

Importance of Recognizing Carpal Tunnel Syndrome for Neurosurgeons: A Review

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Abstract

Idiopathic carpal tunnel syndrome (CTS) is a common complaint, reflecting entrapment neuropathy of the upper extremity. CTS produces symptoms similar to those of other conditions, such as cervical spondylosis or ischemic or neoplastic intracranial disease. Because of these overlaps, patients with CTS are often referred to a neurosurgeon. Surgical treatment of CTS was started recently in our department. Through this experience, we realized that neurosurgeons should have an increased awareness of this condition so they can knowledgeably assess patients with a differential diagnosis that includes CTS and cervical spinal and cerebral disease. We conducted a literature review to gain the information needed to summarize current knowledge on the clinical, pathogenetic, and therapeutic aspects of CTS. Because the optimal diagnostic criteria for this disease are still undetermined, its diagnosis is based on the patient's history and physical examination, which should be confirmed by nerve conduction studies and imaging modalities such as magnetic resonance imaging and ultrasonography. Treatment methods include observation, medication, splinting, steroid injections, and surgical intervention. Understanding the clinical features and pathogenesis of CTS, as well as the therapeutic options available to treat it, is important for neurosurgeons if they are to provide the correct management of patients with this disease.

Key words: carpal tunnel syndrome, diagnosis, treatment, neurosurgeon

Introduction

Idiopathic carpal tunnel syndrome (CTS) is the most common entrapment neuropathy of the upper extremity. It is estimated to occur in 1–4% of the general population and accounts for about 90% of all nerve compression syndromes.^{1,2} It is expected that one to two of five patients who report symptoms of pain, numbness, and a tingling sensation in the hands will be diagnosed with CTS based on a clinical examination and electrophysiological testing.^{1,3,4} CTS has symptoms similar to those seen with other conditions, such as cervical spondylosis or ischemic or neoplastic intracranial disease. Hence, patients with CTS are sometimes referred to a neurosurgeon.³ In our department, surgical treatment of CTS was started recently, and to date 29 surgical interventions have been performed in 24 CTS patients (Table 1). Based on this experience, we realized that neurosurgeons should increase their awareness of CTS if they are to assess it in reference to a cervical spinal disease or cerebral disease. We therefore conducted a literature review to gain sufficient information to summarize

the current clinical and pathogenetic aspects of this disease and the therapeutic options available to treat it. In addition, we have summarized what neurosurgeons need to know to manage CTS correctly.

Characteristics and Symptoms of CTS

CTS is characterized by a symptomatic compression neuropathy of the median nerve at the level of the wrist.^{1,5} Primary features of CTS include unpleasant tingling, pain, or numbness in the distal distribution of the median nerve (thumb, index, middle finger, radial side of the ring finger) as well as reduced grip strength and function of the affected hand.^{1,2} Symptoms tend to be worse at night, and clumsiness is reported during the day with activities requiring wrist flexion. Patients often complain of a phenomenon that can be diagnosed using the “flick sign,” described as shaking or flicking the wrists to relieve symptoms.^{1,2,5} Occasionally, dysesthesia exists in the ulnar nerve distribution, and acroparesthesia that is often referred to all digits (64%) has been reported. Proximal pain is not uncommon (46%).⁶ It is important to note that these findings do not rule out CTS. In some instances, patients

Table 1 Initial surgical cases of carpal tunnel syndrome in our department

Age sex	OP/FV	ILL period (months)	Clinical grade	Levine scale	AAEM grade	Nerve swelling
74 M	OP	24	3	5	severe	-
	Cerebral infarction	31	3	4	moderate	+
51 F	FV	68	3	3	severe	+
		72	1	3	moderate	-
72 F	FV	25	3	4	severe	+
82 M	FV	6	3	5	extreme	+
77 F	OP Cerebral infarction	36	3	3	severe	-
77 M	FV	36	1	3	moderate	-
69 M	FV	24	1	3	moderate	-
70 M	FV	6	3	3	moderate	-
		8	3	3	severe	-
64 M	FV	6	1	3	moderate	+
77 M	OP Cervical spondylosis	36	3	5	extreme	-
78 F	OP Cervical spondylosis	38	1	3	moderate	+
68 M	FV	3	1	3	moderate	-
80 F	FV	24	3	4	severe	-
		36	3	5	severe	-
81 F	OP Cerebral infarction	38	1	3	moderate	-
68 F	FV	3	2	3	moderate	+
80 F	FV	6	1	3	moderate	-
73 F	FV	18	1	3	moderate	+
		20	1	3	moderate	-
61 F	FV	6	3	4	severe	+
69 M	FV	12	1	3	moderate	+
71 F	FV	3	3	3	moderate	+
51 F	OP Cervical spondylosis	24	1	3	moderate	+
84 M	Op Cervical spondylosis	48	3	4	severe	-
78 F	OP Lumbar spondylosis	36	1	3	moderate	-
63 M	FV	6	2	3	moderate	-

