- The symptoms of carpal tunnel syndrome may improve without surgery [7].

DIAGNOSTIC TESTING

- The diagnosis of carpal tunnel syndrome is made by clinical history, physical examination, and supportive diagnostic testing with exclusion of other possible disorders [16].
- Clinicians use symptoms and signs alone, electrodiagnostic testing, or both to diagnose carpal tunnel syndrome [21].
- 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 [16].

- 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 [16].
- The composite sensitivity and specificity of ultrasound for the diagnosis of carpal tunnel syndrome are 77.6% and 86.8%, respectively [102].
- Ultrasonography might represent a useful tool for the diagnosis of carpal tunnel syndrome since this procedure has demonstrated a high sensitivity and specificity [100].
- MRI is not routinely used for diagnosis of carpal tunnel syndrome, though reports are promising especially with newer techniques such as diffusion tensor imaging [15].
- The diagnosis of carpal tunnel syndrome should be based on clinical acumen and physical examination in the vast majority of patients, and ancillary tests should be reserved for patients without clear presentations [15].
- Confirmatory electrodiagnostic testing is likely unnecessary for patients with high or low pretest probability of carpal tunnel syndrome, as it rarely alters the diagnosis [47].
- Electrodiagnostic testing is better reserved for unclear cases or for assessing severity and establishing a baseline [47].
- Some patients are diagnosed and treated for carpal tunnel syndrome who do not have median neuropathy at the wrist [43].
- Patients with typical carpal tunnel syndrome should undergo surgery regardless of the neurophysiological findings [104].
- The CTS-6 assigns a numerical value to 6 diagnostic criteria including nocturnal numbness, numbness in the median nerve territory, positive Phalen's test, positive Tinel sign, loss of 2-point discrimination, and thenar atrophy [95].
- CTS-6 scores range from 0 to 26, and a score >12 is associated with a 0.80 probability of carpal tunnel syndrome [95].
- The Boston Carpal Tunnel Questionnaire has demonstrated similar internal consistency, reliability, and construct validity in diagnosis and severity assessment of carpal tunnel syndrome symptoms as the CTS-6 [95].
- Hand symptom diagrams have the advantages of being low cost, easy to administer, and acceptable in almost all populations within which they are used [98].
- The predictive value of any test for carpal tunnel syndrome is dependent on the prevalence of disease in the population being tested [94].
- Discrepancies in studies examining tests for carpal tunnel syndrome exist in part because of the different nature of the populations being tested, which may result in spectrum bias [94].
- Highly sensitive tests are required to assess or exclude the diagnosis in one quarter of cases of carpal tunnel syndrome [86].
- The specificity of Tinel and Phalen sign tests is high, but their sensitivity is low, which limits their diagnostic value [45].

- It is concluded that the Tinel sign is of no diagnostic value in individual patients with suspected carpal tunnel syndrome [38].
- 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 [42].
- 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 [16].

Investigations

CLINICAL DIAGNOSIS AND PROVOCATIVE TESTS

- Classically, carpal tunnel syndrome presents with nocturnal paresthesias in a median nerve distribution that gradually worsens as nerve injury progresses, leading to sensory loss and thenar muscle atrophy late in the disease course [16].
- A positive Tinel sign at the wrist or development of symptoms after provocative Phalen maneuver can aid in the diagnosis [16].
- Tinel sign and Phalen maneuver are most reliable as adjuncts to other diagnostic tests [16].
- Provocative tests are based on enhancing or inducing the symptoms of a damaged median nerve as it passes through the carpal tunnel [23].
- It is concluded that Tinel's sign is of no diagnostic value in individual patients with suspected carpal tunnel syndrome [38].
- Ancillary tests should be reserved for patients without clear presentations [15].

ELECTRODIAGNOSTIC TESTING

- Thenar atrophy and abductor pollicis brevis weakness can often be detected on physical examination [16].
- Postoperative electrodiagnostic testing may be helpful in assessing recurrent symptoms [15].
- The AAOS Appropriate Use Criteria provide guidance on scenarios where electrodiagnostic studies are or are not necessary [4].

ULTRASONOGRAPHY

- Controversy remains as to whether ultrasonography evaluation could replace electrophysiology in the diagnosis of carpal tunnel syndrome [16].
- 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 [48].
- High resolution ultrasound is a valid and accurate diagnostic modality in carpal tunnel syndrome and correlated to CTS severity [158].

- Preliminary data show that ultrasonography can be used as an ancillary diagnostic modality in patients with suspected CTS, with the cross-sectional area of the median nerve at the tunnel inlet being the most useful diagnostic criterion [195].
- Ultrasonography is a valuable tool in detecting structural anomalies in carpal tunnel syndrome [201].
- The study demonstrates the value of routine sonographic assessment when evaluating patients with carpal tunnel syndrome [174].
- 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 [173].
- Space occupying lesions of the carpal tunnel may be easily missed, and a carpal tunnel view and ultrasound scanning in suspected cases is mandatory [168].

MAGNETIC RESONANCE IMAGING (MRI)

- Reports of MRI in carpal tunnel syndrome are promising, especially with newer techniques such as diffusion tensor imaging, but MRI is not routinely used for diagnosis [15].
- 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, either due to incomplete ligament division, iatrogenic injury, or other cause [16].
- Magnetic resonance imaging proved to be a sensitive and specific tool in the evaluation of persistent postoperative median nerve compression [197].
- 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 [153].
- 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 [128].
- 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 [183].
- 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 [169].

