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Review Article

Carpal Tunnel Syndrome: Current Review

Vijay Sardana[1*], Piyush Ojha[2]

[1*]Senior Professor and Head, [2]Senior Resident, Deparment of Neurology,
Government Medical College and Allied Hospitals, Kota, Rajasthan, INDIA.

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***Correspondence to:**
Dr. Vijay Sardana
10-D, Raj Bhawan Road,
Civil line, Nayapura
Kota, Rajasthan.
vsard13@gmail.com

ABSTRACT

Carpal tunnel syndrome has been considered to be one of the most common disorders of the upper extremities and the most common and prevalent surgically correctable compression neuropathy. The typical symptoms, produced by median nerve compression at wrist, lead to pain which is classically nocturnal, paresthesia, weakness in hand and digits in Median nerve distribution and may lead to thenar atrophy in advanced cases. Although majority of cases are idiopathic, various systemic disorders and occupational factors may also lead to similar symptoms. The diagnosis is primarily clinical, based on detailed patient history and physical examination which can be supported and confirmed by electrophysiological studies. Treatment is primarily symptomatic. Various treatment modalities ranging from observation and nocturnal splinting to surgical treatment, both open and endoscopic procedures, have been tried depending primarily on the severity of involvement. Recent studies have shown both open and endoscopic procedures to be equally effective with fewer complications with endoscopic surgeries.

KEYWORDS: Carpal Tunnel Syndrome, Diagnosis, Endoscopic Carpal Tunnel release, Entrapment Neuropathy, Median Nerve compression.

INTRODUCTION

Carpal tunnel syndrome is one of the most common disorder of the upper extremities and the most prevalent compression neuropathy[1]. Brain (1947) and George Phalen (1950) have been responsible for the recognition of Carpal tunnel syndrome (CTS) as a disease entity; however the term "Carpal tunnel syndrome" was first used by Kremer et al. in 1953. First ever Carpal tunnel release was performed by Herbert Galloway in 1924 and Phalen (1957) holds the credit for popularizing the use of steroids.

EPIDEMIOLOGY

About 3% of US adults are affected, mostly between the ages of 40 and 60 years[2]. Women are almost 3 times more likely than men to develop CTS[1]. The exact epidemiology in Indian population is unknown. Various associated risk factors include diabetes, hypothyroidism, rheumatoid arthritis, pregnancy, obesity, family history, and trauma. A history of hand-related repetitive motions also increases the risk[3, 4]. Occupations that require use of hand-operated vibratory tools or repeated and forceful movements of the hand/wrist (such as assembly work and food processing or packaging) have also been associated with CTS[5].

ANATOMY

The carpal tunnel is defined as the space deep to the Transverse Carpal Ligament, which extends ulnarly from the hook of hamate and triquetrum to scaphoid and trapezium radially, and is bordered posteriorly by the carpal bones. The Carpal tunnel contains the median nerve and nine flexor tendons: the Flexor Digitorum Profundus (FDP) and Flexor Digitorum Superficialis (FDS) tendons to the index, middle, ring and small finger,along with the Flexor Pollicis Longus (FPL) tendon.

The Transverse carpal ligament (TCL) has a variable depth of 10 to13mm[6] and a normal pressure of 2.5 mmHg within the carpal tunnel[7]. Rydevik[8] demonstrated that external compression of 20-30mmHg induces a slower epineurium venule flow which can progress to complete intraneural flow stasis if the pressure increases to 80mmHg. It has been observed that that the critical pressure level for microvessels obliteration and consequent ischemia with total nerve conduction block is around 40-50mmHg[9].

The Median nerve, lying most superficial within the canal, enters the space in the midline or just radial to it and divides into terminal branches at the distal end of the Transverse Carpal Ligament.

The unyielding nature of fibro-osseous tunnel makes Median nerve susceptible to compression. Aberrant muscles like Palmaris profundus, lumbricalis, and/or muscles bellies can further narrow the tunnel volume.