FV: patients who first visited our department, OP: patients who had been followed up as outpatients.

have symptoms only with rigorous activity and present with minimal symptoms or objective findings when examined. This type of presentation is termed "dynamic CTS," and these patients usually benefit from conservative management, including altering their work duties. A well-defined history is particularly important in these cases.⁷⁾

The stages of CTS can be categorized into three stages based on the clinical symptoms. In the first stage, the patient awakens from sleep with a feeling of a numb or swollen hand but with no visible

swelling. Patients sometimes note that shaking or flicking their hand stops the pain, although their hand may feel stiff during the morning. The second stage involves the symptoms being experienced during the day. The third stage occurs when there is hypotrophy or atrophy of the thenar eminence. Sensory symptoms sometimes diminish in this third stage (Table 2A).⁸⁾

In our department, surgery is considered indicated for patients with an advanced stage of CTS or when there is severe sensory disturbance. Among

Table 2 Clinical stages of carpal tunnel syndrome (A) and scored clinical questions for the diagnosis of CTS reported by Levine et al.³²⁾ (B)

A	
Stage 1	Patients usually experience symptoms at night. Common symptoms include: numbness and/or tingling in the hand, a sensation that the hand feels swollen or stiff. Patients may be woken up at night from these symptoms. Shaking the hand may bring symptom relief to some individuals.
Stage 2	Symptoms at night are also present during the day especially with repetitive activities of the hand and/or wrist. Patients may develop motor problems from weakened hand muscles such as decreased grip strength, affecting their ability to hold objects in their hands.
Stage 3	Visible atrophy of the thenar eminence muscles is present. Grip strength is diminished making functional tasks very difficult. Some patients may experience diminished sensory symptoms with increased motor symptoms.
B	
Instructions: Circle YES, NO or N/A and the score either + or –	
Has pain in the wrist woken you at night?	Yes 1, No 0
Has tingling and numbness in your hand woken you during the night?	Yes 1, No 0
Has tingling and numbness in your hand been more pronounced first thing in the morning?	Yes 1, No 0
Do you have/perform any trick movements to make the tingling, numbness go from your hands?	Yes 1, No 0
Do you have tingling and numbness in your little finger at any time?	Yes 1, No 0
Has tingling and numbness presented when you were reading a newspaper, steering a car or knitting?	Yes 1, No 0
Do you have any neck pain?	Yes 1, No 1, N/A 0
Has the tingling and numbness in your hand been severe during pregnancy?	Yes 1, No 1, N/A 0
Has wearing a splint on your wrist helped the tingling and numbness?	Yes 2, No 0, N/A 0
Total =	

A score of 3 or more has been submitted to analysis in comparison with nerve conduction studies. A score of 5 or more is recommended for use of the test as a diagnostic screening tool to replace nerve conduction studies.

the 29 patients who underwent surgery, 13 were at stage 3 with thenar eminence atrophy. Another 8 patients were being seen as outpatients for observation of other diseases (cervical spondylosis 4, cervical infarction 3, lumbar spondylosis 1). These 8 patients had had been ill for more than 2 years and had an advanced stage of CTS. In our experience, patients with severe thenar atrophy and mild sensory disturbance tend not to complain of their symptoms. Therefore, at the outpatient examination, it is important to evaluate thenar muscle atrophy so as not to overlook the presence of advanced CTS (Table 1).

Epidemiology and Risk Factors of CTS

CTS is estimated to occur in about 1–4% of the general population, with an annual incidence of up to 276/100,000 population having been reported.^{1,2,9,10)} Its more frequent presentation in women has also been noted, with the female/male distribution at two-thirds to one-third.¹⁾ The development of CTS

is also related to age. Although CTS is observed in all age groups, it occurs within a peak range of 40–60 years. Only 10% of reported cases of CTS are in patients <30 years of age.^{9,10)} The mean age of our surgical patients was 71.4 ± 8.6 years, and the CTS was most frequently recognized when they were in their seventies (fifties 2, sixties 7, seventies 10, eighties 5) (Table 1). Although the correlation between age and clinical presentation of CTS has not been clearly defined, older adults tend to present with more severe, long-term nerve entrapment, causing thenar weakness or atrophy, than in younger adults.¹¹⁾ We speculated that our surgical patients were older than reported cases because advanced-stage CTS is the main indication for surgery. It is widely considered that surgery may be ineffective in those with advanced-stage CTS, although good postoperative clinical and electrophysiological results have been reported even in extreme cases of CTS.¹²⁾