RADIOGRAPHY AND OTHER IMAGING

- Although wrist radiography is appropriate for some specific patient subgroups when suggested by history or findings on physical examination, its use as a routine screening procedure in most patients with CTS seems unjustified [177].
- 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 C'T should be supplemented in order to rule out SOLs around the carpal tunnel, if necessary [180].

- Careful examination and wrist imaging on suspicion of local pathology, especially a space-occupying lesion, are needed when the condition is unilateral and the aetiology is not clear from the history and on physical examination [203].

DIAGNOSTIC CHALLENGES AND SPECIFIC ETIOLOGIES

- Carpal tunnel syndrome is a common nerve compression syndrome generally not considered difficult to diagnose, though the method of diagnosis may vary among clinicians [20].
- 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 [3].
- Carpal tunnel syndrome caused by a space occupying lesion is rare and more complicated than idiopathic carpal tunnel syndrome [188].
- Amyloidosis diagnosis after carpal tunnel release is rare but is associated with poor outcomes [172].
- Most patients concomitantly treated for ulnar nerve compression at the elbow and carpal tunnel syndrome have objective findings of both conditions [205].

Treatment

NON-OPERATIVE MANAGEMENT

- Initial conservative management for mild and/or moderate carpal tunnel syndrome symptoms includes hand therapy, activity modification with splinting, and corticosteroid injection [16].
- Splinting is a basic, easily implemented, inexpensive, and effective intervention for carpal tunnel syndrome [139].
- Steroid injection into the carpal tunnel is effective and may be superior to splinting alone when combined with it [139].
- A short pulse of systemic steroid treatment might be effective for carpal tunnel syndrome, although the risk of long-term complications from even a short systemic exposure is not fully known [139].
- Systemic steroid treatment is superior to placebo but is not as effective as local steroid injection for carpal tunnel syndrome [139].
- Corticosteroid injection is safe and effective for the temporary relief of carpal tunnel syndrome symptoms, but most patients will eventually require surgery for long-term control [59].
- 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 [31].
- Local steroid injection for carpal tunnel syndrome has an overall success rate of 45% after a mean follow-up of 16 months [113].
- 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 [111].

- After 2 years, surgery is more effective than steroid injection in carpal tunnel syndrome [159].
- Steroid injection is a feasible, non-expensive and quite effective therapy in carpal tunnel syndrome [159].
- A significant number of patients who would otherwise have undergone surgery for failure of traditional conservative treatment were spared the surgical morbidity of a carpal tunnel release through the use of nerve and tendon gliding exercises [134].
- Lymphatic drainage techniques may serve as a beneficial adjunct therapy for carpal tunnel syndrome, particularly in pain management and nerve decompression, but their effects on functional recovery remain inconclusive [148].
- Platelet-rich plasma (PRP) is a safe modality that effectively relieves pain and improves disability in patients with carpal tunnel syndrome [114].
- The duration of compression of the median nerve at the carpal canal is significantly related to the effectiveness of conservative management [130].
- 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 [51].
- Patients with carpal tunnel syndrome can be successfully treated without surgery [22].
- Both surgical and conservative interventions had treatment benefit in carpal tunnel syndrome [110].
- The symptoms of carpal tunnel syndrome may improve without surgery, but further studies are needed to understand the natural history of the disorder [7].
- Non-surgical management of carpal tunnel syndrome is favorable compared with no treatment while the patient awaits surgery [119].
- Early self-management for the prevention of neuropathies may reduce the incidence of bilateral symptoms and the number of patients requiring decompressive surgery [119].

OPERATIVE MANAGEMENT

- Surgical decompression of the transverse carpal ligament is the benchmark procedure for the treatment of carpal tunnel syndrome [16].
- There has been no definitive difference in long-term functional outcome between open and endoscopic carpal tunnel release [16].
- Patients undergoing endoscopic release often have a more abbreviated recovery with less incisional pain compared to open release [16].
- 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 [16].
- In carpal tunnel syndrome, endoscopic surgery was associated with less postoperative pain than open surgery, but the small size of the benefit and similarity in other outcomes make its cost effectiveness uncertain [55].
- 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 [106].

- 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 [16].
- No approach has yet demonstrated superiority over other techniques currently in use in large, randomized controlled surgical trials [16].
- 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 [16].
- Clinical severity of carpal tunnel syndrome at intake is the most important factor in estimating symptom relief after surgical treatment [25].
- Early operative treatment is more likely to lead to a complete recovery in carpal tunnel syndrome [32].
- Acute carpal tunnel syndrome requires urgent surgical intervention to avoid or diminish serious sequelae, unlike chronic carpal tunnel syndrome where urgent surgery is seldom needed [142].
- Carpal tunnel release should be recommended to patients who have failed nonsurgical treatment [26].
- The AAOS guideline makes nine specific recommendations, including that carpal tunnel release is recommended [129].
- Symptoms in the non-dominant hand resolved faster after carpal tunnel release in patients with severe carpal tunnel syndrome [109].

RECURRENT AND RECALCITRANT CASES

- The recurrence rate after primary carpal tunnel release is approximately 2% [81].
- Complications and failures after primary carpal tunnel release are estimated to be 3% to 19% [81].
- Unrelieved symptoms may lead to repeat operation in 12% of patients [81].
- Rates of recurrent symptoms after carpal tunnel release may be as high as 4.5% [16].
- Recurrent symptoms after carpal tunnel release are thought to be due to scarring, tenosynovitis, and/or adhesive tethering [16].
- Recurrent symptoms should be differentiated from persistent symptoms, which may be due to an incompletely divided ligament during the index procedure or incorrect diagnosis [16].
- Repeat open median nerve neurolysis is often performed when symptoms recur, either by itself or in conjunction with local tissue flaps or wraps [16].
- 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 [16].
- 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 [107].
- 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 [81].