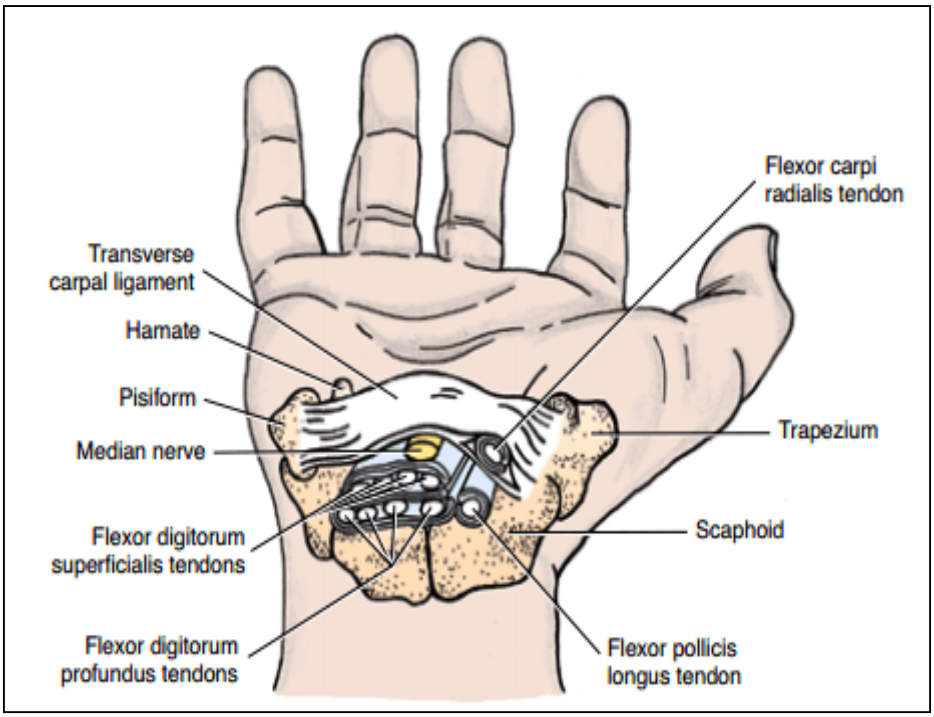

Figure 1: Anatomy of Carpal Tunnel (http://epomedicine.com/wp-content/uploads/2014/05/carpal-tunnel.png)

Local Causes	Systemic Causes
1. Acute form (fracture, crushing hand injury, burn, hemorrhage, median artery thrombosis, infection)	1. Pregnancy
2. Distal radius malunion	2. Endocrinopathy (Diabetes, hypothyroidism)
3. Carpal Canal stenosis	3. Congestive heart failure
4. Anomalous structures (Palmaris profundus, reversed Palmaris longus, anomalous branch of radial artery)	4. Collagen and autoimmune diseases (RA, gout, scleroderma)
5. Space occupying lesions (ganglion, lipoma, fibroma etc.)	5. Amyloidosis
	6. Alcoholism
	7. Myeloma
	8. Obesity
	9. Storage disorders (Mucopolysacharidosis etc.)

Table 1: Causes of Carpal Tunnel Syndrome

ETIOPATHOGENESIS

The onset of symptoms can be either acute or insidious. Acute presentation is characterized by rapid and sustained increase in pressure within carpal tunnel which requires urgent decompression.

The causes for acute presentation include wrist trauma, infection, hematoma and high pressure injections. Most of the cases have an insidious presentation with chronic symptoms. Various anatomic factors which behave as space occupying lesions also play a role in the symptoms. Various systemic factors constrict the already slender space in carpal tunnel either by increasing the interstitial tissue pressure or causing pathological material deposition.

Carpal Tunnel Syndrome complicates approximately 45% of pregnancies, developing in third trimester which often improves with conservative treatment post-partum[10]. Various retrospective studies have linked use of keyboards and occupational vibratory exposure to CTS[11].