Ethnic differences in the epidemiology of CTS have also been reported. Garland et al. reported that white U.S. Navy personnel had CTS at a rate

two to three times that of black personnel in North America.¹³⁾ Nathan et al. compared CTS symptoms between Japanese and North American workers and concluded that the prevalence of CTS was much lower in the Japanese than in the American population.¹⁴⁾ Gorsche et al. investigated the incidence of CTS in a meat-packing plant. They reported that the incidences for Asian mixed, white, and other ethnicities were 12.0, 12.2, and 7.2 cases/100 person-years, respectively.¹⁵⁾ CTS appears to be rare among nonwhite South Africans, whereas Caucasians and Asians are considered to be at high risk of CTS.^{11,16)}

CTS remains an idiopathic syndrome, although certain risk factors have been associated with it. Medical risk factors can be divided into three categories: mechanical; anatomical; physiological. These three types sometimes occur simultaneously and influence each other.^{1,2)}

Mechanical factors

CTS is sometimes caused by physical occupational activities, such as repeated and forceful movements of the hand and wrist or use of hand-held, powered, vibratory tools.^{17–20)} The dominant hand is more frequently affected by CTS, although it is not uncommon for both hands involved, especially if there are constitutionally narrow canals. In addition, overuse of the nonparetic hand of stroke patients or more frequent use of the hand without a tremor in patients with Parkinson's disease may result in CTS.^{21,22)} Although our surgical cases did not involve such patients, neurosurgeons should pay attention to the occurrence of CTS when following patients with a paretic hand or hand tremor.

Anatomical factors

The carpal tunnel is narrower in some people than in others.^{23,24)} For this reason, CTS occurs more commonly in women. Anomalies such as a persistent median artery, ganglion cyst, or tumor can occupy space in the carpal canal and thus increase interstitial fluid pressure.²⁵⁾ Trauma may also cause CTS because of canal volume restriction as a result of hemorrhage, distorted anatomy, or scar formation.²⁶⁾

Physiological risk factors

CTS can be associated with a number of medical conditions, including obesity, drug toxicity, alcoholism, diabetes, hypothyroidism, rheumatoid arthritis, primary amyloidosis, and renal failure.^{1,25,27)} Rheumatoid arthritis and renal failure may lead to increased pressure in the carpal tunnel secondary to pannus formation and amyloid deposition, respectively.²⁸⁾ Drug toxicity, diabetes, and alcoholism may have

direct injurious effects on the median nerve.^{1,2,29)} Many of these risk factors for CTS coincide with those of stroke or atherosclerosis.³⁰⁾ Thus, when following chronic-phase post-stroke patients, it is important to consider the risk factors that coincide with those for CTS.

CTS can occur during pregnancy, with a reported incidence of 20–45%. Symptoms typically develop during the third trimester, vary in severity, and abate postpartum with nonsurgical management. The etiology of gestational CTS remains uncertain, but symptom onset is conceivably related to fluid retention. Conservative measures are appropriate because symptoms resolve after delivery in most women with pregnancy-related CTS.³¹⁾

Diagnosis of CTS

The optimal diagnostic criteria for CTS remain uncertain. A thorough history and physical examination are key to making the diagnosis, but their results should be confirmed by electrophysiological testing and imaging evaluation, including magnetic resonance (MR) imaging and ultrasonography (US).^{1,2,32)}

There are also some provocative tests for CTS (Table 2B), among which the Phalen and Tinel tests are most commonly used in the clinical setting. The sensitivity of the Phalen test is in the range of 67–83%, and the specificity is 40–98%.³³⁾ The Tinel test has a sensitivity in the range of 48–73% and specificity of 30–94%.³³⁾

The flick sign is not strictly a provocative test. It entails asking patients what they do when they experience symptoms in the hand during the night. If the patient demonstrates a “shaking out” movement by flicking the wrists, the flick sign is positive. The flick sign is reported to show 93% sensitivity and 95% specificity for CTS.^{1,2,34)}

It is important to understand the sensitivity and specificity of provocative tests when diagnosing CTS. In other words, CTS cannot be ruled out simply because provocative tests are negative, nor can they be diagnosed simply because provocative tests are positive.

Levine et al.³⁵⁾ reported a scored questionnaire that is useful during the initial assessment of patients with CTS (Table 3A). Validated by Kamath and Stothard,³⁶⁾ the results of the questionnaire showed a sensitivity of 85% compared with 92% for nerve conduction studies (NCSs). For the initial assessment of whether a patient presenting with dysesthesia in the fingers should undergo surgery, they recommended that a scored questionnaire replace NCSs to save time, personnel, and cost.³⁶⁾

Table 3 Sensitivity and specificity of provocative tests for CTS (A) and electrophysiological classification of the severity of CTS defined by the American Association of Electrodiagnostic Medicine (B)