- 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 after reoperation [81].
- Temporary relief following a corticosteroid injection is a good prognostic sign when considering reoperation for recurrent carpal tunnel syndrome [81].
- Recurrent carpal tunnel syndrome was demonstrated more often in patients with diabetes [81].
- Persistent symptoms and more than one prior carpal tunnel syndrome had higher odds of not changing or worsening postoperative pain after reoperation [81].
- Higher preoperative pain, use of pain medication, and workers' compensation were significant predictors of higher postoperative average pain after reoperation [81].
- Neural adhesion lysis and early nerve gliding exercises are essential in the management of problematic recurrent carpal tunnel cases [81].
- Synovial or hypothenar fat pad flaps are rarely necessary in the management of problematic recurrent carpal tunnel cases [81].

PROGNOSIS AND RECOVERY

- Timing of recovery after carpal tunnel decompression is related to preoperative electrodiagnostic studies [82].
- Reinnervation in patients with decreased conduction velocity and increased latency will take just a few months [82].
- Axonal regeneration in patients with decreased compound muscle action potential (CMAP) will take much longer [82].
- 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 [82].
- Reinnervation of the thenar muscles occurs after carpal tunnel decompression, although it takes longer and return of motor function may not be complete in patients with severe carpal tunnel syndrome [82].
- Patients can expect restoration of full range of motion at the wrist after carpal tunnel decompression [82].
- Rarely, patients with severe carpal tunnel syndrome and thenar atrophy experience a postoperative flare with complaints of pain, stiffness, and swelling likely caused by a reinnervation hypersensitivity [82].
- Patients experiencing a postoperative flare due to reinnervation hypersensitivity are treated with hand therapy and occasionally a short burst of oral steroids [82].
- Patients can also experience pillar pain after carpal tunnel release, which is likely microneuroma related [82].
- 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 [82].
- If pillar pain develops after carpal tunnel release, patients are referred to hand therapy for scar massage and desensitization [82].

- Pre-operative electrodiagnostic testing predicts time to resolution of symptoms after carpal tunnel release [1].

Complications

- A review of 186 operative cases of carpal tunnel syndrome disclosed a total of 34 complications in 22 patients, with an incidence of 12% [151].
- At an average follow-up of 4.5 years, 28% of hands had persistent symptoms after carpal tunnel release by the Agee endoscopic technique [68].
- In a long-term follow-up study of dual-portal endoscopic release, severe hypesthesia was reported in 8 cases out of 90 [171].
- In a long-term follow-up study of dual-portal endoscopic release, hypesthesia was reported to be worse than preoperatively in 4 cases out of 90 [171].
- In a long-term follow-up study of dual-portal endoscopic release, paresthesia was reported to be worse than preoperatively in 4 cases out of 90 [171].
- 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% [53].
- Recurrence of carpal tunnel syndrome after carpal tunnel release surgery was common, occurring in 61.9% of patients with mucopolysaccharidosis type I [131].
- Transection of the motor branch of the ulnar nerve is a complication of two-portal endoscopic carpal tunnel release [5].
- 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 [40].
- Delayed carpal tunnel syndrome is typically due to alterations in carpal tunnel anatomy and requires etiology-specific treatment [44].
- Patients with a prior history of carpal tunnel syndrome are at increased risk of recurrent symptoms after radial artery cannulation [64].
- The authors suggest considering an infectious etiology in atypical carpal tunnel syndrome presentations or when symptoms persist after surgery [167].
- Dissatisfaction after limited incision carpal tunnel release seems to correlate with mood and successful relief of symptoms [192].
- Some patients note some increased tingling after complete release [192].
- Fibrosis may be a contributing factor in recurrent or persistent carpal tunnel syndrome, but it is an entity that cannot currently be objectively verified or falsified [192].
- If intraoperative observation suggests intraneural injury during revision for recurrent carpal tunnel syndrome, additional procedures to repair the nerve may also need to be considered [192].

- If local soft tissues are extremely fibrotic or otherwise deficient during revision for recurrent carpal tunnel syndrome, the importance of supple tissue, in the form of pedicled or free grafts, might be considered [192].
- Carpal tunnel release using the radial sided approach compared with the two-incision approach is a subject of comparison in surgical literature [1].
- Comparison of longitudinal open incision and two-incision techniques for carpal tunnel release is documented in surgical literature [1].
- Comparison of short wrist transverse open and limited open techniques for carpal tunnel release is documented in a randomized controlled trial [1].
- Surgical ultrasound-guided carpal tunnel release is a documented technique [1].
- Evaluation of the effectiveness and safety of ultrasound-guided percutaneous carpal tunnel release has been performed in a cadaveric study [1].
- A clinical study of the modified thread carpal tunnel release has been conducted [1].
- Endoscopic carpal tunnel release is preferred over mini-open despite similar outcome in a randomized trial [1].
- Carpal tunnel release in patients with diabetes results in poor outcomes in long-term study according to one source [1].
- Long-term improvement in patients with diabetes remained after carpal tunnel release to the same extent as for patients without diabetes according to another source [56].
- Endoscopic release for severe carpal tunnel syndrome in octogenarians is a documented procedure [1].
- Does carpal tunnel release provide long-term relief in patients with hemodialysis-associated carpal tunnel syndrome is a subject of study [1].
- Risk factors for re-recurrent carpal tunnel syndrome in patients undergoing long-term hemodialysis have been studied [1].
- Outcomes of open and endoscopic carpal tunnel release have been compared in a meta-analysis [1].
- The benefit of carpal tunnel release in patients with electrophysiologically moderate and severe disease has been studied [1].
- Carpal tunnel release a randomized comparison of three surgical methods has been conducted [1].
- Long-term outcomes of carpal tunnel release have been critically reviewed [1].
- A cost analysis of carpal tunnel release surgery performed wide awake versus under sedation has been conducted [1].
- Predicting the outcome of revision carpal tunnel release has been studied [1].
- Results of endoscopic carpal tunnel release relative to surgeon experience with the Agee technique have been studied [1].
- Whether prior local corticosteroid injection prejudices the outcome of subsequent carpal tunnel decompression has been studied [1].