DIAGNOSIS

Carpal tunnel syndrome is primarily a clinical diagnosis. The most common complaint by patients is "Nocturnal Acroparesthesia", which is a painful tingling sensation in the distribution of Median nerve, which may even disturb sleep. Patients are often awakened by numbness or tingling with an intense desire to shake out the affected hand (Flick sign[12]); however daytime paresthesias may also occur. Patients with severe CTS may have paradoxically less pain, because of increasing sensory loss[13]. Certain positions or activities may trigger paresthesias in daytime such as the act of sewing, pray position, holding the phone or a book while reading. Patients may not be able to exactly localize the paresthesias initially in a large number of cases, thus relating it to whole hand and back of the hand as well as to the palmar surface, but when subjected to provocative maneuvers to reproduce symptomatology, often localise paresthesias over the radial three fingers and to the radial side of the fourth finger. Chronic delayed presentations

may be in form of numbness in fingers, grip weakness and reduced finger dexterity. In the late stages of the disease, examination may reveal sensory loss in Median nerve distribution; with sparing of Thenar eminence (sensory loss in the thenar eminence indicates a lesion proximal to the carpal tunnel, rather than CTS itself[14]). Weakness of thumb abduction and opposition may occur, along with Thenar eminence atrophy, in advanced stages[22]. Bilateral CTS is common; although the symptoms may be more in one hand.

A detailed physical examination including cervical spine and neurological examination of the upper limb should be done to exclude CTS mimics.

Various Provocative tests for CTS[15] have been described.

Phalen's Test

When asked to hyper-flex the wrist and hold the position for 60 seconds to increase pressure on the median nerve, a positive test is indicated by the onset of pain or paresthesias. A meta-analysis found the sensitivity and specificity of a positive Phalen's sign to be 68% and 73%, respectively[16].

Tinel's test

When the volar surface of the patient's wrist is tapped, either just proximal to or on top of the carpal tunnel, onset of pain or paresthesias in the Median nerve distribution indicates a positive result. This test is less sensitive than Phalen's maneuver, but has a similar specificity[17].

The Median nerve (Durkan's) compression test

Pain or paresthesias develop within 30 seconds of applying pressure over the transverse carpal ligament.

The Hand elevation test

Pain or paresthesias develop when the patient raises both hands overhead for 60 seconds.

Combining results of provocative maneuvers may increase sensitivity and specificity. Positive results in both the Phalen's and Median nerve compression tests, for example, have a collective sensitivity and specificity of 80% and 92%, respectively[17].

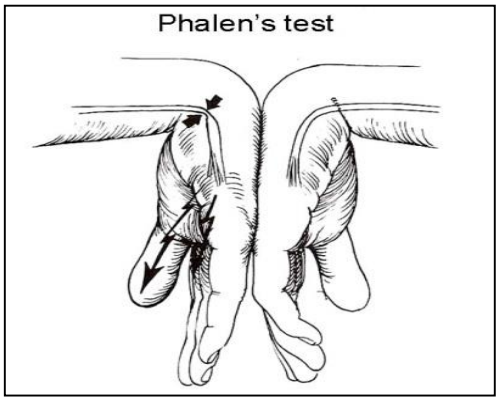

Figure 2: Phalen's Test
(http://www.boomnc.com/wp-content/uploads/carpal-tunnel-phalens.jpg)

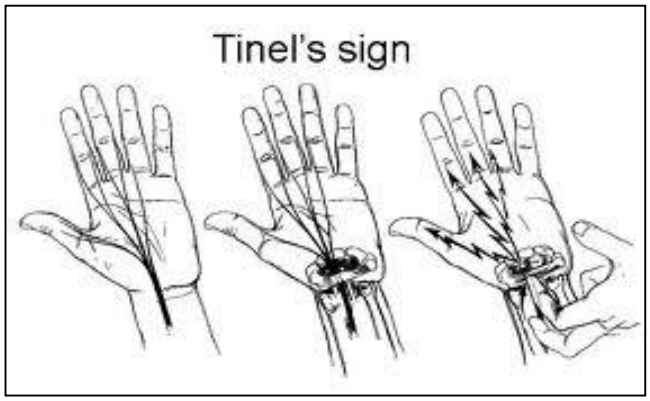

Figure 3: Tinel's Test.
(http://www.geronguide.com/gallery/var/albums/Carpal-Tunnel-Syndrome/carpal-tunnel-syndrome-diagnosis-01.jpg?m=1355678187)