A			
Provocative test	Maneuver	Sensitivity (%)	Specificity (%)
Tinel's test	Percussion over the median nerve at the wrist and palm.	23–60	64–87
Phalen's test	The wrist is allowed to drop into 90 degrees of flexion under the influence of gravity for 30–60 seconds.	67–83	40–98
Reverse Phalen's test	Maintain full wrist and finger extension for two minutes.	57	78
Durkan's test	Pressing on carpal tunnel with the examiners thumbs or a device designed to apply a standard amount of pressure.	64	83
The hand elevation test	The hands are held above the head for two minutes.	75.5	98.5
The tourniquet test	Apply a blood pressure cuff, inflated to between systolic and diastolic pressure. This obstructs venous return from the arm.	21–59	36–87
B			
Negative CTS	Normal findings on all tests including comparative and segmental studies.		
Minimal CTS	Abnormal findings only on comparative or segmental tests.		
Mild CTS	SCV slowed in the finger-wrist tract with normal DML.		
Moderate CTS	SCV slowed in the finger-wrist tract with increased DML.		
Severe CTS	Absence of sensory response in the finger-wrist tract with increased DML.		
Extreme CTS	Absence of thenar motor response.		

CTS: carpal tunnel syndrome, DML: distal motor latency, SCV: sensory nerve conduction velocity.

NCSs

Prolonged motor and sensory latencies of the median nerve and reduced sensory and motor conduction velocities in properly performed NCSs are accepted as diagnostic criteria for CTS. Some authors, however, have recently reported that optimal diagnostic criteria remain uncertain.³⁷⁾ Many factors may influence the amplitude and latency of an individual nerve, giving a false-positive or false-negative result. Such factors include age, sex, finger diameter, concurrent systemic disease, obesity, and temperature.³⁸⁾ Applying a NCS as a relative comparison of two nerve segments—the median nerve and another nerve segment that does not travel through the carpal tunnel—could be useful. This technique is the most sensitive and accurate, with a sensitivity of 80–92% and specificity of 80–99%.³⁹⁾ The electrophysiological classification of the severity of CTS has been defined by the American Association of Electrodiagnostic Medicine (AAEM) (Table 3B).¹⁾

If CTS was suspected, we first applied the Levine scale. A score of ≥ 3 indicates that an analysis with nerve conduction studies is recommended. When the score is ≥ 5 , use of this test is recommended as a diagnostic screening tool to replace NCS. All of our patients were subjected to NCS and MRI.

All of our surgical patients had a Levine scale score of ≥ 3 , and the distal motor latency of the median nerve was confirmed to be prolonged compared with the latencies of the ulnar nerve, which were moderate, severe, or extreme according to AAEM grade (Table 3B). Recent clinical studies, however, have demonstrated that subjective symptoms of CTS do not correlate well with NCS data.³²⁾ In fact, patients with mild to moderate median nerve dysfunction tend to report significantly more pain than those with severe median nerve dysfunction. In addition, $>10\%$ of CTS patients with significant symptoms present with normal electrophysiology.³⁴⁾

MR imaging

MR imaging provides good soft tissue images and is an excellent technique for identifying rare pathological causes of CTS such as a ganglion, hemangioma, or bone deformity, the presence of which may alter surgical intervention.^{1,2)} Proximal swelling, flattening, and high signal intensity of the median nerve on a T₂ image and increased bowing of the transverse carpal ligament (TCL) are regarded as characteristic findings for idiopathic CTS. Furthermore, sagittal images are useful for identifying the site accurately and allow determination of the severity of nerve compression.⁴⁰⁾

Swelling of the median nerve was apparent in 13 of the 29 operated patients (Table 1). Further study is needed to determine the association between these MRI findings and clinical symptoms. What is most important, however, is that the diagnostic sensitivity of CTS using MRI is 96%, whereas its specificity is extremely low at 33–38%.¹⁾ CTS cannot be diagnosed simply because MRI reveals nerve compression.

US

US is a noninvasive, easily performed procedure for assessing the median nerve morphology. MR imaging can better show the carpal tunnel margins, retinacular attachments, and nerve edema. Nevertheless, the main benefits of US over MRI in the diagnosis of CTS are the ease of availability, shorter examination time, and reduced cost.^{1,2)} There have been many reports on the use of US for diagnosing CTS. Previously studied diagnostic standards described measuring the cross-sectional area of the median nerve and calculating the flattening ratio using US.^{41–43)} A lack of consensus remains, however, regarding the most appropriate median nerve cross-sectional area threshold for establishing the diagnosis of CTS. Kim et al. measured cross-sectional areas of not only the median nerve but also the carpal tunnel and introduced the nerve/tunnel index. They concluded that the nerve/tunnel index is unaffected by body indices or sex and thus may be a useful, objective standard for diagnosing CTS.⁴⁴⁾

Differential Diagnosis of CTS

When diagnosing CTS, it is important to remember that many other conditions produce similar symptoms. A thorough physical examination along with an accurate patient history is an important first step toward a correct diagnosis.^{1,2)} If symptoms include neck pain and Spurling's sign is positive, cervical spine pathology should be included in the differential diagnosis.