- Prognostic indicators for recurrent symptoms after a single corticosteroid injection for carpal tunnel syndrome have been identified [1].
- Clinical course and prognostic factors in conservatively managed carpal tunnel syndrome have been systematically reviewed [1].
- Carpal tunnel syndrome: making evidence-based treatment decisions is a topic of clinical review [1].
- Unusual causes of carpal tunnel syndrome: space occupying lesions have been described [1].
- Predictors of the patient-centered outcomes of surgical carpal tunnel release have been studied in a prospective cohort study [1].
- Electromyography, ultrasonography, computed tomography, magnetic resonance imaging in idiopathic carpal tunnel syndrome determined by clinical findings have been compared [1].
- Diagnosing carpal tunnel syndrome is a subject of clinical review [1].
- Outcomes following carpal tunnel release in patients receiving workers' compensation have been systematically reviewed [1].
- Incidence of carpal tunnel syndrome requiring surgical decompression has been reviewed over a 10.5-year period of 2,309 patients [1].
- Surgery versus conservative therapy in carpal tunnel syndrome in people aged 70 years and older has been compared [1].
- A comparison of three diagnostic tests for carpal tunnel syndrome using latent class analysis has been conducted [1].
- Comparison of ultrasound and electrodiagnostic testing for diagnosis of carpal tunnel syndrome has been conducted using a validated clinical tool as the reference standard [1].
- The clinical practice guideline on carpal tunnel syndrome and workers' compensation has been discussed [1].
- Reoperation surgery for persistent and recurrent carpal tunnel syndrome and for failed carpal tunnel release has been described [1].
- Endoscopic carpal tunnel release using the single proximal incision technique has been described [5].
- Endoscopic release of the carpal tunnel: a randomized prospective multicenter study has been conducted [5].
- Endoscopic carpal tunnel release: a prospective study of complications and surgical experience has been conducted [5].
- Surgical technique to reduce scar discomfort after carpal tunnel surgery has been described [5].
- Comparison between partial and minimal medial epicondylectomy with decompression for the treatment of cubital tunnel syndrome has been conducted [5].
- Severe carpal tunnel syndrome potentially needing surgical treatment in a general population has been studied [5].
- Carpal tunnel release using a short palmar incision and a new knife has been described [5].
- Reduction in pain associated with open carpal tunnel decompression has been studied [5].

- Endoscopic carpal tunnel release in rheumatoid patients has been described [5].
- Whether splintage helps pain after carpal tunnel release has been studied [5].
- A randomized controlled trial of Knifelight and open carpal tunnel release has been conducted [5].
- Neurophysiological recovery after open carpal tunnel decompression: comparison of simple decompression and decompression with epineurotomy has been studied [5].
- Controversies in carpal tunnel syndrome have been discussed [5].
- Recurrent carpal tunnel syndrome has been discussed [5].
- Electrical studies as a prognostic factor in the surgical treatment of carpal tunnel syndrome have been studied [5].
- Complications related to carpal tunnel release have been discussed [5].
- Minimal-incision open carpal tunnel decompression has been described [5].
- Carpal tunnel release has been described [5].
- Basal joint arthroplasty and carpal tunnel release through a single incision: an in vitro study has been conducted [5].
- Return-to-work interval and surgery for carpal tunnel syndrome: results of a prospective series of 233 patients have been reported [5].
- Poor outcome for neural surgery (epineurotomy or neurolysis) for carpal tunnel syndrome compared with carpal tunnel release alone: a meta-analysis of global outcomes has been conducted [5].
- Endoscopic carpal tunnel release: thirteen years' experience with the Chow technique has been reported [5].
- Endoscopic release of the carpal ligament: a new technique for carpal tunnel syndrome has been described [5].
- Endoscopic release of the carpal ligament for carpal tunnel syndrome: 22-month clinical results have been reported [5].
- Endoscopic carpal tunnel release: two-portal technique has been described [5].
- Endoscopic release of the carpal ligament for carpal tunnel syndrome: long-term results using the Chow technique have been reported [5].
- The hypothenar fat pad transposition flap: a modified surgical technique has been described [5].
- Raynaud's phenomenon in idiopathic carpal tunnel syndrome: postoperative alteration in its prevalence has been studied [5].
- The incidence of recurrence after endoscopic carpal tunnel release has been studied [5].
- Outcome of reoperation for carpal tunnel syndrome has been studied [5].
- Anatomy of the flexor retinaculum has been described [5].
- Symptoms may return after carpal tunnel surgery [5].
- Management of recurrent carpal tunnel syndrome with microneurolysis and the hypothenar fat pad flap has been described [5].