DIAGNOSTIC STUDIES

Electrodiagnostic Testing (EDS)

The goals of an electrodiagnostic examination are to localize the lesion; to show the involvement of motor, sensory fibers, or both; to define the physiologic basis (axonal loss, demyelination) and the severity of the lesion (degree of axonal loss, the continuity of axons), as well as the time course of the lesion (evidence of reinnervation or of ongoing axonal loss).

The main objective of the neurophysiological assessment of a patient with supposed CTS is to confirm the clinical suspicion of median nerve compression at wrist suggested by history and clinical examination. Motor and sensory nerve conduction velocity of the median nerve and other nerves along with the needle EMG examination of one or several muscles also allows the diagnosis of other coexisting diseases often associated with CTS such as radiculopathies, plexopathies etc.

The neuro physiological studies may also allows quantification of the severity and the type of nerve lesion in the preoperative work-up of a CTS patient and may be of value in medicolegal cases if the patient has unsatisfactory improvement after the intervention.

Results of the nerve conduction studies are compared to age-dependent normal values and to results from other nerves on either the same or the contralateral hand. In a 2002 systemic review, the sensitivity of NCS for CTS was 56% to 85% and the specificity was 94% to 99%[18].

The American Academy of Orthopedic Surgeons (AAOS) recommends EDS when CTS surgery is being considered and may also be used after surgery, to verify neurologic improvement.

Imaging

Routine radiographs are normal in majority of cases except those with post traumatic or arthritic cause for CTS. MRI and ultrasonography may be helpful in measuring differing canal size and to define pathology in

Table 2: Diagnostic tests for Carpal Tunnel Syndrome (CTS)*

Test	How Performed	Condition measured	Positive result	Interpretation of Positive Result
Phalen's test	Patient places elbows on table, forearms vertical, wrists flexed	Paresthesias in response to position	Numbness or tingling in Median nerve distribution within 60s	Probable CTS (sensitivity 0.75; specificity 0.47)
Percussion test (Tinel's)	Examiner lightly taps along median nerve at the wrist, proximal to distal	Site of nerve lesion	Tingling response in fingers at site of compression	Probable CTS if response is at the wrist (sensitivity 0.60; specificity 0.67)
Carpal tunnel compression test	Direct compression of median nerve by examiner	Paresthesias in response to pressure	Paresthesias within 30 sec	Probable CTS (sensitivity 0.87; specificity 0.90)
Hand diagram	Patient marks sites of pain or altered sensation on outline diagram of the hand	Patient's perception of site of nerve deficit	Signs on palmar side of radial digits without signs in palm	Probable CTS (sensitivity 0.96; specificity 0.73); negative predictive value of a negative test = 0.91
Hand-volume stress test	Measure hand volume by water displacement; repeat after 7-min stress test and 10-min rest	Hand volume	Hand volume increased by 10 ml or more	Probable Dynamic CTS
Direct measurement of carpal tunnel pressure	Wick or infusion catheter is placed in carpal tunnel; pressure is measured	Hydrostatic pressure while resting and in response to position or stress	Resting pressure of 25 mm Hg or more (this value is variable and may not be valid in and of itself)	Hydrostatic compression at wrist is probable cause of CTS
Static two-point Discrimination	Determine minimum separation of two points perceived as distinct when lightly touched on palmar surface of digit	Innervation density of slowly adapting fibers	Failure to discriminate points more than 6 mm apart	Advanced nerve dysfunction
Moving two-point Discrimination	As above, but with points moving	Innervation density of quickly adapting fibers	Failure to discriminate points more than 5 mm apart	Advanced nerve dysfunction
Vibrometry	Vibrometer head is placed on palmar side of digit; amplitude at 120 Hz increased to threshold of perception; compare median and ulnar nerves in both hands	Threshold of quickly adapting fibers	Asymmetry with contralateral hand or between radial and ulnar digits	Probable CTS (sensitivity 0.87)
Semmes-Weinstein monofilament test	Monofilaments of increasing diameter touched to palmar side of digit until patient can tell which digit is touched	Threshold of slowly adapting fibers	Value greater than 2.83 in radial digits	Median nerve impairment (sensitivity 0.83)
Distal sensory latency and conduction Velocity	Orthodromic stimulus and recording across wrist	Latency and conduction velocity of sensory fibers	Latency greater than 3.5 msec or asymmetry greater than 0.5 msec compared with contralateral hand	Probable CTS
Distal motor latency and conduction velocity	Orthodromic stimulus and recording across wrist	Latency and conduction velocity of motor fibers of median nerve	Latency greater than 4.5 msec or asymmetry greater than 1.0 msec	Probable CTS
Electromyography	Needle electrodes placed in muscle	Denervation of thenar Muscles	Fibrillation potentials,sharp waves, increased insertional activity	Very advanced motor median nerve compression