Another important point is that bilateral CTS is common. Padua et al. reported that the incidence of bilateral clinical CTS was 87%, and follow-up of patients with unilateral CTS showed that contralateral symptoms developed in most cases.⁴⁵⁾ If cervical myelopathy is suspected, in which symmetrical sensory disturbance is commonly recognized, CTS should be carefully discriminated.⁴⁶⁾ If there is tenderness at the proximal forearm and sensory changes are found in the palm and the first three fingers, pronator teres syndrome should be also considered.⁴⁷⁾ Concomitant ulnar or

cubital tunnel syndrome should be considered if signs include first dorsal interosseous weakness or tingling in the fourth and fifth digits.^{1,2)} Raynaud's phenomenon—vibration white finger—should be considered if the patient has a history of exposure to cold temperatures or vibration.⁴⁸⁾ Osteoarthritis of the metacarpophalangeal joint or wrist should also be considered if joint pain, pain experienced during motion, or radiologically apparent arthritis is recognized.⁴⁹⁾ Multiple sclerosis, syringomyelia, and brachial plexus injuries should also be excluded, although they are less common neurological conditions.^{1,2)}

Natural Course of CTS

Before selecting the best treatment option, it is important to assess the course of untreated CTS. There are, however, only a few reports on the natural course of CTS. Padua et al. prospectively followed 274 untreated hands with idiopathic CTS. During the observation period (10–25 months), symptom alleviation was observed in 35%, and the symptoms did not worsen in 45%. However, 68% of the patients had difficulty participating in their hobbies and working, and 32% of patients found it necessary to change their occupation and stop their hobbies.⁵⁰⁾ A good prognosis was associated with a short duration of symptoms, young age, and a negative Phalen sign. A report from Japan stated that natural improvement was seen in 30% of patients.⁵¹⁾

Treatment

Treatment of CTS can be broadly categorized into nonsurgical and surgical methods. Treatment decisions on CTS are based on the severity of the symptoms. Treating CTS with noninvasive options has been recommended first, with surgery considered only if noninvasive treatment proved ineffective.⁵²⁾ Recent literature, however, shows a trend toward recommending early surgery with or without median nerve denervation.⁵³⁾ Thus, more research is needed to determine the best treatment for patients with mild to moderate symptoms and to identify which patients should forego conservative management and undergo surgery as the initial treatment.⁵⁴⁾

Nonsurgical treatment

A variety of nonsurgical treatment options are available, including vitamins B₆ and B₁₂, nonsteroidal anti-inflammatory drugs, steroids, splinting, and exercise, among others. The currently available

literature suggests that splinting and oral or injected corticosteroids may be significantly effective for alleviating the symptoms of CTS, although they often provide only short-term relief.⁵⁵⁾

Splinting is commonly prescribed to minimize motion at the wrist and subsequently decrease symptoms because CTS has been associated with forceful, repetitive hand and wrist activity. Splinting may also be helpful for the common symptom of nocturnal paresthesia by limiting prolonged periods of excessive wrist flexion or extension during sleep. Intercarpal injections of corticosteroid are commonly considered to relieve the early symptoms of CTS, and the response may predict the response to carpal tunnel release.⁵⁶⁾ To avoid median nerve injury, injection into the medial palmaris longus tendon is recommended.⁵⁶⁾ A different steroidal treatment approach is the use of oral steroids (e.g., prednisolone), which have proven to be effective in the short term.⁵⁷⁾

Surgical treatment

There are two methods used for surgical treatment of CTS: open release and endoscopic release. Regardless of which treatment option is selected, the most important action is complete division of the TCL.

Traditionally, open carpal tunnel release (OCTR) has been done through a relatively large 4- to 5-cm longitudinal incision beginning at Kaplan's cardinal line distally and extending proximally beyond the distal wrist crease.^{5,54,58)} OCTR is comparatively easy to perform, and good symptomatic relief with a low complication rate is achieved in the majority of patients.^{1,2,5,58)} Longer incisions, however, may result in longer healing times and increased scar tenderness,^{5,59)} which can affect patient satisfaction even after successful treatment of the pathology.⁶⁰⁾ Therefore, the size of this incision has gradually decreased over time, and most surgeons today perform OCTR through a 2- to 4-cm incision.⁵⁾ Several modifications regarding the length, location, and shape of the incision for OCTR have been reported.^{59–63)}

Long-term nerve compression may result in fibrotic changes, which generate further mechanical pressure and, ultimately, CTS. In such cases, longitudinal epineurotomy of the nerve has been suggested as an option that could convey greater pressure release, more prominent nerve volume recovery, and better outcomes.^{64,65)} Consequently, this method has been widely used, although a recent randomized controlled trial failed to demonstrate additional benefits of epineurotomy on the electrophysiological and clinical outcomes.⁶⁶⁾

Complications such as postoperative bleeding and infection seldom occur with OCTR, although several rare complications have been recognized. Early complications include the incomplete release of the TCL, the injury to the median or ulnar nerve, the injury to the palmar cutaneous or recurrent motor branch of the median nerve, and injury to the superficial palmar arch or ulnar artery.^{1,2,54)} Late complications include scar tenderness, loss of grip strength, pillar pain, and (rarely) reflex sympathetic dystrophy.