- A noninvasive technique for diagnosis of chronic compartment syndrome in the first dorsal interosseous muscle has been described [5].
- Injury to the medial antebrachial cutaneous nerve during cubital tunnel surgery has been described [5].
- Value of some clinical provocative tests in carpal tunnel syndrome: do we need electrophysiology and can we predict the outcome has been discussed [5].
- Transection of the motor branch of the ulnar nerve as a complication of two-portal endoscopic carpal tunnel release: a case report has been published [5].
- Pedicled fat flap coverage of the median nerve after failed carpal tunnel decompression has been described [5].
- Carpal tunnel decompression: is lengthening of the flexor retinaculum better than simple division has been studied [5].
- Carpal tunnel syndrome and work has been discussed [5].
- A new diagnostic test for carpal tunnel syndrome has been described [5].

Recovery

- Complete restoration of clinical and electrophysiologic nerve function was observed only in patients with mild carpal tunnel syndrome [141].
- 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 [229].
- Patients with clinical features of carpal tunnel syndrome but normal nerve conduction studies reported significant improvements in patient-reported outcomes at 1 year after decompression, although the improvement was significantly less than that observed in patients with abnormal nerve conduction studies [70].
- Long-term improvement in patients with diabetes remained after carpal tunnel release to the same extent as for patients without diabetes [56].
- Patients undergoing revision open carpal tunnel decompression for recurrent carpal tunnel syndrome experience a significant improvement in function and health-related quality of life [69].
- Sensory, functional, and symptomatic recovery from the third month to the sixth month following surgery affected sleep parameters and improved the sleep quality of patients with carpal tunnel syndrome [126].
- Ultrasound-guided carpal tunnel release quickly improves hand function and reduces hand discomfort; improvement persisted beyond one year [67].
- At an average follow-up of 4.5 years, 28% of hands had persistent symptoms after endoscopic carpal tunnel release, but results were scarcely different from the conventional technique with no patient requiring reoperation [68].
- Complete resolution of symptoms was noted in 10 of 76 hands at the final follow-up examination for conservative management [239].

- The changes in electrophysiological findings occurring spontaneously in carpal tunnel syndrome and after treatment by injection are not statistically significant at two years [240].
- The carpal canal pressure was related to the latency and to the duration of symptoms [235].
- This property of prolonged recovery time in patients with carpal tunnel syndrome suggests a possible cause for carpal tunnel syndrome in the occupational setting [66].

Key Evidence

- [Paper] Carpal tunnel syndrome is the most frequently diagnosed, best understood and most easily treated entrapment neuropathy. [2] ([10.1016/0266-7681_88_90046-0](#))
- [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. [3] ([10.1177/17531934221080631](#))
- [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. [4] ([10.5435/jaaos-d-17-00454](#))
- [L4] The procedure is not suitable for severe carpal tunnel syndrome or when direct visualization of the median nerve and the carpal tunnel is necessary. [6] ([10.1016/s0266-7681\(02\)00363-7](#))
- [L3] The symptoms of carpal tunnel syndrome may improve without surgery, but further studies are needed to understand the natural history of the disorder. [7] ([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. [8] ([10.1177/17531934261433793](#))
- [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. [9] ([10.1177/1558944719857815](#))
- [L3] Carpal tunnel decompression surgery is safe and effective, with 97% of patients experiencing complete or partial relief. [10] ([10.1054/jhsb.2001.0616](#))
- [L4] Endoscopic carpal tunnel release is safe and yields predictable long-term results. [12] ([10.1016/s0894-1130\(12\)80295-x](#))
- [L5] The authors conclude that more accurate means of selecting patients who will benefit from surgery in the early stages of carpal tunnel syndrome are needed. [13] ([10.1016/s0363-5023\(98\)80143-3](#))
- [L3] Even when the patient presents with a typical clinical presentation of carpal tunnel syndrome the diagnosis is only confirmed electrophysiologically in 61% of cases. [18] ([10.1016/0266-7681\(94\)90244-5](#))
- [L5] Carpal tunnel syndrome is a common nerve compression syndrome generally not considered difficult to diagnose, though the method of diagnosis may vary among clinicians. [20] ([10.1016/j.pmr.2014.01.004](#))