Pillar pain (with an incidence of 6–36%) is characterized by pain or tenderness in the thenar or hypothenar eminence or radial and ulnar tenderness. The exact etiology of pillar pain is not clear. A possible etiology involves alteration of the carpal arch structures, division of the terminal branches of the palmar cutaneous nerve, and scar formation between the divided transverse carpal ligament and skin.⁶⁷⁾

Endoscopic carpal tunnel release (ECTR) was developed by Okutsu and colleagues and reported in 1986.⁶⁸⁾ Endoscopic surgery uses a thin tube with a camera attached to the endoscope. The endoscope is guided through a small incision in the wrist (single-portal technique) or at the wrist and palm (two-portal technique). The endoscope allows the physician see structures in the wrist such as the TCL. ECTR release is sometimes favored over OCTR because it allows preservation of the superficial fascia and adipose tissue over the flexor retinaculum, which allows faster recovery of grip strength, less scar tenderness and pillar pain, and earlier return to work. It is associated with an increased risk of nerve or artery injury, however, because of limited visualization.⁵⁸⁾ ECTR is also associated with high costs and requires additional equipment. The decision to perform ECTR instead of OCTR seems to be guided by the surgeon's experience and the patient's preference.

All of the CTS operations in our department were performed with OCTR through a 2- to 4-cm incision without epineurotomy. No significant complications were observed, and good symptomatic relief was achieved in all patients. Severe pain tended to be alleviated within several days after surgery. Relatively mild numbness, however, tended to diminish only gradually, within a few months. Scar tenderness is common during the subacute recovery phase following carpal tunnel release. Some patients with mild numbness, therefore, were not satisfied with the results of surgery within several months. What is most important for the surgeon here is to educate the patient

Table 4 Summary of what neurosurgeons need to know to manage CTS correctly**Optimal diagnostic criteria still remain undetermined.**

(A thorough history and physical examination are key in making the diagnosis, which should be confirmed by electrodiagnostic testing and image examination.)

The area of dysesthesia does not necessarily restricted in area of distal median nerve.

(CTS cannot be ruled out simply because dysesthesia spread beyond the area of distal median nerve.)

The sensitivity and specificity of provocative tests should be correctly understood.

(CTS cannot be ruled out simply because provocative tests are negative, nor can they be diagnosed simply because provocative tests are positive. Scored questionnaire by LeVive was useful.)

Bilatera CTS is common.

(If cervical myelopathy is suspected, in which symmetrical sensory disturbance is commonly recognized, CTS should be carefully discriminated.)

Subjective symptoms of CTS do not correlate well with NCS data, and over 10% of CTS patients with significant symptoms present with normal electrohysiology.

(CTS cannot be ruled out simply because NCS data do not correlate with symptoms.)

A sensitivity of diagnosis of CTS using MRI is 96%, however, its specificity is extremely low at 33–38%.

(Diagnosis cannot be made simply because nerve compression is revealed in imaging modality.)

Many of risk factor of CTS coincide with that of the stroke or atherosclerosis.

(In case of following up chronic phase post-stroke patients, it is important to check up risk factors coinciding with CTS.)

Patients with severe thenar atrophy and mild sensory disturbance tend not to complain of their symptoms.

(In outpatient examination, checking up thenar muscle atrophy is important not to overlook CTS of advanced stage.)

Overuse of the nonparetic hand of stroke patients or more frequent use of the hand without a tremor in patients with Parkinson's disease may result in CTS.

(Attention should be paid for the occurrence of CTS when following up patients with paretic hand or hand tremor.)

Patients with mild numbness tend not to be satisfied within several months after surgery.

(What is most important for surgeon is to educate the patient preoperatively about the postoperative course of symptom and scar tenderness.)

preoperatively about the postoperative course of symptoms and scar tenderness.

Thus, we have conducted a literature review to summarize current knowledge on the clinical, pathogenetic, and therapeutic aspects of CTS. Based on this review and our experience, what neurosurgeons need to know to manage CTS correctly is summarized in Table 4.

Illustrative Cases

Case 1: CTS was diagnosed in a patient who was concerned about cerebral infarction recurrence.

A 75-year-old man suffered right and left cerebral infarctions at 5 and 3 years earlier, respectively (Figs. 1A and 1B). During both events, he felt numbness in the bilateral upper limbs but without sequelae. Currently, with a 3-week history of numbness over the bilateral thumb, forefinger, middle finger, and

half of the ring finger (right < left), he consulted our department because he was concerned about possible recurrence of a cerebral infarction or other possible cerebral disease. Brain MR imaging confirmed that there was no acute-phase cerebral infarction. Because of the area of dysesthesia, CTS was suspected. MR imaging of the carpal tunnel revealed compression of the median nerve (Figs. 1C and 1D). NCSs showed prolonged distal motor latencies (DMLs) of the median nerve. In addition, he underwent a motor comparison technique that recorded the median compound muscle action potential (CMAP) latency from the second lumbrical and the ulnar CMAP latency from the interossei. It demonstrated prolonged DML of the median nerve compared with ulnar nerve (Figs. 1E and 1F). Based on these findings, bilateral CTS was diagnosed and left OCTR was performed. His sensory disturbance in the left hand was alleviated.

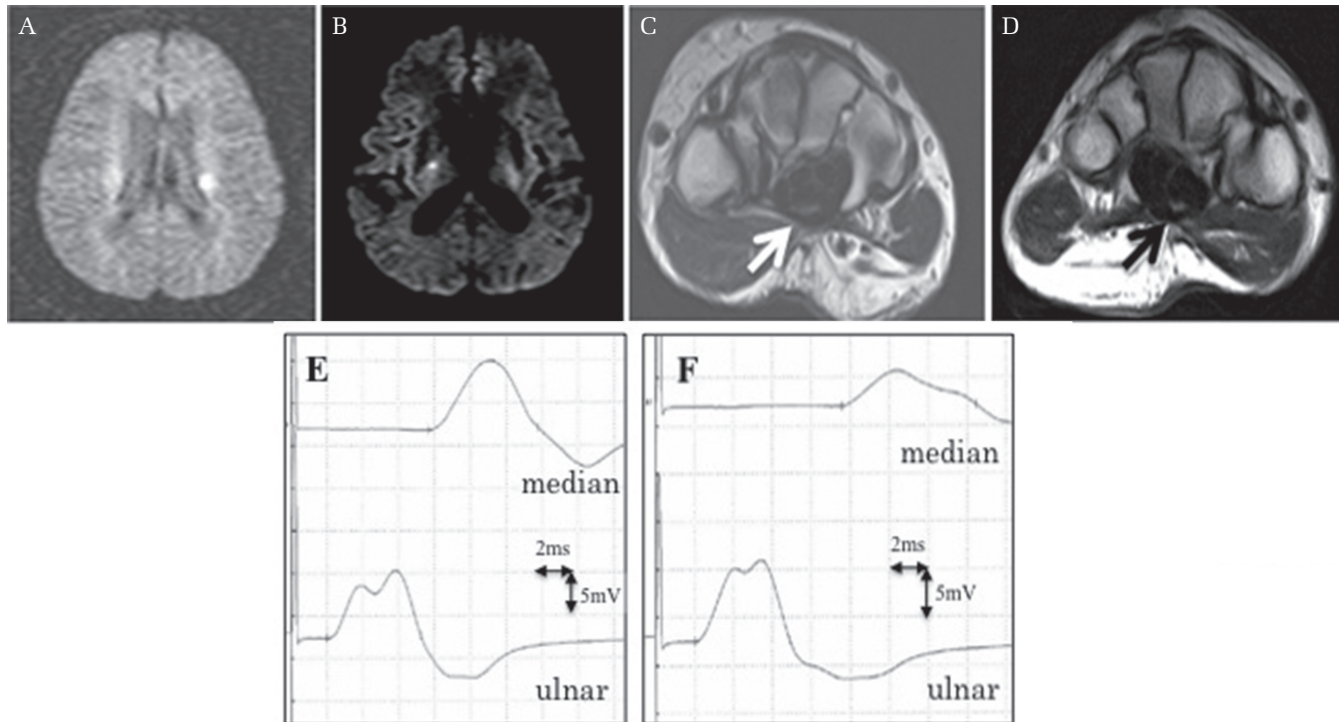


Fig. 1 Results of the preoperative examination of case 1. Diffusion-weighted magnetic resonance (MR) images 5 years (A) and 3 years (B) before the current presentation. They show lacunar infarctions in the *left* and *right* cerebral white matter, respectively. Axial images of bilateral T_2 -weighted MR images of the carpal tunnel show increased signal intensity, indicating median nerve compression (C: *right*, D: *left*). Nerve conduction study with a motor comparison technique records the median component motor action potential (CMAP) latency from the second lumbrical (*top* tracing) and the ulnar CMAP latency from the interossei (*bottom* tracing). There is prolonged distal motor latency of the median nerve compared with that of the ulnar nerve (E: *right*, F: *left*).

Case 2: CTS was diagnosed in a patient with cervical spondylosis who had been treated conservatively and followed.