- [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. [21] ([10.1016/j.jhsa.2014.03.039](#))
- [L4] Patients with carpal tunnel syndrome can be successfully treated without surgery. [22] ([10.1016/0363-5023\(93\)90329-2](#))
- [L4] [23] ([10.1038/ncpneuro0216](#))
- [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. [24] ([10.1177/1558944720949951](#))
- [L2] Clinical severity of carpal tunnel syndrome at intake is the most important factor in estimating symptom relief after surgical treatment. [25] ([10.1016/j.jhsa.2018.05.017](#))
- [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. [26] ([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. [27] ([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. [28] ([10.1212/wnl.58.11.1589](#))
- [L4] Consequently, patients in high-allergy cohorts can be expected to benefit from carpal tunnel release. [29] ([10.1177/15589447241284304](#))
- [L4] Surgical decompression of the carpal tunnel is the treatment of choice and long-term follow-up is recommended. [30] ([10.1016/s0266-7681\(96\)80023-4](#))
- [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. [31] ([10.1177/1753193412469580](#))
- [L5] Early operative treatment is more likely to lead to a complete recovery in carpal tunnel syndrome. [32] ([10.1016/0266-7681_90_90060-h](#))
- [L5] A rational plan of therapy is available for each category of complications of carpal tunnel syndrome. [33] ([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. [37] ([10.1016/j.jhsa.2024.07.004](#))
- [L4] It is therefore concluded that the sign is of no diagnostic value in individual patients with suspected carpal tunnel syndrome. [38] ([10.1016/0266-7681\(87\)90190-2](#))
- [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. [40] ([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. [41] ([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. [42] ([10.1007/s11552-012-9435-z](#))
- [L4] Some patients are diagnosed and treated for CTS who do not have median neuropathy at the wrist. [43] ([10.1016/s0363-5023\(98\)80089-0](#))
- [L5] Delayed carpal tunnel syndrome is typically due to alterations in carpal tunnel anatomy and requires etiology-specific treatment. [44] ([10.1016/j.hcl.2017.09.003](#))
- [Paper] [45] ([10.1016/j.apmr.2014.06.022](#))
- [L5] Confirmatory electrodiagnostic testing is likely unnecessary for patients with high or low pretest probability of carpal tunnel syndrome, as it rarely alters the diagnosis; it is better reserved for unclear cases or for assessing severity and establishing a baseline. [47] ([10.1016/j.jhsa.2020.09.007](#))
- [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. [48] ([10.2106/jbjs.o.01067](#))
- [L3] Given specific clinical criteria for establishing the diagnosis of carpal tunnel syndrome, electrodiagnostic testing does not appear to correlate with improved final symptomatic outcome after carpal tunnel release. [50] ([10.1016/s0363-5023\(96\)80164-x](#))
- [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. [51] ([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%. [53] ([10.1302/0301-620x.99b10.bjj-2016-0587.r2](#))
- [L1] In carpal tunnel syndrome, endoscopic surgery was associated with less postoperative pain than open surgery, but the small size of the benefit and similarity in other outcomes make its cost effectiveness uncertain. [55] ([10.1136/bmj.38863.632789.1f](#))
- [L2] Long-term improvement in patients with diabetes remained after carpal tunnel release to the same extent as for patients without diabetes. [56] ([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. [58] ([10.1016/j.jhsa.2012.07.041](#))
- [L5] Corticosteroid injection is safe and effective for the temporary relief of carpal tunnel syndrome symptoms, but most patients will eventually require surgery for long-term control of their symptoms. [59] ([10.1016/j.jhsa.2008.06.023](#))
- [L4] The outcome of carpal tunnel decompression syndrome is good in the majority of the cases, with open and endoscopic techniques providing similar results. [60] ([10.1054/jhsb.2002.0780](#))

- [L4] There are no clear indications on how health utilities can be integrated into decision analysis models and economic evaluation regarding carpal tunnel syndrome of various severities. [61] ([10.1177/1753193420922791](#))
- [L2] Patients with a prior history of carpal tunnel syndrome are at increased risk of recurrent symptoms after radial artery cannulation. [64] ([10.1016/0363-5023\(93\)90091-g](#))
- [L5] [65] ([10.1002/mus.23824](#))
- [L4] This property of prolonged recovery time in patients with carpal tunnel syndrome suggests a possible cause for carpal tunnel syndrome in the occupational setting. [66] ([10.1016/0363-5023\(89\)90178-0](#))
- [L4] Ultrasound-guided carpal tunnel release quickly improves hand function and reduces hand discomfort; improvement persisted beyond one year. [67] ([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. [68] ([10.1054/jhsb.1999.0226](#))
- [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. [69] ([10.1177/1753193419875945](#))
- [L3] Patients with clinical features of carpal tunnel syndrome but normal nerve conduction studies reported significant improvements in patient-reported outcomes at 1 year after decompression, although the improvement was significantly less than that observed in patients with abnormal nerve conduction studies. [70] ([10.1177/1753193419866646](#))
- [L4] The altered hand dynamics in CTS patients may have implications for the pathophysiology and clinical evaluation of CTS, and ultrasound-based classification models may further support the diagnosis of CTS. [71] ([10.1002/mus.23246](#))
- [L5] Nerve gliding associated with wrist movements can be considerably increased and nerve strain substantially reduced by simultaneously moving neighboring joints. [72] ([10.1002/jor.20310](#))
- [Paper] This new animal model demonstrates a temporally unambiguous relationship between exposure to a moderately forceful, repetitive manual task and development of median mononeuropathy at the wrist. [75] ([10.1002/jor.20363](#))
- [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. [79] ([10.1186/1471-2474-14-240](#))
- [L2] Symptoms and signs characteristic of carpal tunnel syndrome significantly, but incompletely coincided with electrophysiological testing. [84] ([10.1177/1753193412461860](#))
- [L3] Highly sensitive tests are required to assess or exclude the diagnosis in one quarter of cases of carpal tunnel syndrome. [86] ([10.1016/0266-7681\(94\)90245-3](#))
- [L4] Carpal tunnel syndrome can be the initial manifestation of scleroderma (systemic sclerosis). [87] ([10.1016/s0363-5023\(88\)80009-1](#))
- [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. [90] ([10.1097/corr.0000000000002822](#))

- [L4] Carpal tunnel syndrome is the commonest peripheral nerve problem in the United Kingdom and is readily treatable if recognised early. [92] ([10.1136/bmj.39282.623553.ad](#))
- [L3] [94] ([10.1053/jhsu.1999.0704](#))
- [L4] [98] ([10.1093/occmed/kqn123](#))
- [L1] [100] ([10.1016/j.apmr.2017.08.489](#))
- [L1] [102] ([10.1007/s11999-010-1637-5](#))
- [L3] Patients with typical carpal tunnel syndrome should undergo surgery regardless of the neurophysiological findings. [104] ([10.1054/jhsb.2000.0496](#))
- [L1] The procedures provided similar symptom relief and hand strength and sensibility recovery, and were safe for patients with carpal tunnel syndrome. [106] ([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. [107] ([10.5435/jaaos-d-18-00004](#))
- [L4] Symptoms in the non-dominant hand resolved faster after carpal tunnel release in patients with severe carpal tunnel syndrome. [109] ([10.1142/s0218810417500344](#))
- [L1] Both surgical and conservative interventions had treatment benefit in carpal tunnel syndrome. [110] ([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. [111] ([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. [113] ([10.1016/j.jhsa.2021.09.022](#))
- [L1] The study demonstrates that PRP is a safe modality that effectively relieves pain and improves disability in patients with carpal tunnel syndrome. [114] ([10.1038/s41598-017-00224-6](#))
- [L4] Patients who have problematic class II CTS or failed carpal tunnel median neuropathy class III are likely to do poorly with a simple surgical release. [118] ([10.1016/s0894-1130\(12\)80296-1](#))
- [L4] [119] ([10.1258/ht.2009.010002](#))
- [L4] Among the large group of carpal tunnel syndromes, it is possible to distinguish two distinct entities, which are related to a persistent median artery. [121] ([10.1016/s0363-5023\(85\)80163-5](#))
- [L4] Sensory, functional, and symptomatic recovery from the third month to the sixth month following surgery affected sleep parameters and improved the sleep quality of patients with carpal tunnel syndrome. [126] ([10.1177/1753193418808182](#))
- [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. [128] ([10.2106/jbjs.25.01685](#))

- [L1] The guideline makes nine specific recommendations, including that nonsurgical treatment is an option, early surgery is an option with denervation, and carpal tunnel release is recommended. [129] ([10.5435/jaaos-d-17-00575](#))
- [L4] The duration of compression of the median nerve at the carpal canal is significantly related to the effectiveness of conservative management. [130] ([10.1016/s0894-1130\(04\)00194-2](#))
- [L3] Recurrence of carpal tunnel syndrome after carpal tunnel release surgery was common, occurring in 61.9% of patients. [131] ([10.1177/17531934261416366](#))
- [L3] Thus, a significant number of patients who would otherwise have undergone surgery for failure of traditional conservative treatment were spared the surgical morbidity of a carpal tunnel release ($p = 0.0001$). [134] ([10.1016/s0894-1130\(98\)80035-5](#))
- [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. [136] ([10.1054/jhsb.1999.0328](#))
- [L4] Clinical symptoms of carpal tunnel syndrome improved in all 55 hands, and postoperative electrophysiologic data remained within normal range in patients who agreed to receive electrophysiologic examinations. [138] ([10.1016/s0363-5023\(05\)80442-3](#))
- [L5] [139] ([10.1016/j.jhsa.2009.01.010](#))
- [L2] The outcome of carpal tunnel release in terms of improvement in the symptom and functional scores is sufficient to justify surgery in the elderly, but surgical outcomes are less predictable than in younger patients. [140] ([10.1016/j.jhsb.2005.07.005](#))
- [L2] Complete restoration of clinical and electrophysiologic nerve function was observed only in patients with mild carpal tunnel syndrome. [141] ([10.1016/s0363-5023\(98\)80056-7](#))
- [L5] Acute carpal tunnel syndrome requires urgent surgical intervention to avoid or diminish serious sequelae, unlike chronic carpal tunnel syndrome where urgent surgery is seldom needed. [142] ([10.5435/00124635-200805000-00006](#))
- [L4] Transverse movement of the median nerve is most marked with forearm supination, irrespective of other changes in the kinetic chain. [143] ([10.1258/ht.2011.011017](#))
- [L3] Surgery should be considered as the initial form of treatment when patients are diagnosed with carpal tunnel syndrome confirmed by nerve conduction studies, as this provides symptom resolution with a favorable cost analysis. [144] ([10.1016/j.jhsa.2009.04.034](#))
- [L3] A management model based on a questionnaire score for symptoms and signs was developed to select patients with a high probability of CTS for carpal tunnel release without nerve conduction studies. [145] ([10.1177/1753193409105566](#))
- [L1] Lymphatic drainage techniques may serve as a beneficial adjunct therapy for carpal tunnel syndrome, particularly in pain management and nerve decompression, but their effects on functional recovery remain inconclusive. [148] ([10.1186/s13018-025-05887-w](#))
- [L4] A review of 186 operative cases of carpal tunnel syndrome disclosed a total of 34 complications in 22 patients, with an incidence of 12%. [151] ([10.1016/s0363-5023\(78\)80118-x](#))