An 84-year-old man with a 5-year history of numbness of the bilateral hands had been diagnosed with cervical spondylosis at other hospital. He later consulted our department because the numbness in the bilateral hands (right > left) had worsened over several weeks. Cervical MRI revealed cervical spondylosis between C4 and C7 (Figs. 2A and 2B). In addition, concomitant CTS was suspected because his sensory disturbance worsened at night and was distributed in the radial sides of the bilateral hands. MR imaging for CTS of the right hand showed flattening and increased signal intensity of the median nerve on T_2 -weighted images (Figs. 2C and 2D). NCSs showed prolonged DMLs of the median nerve. He also underwent a motor comparison technique that recorded the median CMAP latency from the second lumbrical and the ulnar CMAP latency from the interossei. It demonstrated prolonged DML of the median nerve compared with that of the ulnar

nerve (Fig. 2E). Based on these findings, CTS was diagnosed, and right OCTR was performed. The sensory disturbance in his right hand was alleviated.

Conclusion

Neurosurgeons frequently encounter patients with CTS because of its high prevalence and the fact that its symptoms are similar to those of other diseases (e.g., cervical spinal disease, ischemic or neoplastic cerebral disease). This review of the recent literature has provided an overview of this common condition. Understanding the clinical features and pathogenesis and being aware of the available treatments for CTS is important for proper management of patients with this disease.

Conflicts of Interest Disclosure

The authors have no personal, financial, or institutional conflicts of interest regarding any of the drugs, materials, or devices in this article. The authors who

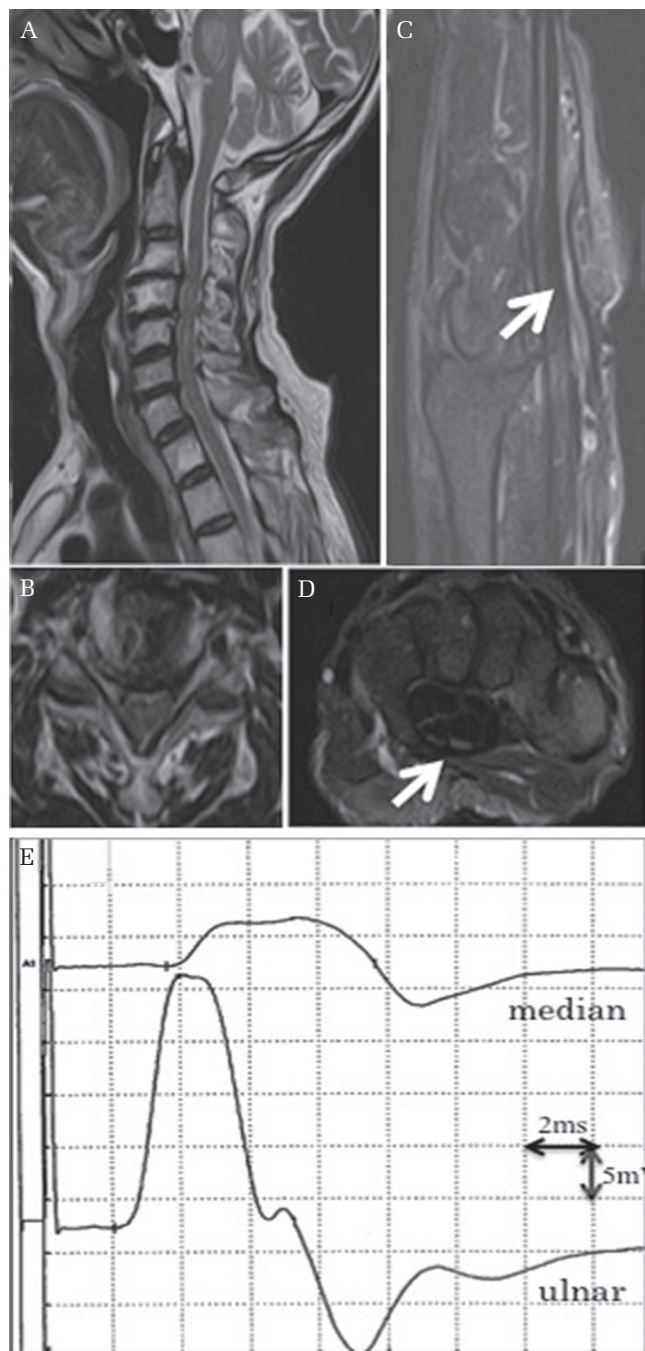


Fig. 2 Results of the preoperative examination of case 2. T₂-weighted MR image of the cervical spine shows cervical spondylosis causing compression (with high signal intensity) of the spinal cord (A: sagittal image, B: axial image at the level of C5/6). T₂-weighted image of the right carpal tunnel shows flattening of the median nerve (C: sagittal image, D: axial image of proximal carpal tunnel, E: axial image of the distal carpal tunnel). A motor comparison technique shows median CMAP latency from the second lumbrical (*upper*) and ulnar CMAP latency from the interossei (*lower*). The distal motor latency of the median nerve was prolonged compared with that of the ulnar nerve in the right hand (E).

are members of the Japan Neurosurgical Society (JNS) have registered online and filled out the Self-reported COI Disclosure Statement Forms through the JNS members' website.

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