- [L4] We found a very low incidence of lesions occurring proximal to the tunnel at the axis of wrist motion. [152] ([10.1016/0266-7681\(90\)90056-a](#))
- [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. [153] ([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. [158] ([10.1186/s12891-019-3010-5](#))
- [L1] [159] ([10.1093/rheumatology/kes053](#))
- [L3] The results provide some support for a causative association between wrist morphometry, as measured by the wrist index, and CTS, but this difference is too small to be of diagnostic value in clinical or epidemiological practice. [162] ([10.1177/1753193408090142](#))
- [L5] [165] ([10.1016/s0749-0712\(21\)00307-3](#))
- [L4] Wrist circumference was not a predictor of the smallest carpal canal area. [166] ([10.1016/s0363-5023\(87\)80246-0](#))
- [L4] The authors suggest considering an infectious etiology in atypical carpal tunnel syndrome presentations or when symptoms persist after surgery. [167] ([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. [168] ([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. [169] ([10.1016/j.jhsa.2020.06.006](#))
- [L4] Carpal tunnel syndrome impairs the ability to perform precision pinch across the movement and at digit-contact. [170] ([10.1002/jor.22600](#))
- [L4] [171] ([10.1227/01.neu.0000335784.90217.9d](#))
- [L4] Amyloidosis diagnosis after carpal tunnel release is rare but is associated with poor outcomes. [172] ([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. [173] ([10.1177/0883073810387299](#))
- [L4] The study demonstrates the value of routine sonographic assessment when evaluating patients with carpal tunnel syndrome. [174] ([10.1016/j.jhsg.2025.100903](#))
- [L4] [176] ([10.1007/s00776-010-1496-7](#))
- [L4] Although wrist radiography is appropriate for some specific patient subgroups when suggested by history or findings on physical examination, its use as a routine screening procedure in most patients with CTS seems unjustified. [177] ([10.1016/s0363-5023\(05\)80190-x](#))
- [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. [180] ([10.3349/ymj.2009.50.2.257](#))

- [L4] Wrist ratio was the only significant predictor in the logistic regression analysis. [182] ([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. [183] ([10.2106/jbjs.25.00787](#))
- [L4] Flexion of the wrist and/or fingers produces a palmar rearrangement of the flexor tendons creating potential compression of the median nerve. [185] ([10.1016/0363-5023\(90\)90019-n](#))
- [L4] Carpal tunnel syndrome caused by a space occupying lesion is rare and more complicated than idiopathic carpal tunnel syndrome. [188] ([10.1177/1753193411414352](#))
- [L5] [192] ([10.1016/j.jhsa.2009.04.031](#))
- [L4] This study confirms that patients suffering from idiopathic CTS have high canal pressures, especially at the extremes of wrist positions, with pressures maximal with maximal wrist extension. [194] ([10.1053/jhsu.2002.36541](#))
- [L3] Preliminary data show that ultrasonography can be used as an ancillary diagnostic modality in patients with suspected CTS, with the cross-sectional area of the median nerve at the tunnel inlet being the most useful diagnostic criterion. [195] ([10.1177/1753193408090396](#))
- [L4] Magnetic resonance imaging proved to be a sensitive and specific tool in the evaluation of persistent postoperative median nerve compression. [197] ([10.1016/0363-5023\(93\)90254-z](#))
- [L5] Hence Ultrasonography is a valuable tool in detecting structural anomalies in carpal tunnel syndrome. [201] ([10.1142/s2424835518720165](#))
- [L4] We conclude that careful examination and wrist imaging on suspicion of local pathology, especially a space-occupying lesion, are needed when the condition is unilateral and the aetiology is not clear from the history and on physical examination. [203] ([10.1016/0266-7681\(93\)90236-9](#))
- [L3] Most patients concomitantly treated for ulnar nerve compression at the elbow and carpal tunnel syndrome have objective findings of both conditions. [205] ([10.1177/1558944718813669](#))
- [L4] The study suggests an alternative pressure-mediated biomechanical model that could explain why slowing of conduction in the median nerve occurs just distal to the distal edge of the carpal tunnel, even though pressures in the more proximal segments may be greater. [206] ([10.1016/s0266-7681\(98\)80009-0](#))
- [L4] Splints that immobilize the wrist in a functional position of extension do not minimize carpal tunnel pressure. [210] ([10.2106/00004623-199511000-00008](#))
- [L5] This review aims to provide a detailed description of the SSCT as an anatomical structure, its (biomechanical) contribution to the carpal tunnel and the relation with the surrounding tendons and nerve. [211] ([10.1016/j.jelekin.2017.10.007](#))
- [L3] Carpal tunnel syndrome impairs the performance of precision pinch movement as indicated by the increased variability. [214] ([10.1016/j.jhsa.2008.02.030](#))
- [L5] It lies in the path of the normal carpal tunnel approach. [215] ([10.1016/s1297-3203\(01\)00048-8](#))

- [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. [216] ([10.1016/j.jhsa.2008.01.004](#))
- [L4] [219] ([10.1016/j.injury.2024.111536](#))
- [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. [220] ([10.1016/j.apmr.2007.02.015](#))
- [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. [229] ([10.1177/1753193415576248](#))
- [L4] [230] ([10.1016/0363-5023\(91\)90208-s](#))
- [L4] The carpal canal pressure was related to the latency and to the duration of symptoms. [235] ([10.1016/j.jhsa.2006.03.004](#))
- [L2] Complete resolution of symptoms was noted in 10 of 76 hands at the final follow-up examination. [239] ([10.1016/0363-5023\(94\)90054-x](#))
- [L3] The changes in electrophysiological findings occurring spontaneously in carpal tunnel syndrome and after treatment by injection are not statistically significant at two years. [240] ([10.1016/0266-7681\(92\)90191-4](#))

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