* adapted from Szabo RM, Madison M: Carpal tunnel syndrome. Orthop Clin North Am 1992 ;23: 105

uncommon cases like fatty infiltration of median nerve, bursitis, and demonstration of neuroma or other space occupying lesions.

Imaging usually shows flattening of nerve at the level of hook of hamate. Imaging methods can be of use in recurrent CTS after surgical release to look for real canal widening, inflammation, incomplete resection of ligament, scarring etc.

Thus, AAOS does not currently recommend the routine use of ultrasound or MRI in the diagnosis of CTS.

Table 3: Summary of Electrodiagnostic tests for the diagnosis of Carpal Tunnel Syndrome

1. Distal Median Motor Latency > 4.4 ms
2. Difference between distal motor latency of Median and Ulnar nerves > 1.1 ms
3. Difference between distal Sensory latency of Median and Ulnar nerves > 0.2 ms
4. Difference between median and ulnar sensory latencies on stimulating fourth digit and recording from wrist at equal distance > 0.2 ms
5. Difference between median and radial sensory latencies on stimulating thumb and recording from wrist at equal distance > 0.4 ms
6. Palm wrist conduction : Difference between median and ulnar sensory latencies across 8 cm > 0.4 ms

Table 4 : CTS Mimics

- Median nerve contusion
- Cervical radiculopathy
- Thoracic outlet syndrome
- Pronator syndrome
- Idiopathic brachioplexitis (Parsonage-Turner syndrome/ Neuralgic amyotrophy)
- Intracranial neoplasm
- Multiple sclerosis
- Cervical syringomyelia
- Pancoast tumor
- Peripheral nerve tumor (schwannoma, hamartoma, etc.)
- Lower trunk brachial plexopathy
- Ulnar neuropathy
- Radial neuropathy
- Generalized neuropathy (diabetes/mononeuritis multiplex)
- Churg-Strauss syndrome

MANAGEMENT

Management options for CTS range from non-surgical measures to steroid injections to surgical carpal tunnel release including open as well as endoscopic methods which is determined by the clinical and electrophysiological severity of involvement, chronicity of symptoms and individual patient choices.

Non-surgical Measures

Multiple nonsurgical options are available, but the best evidence supports use of splints, steroid injection, and oral steroids. Splinting or steroids alone may bring long-term relief in mild to moderate cases[19]; in fact, about a third of mild cases improve spontaneously[20].

Conservative therapy may also be useful in patients not willing for surgery or cases of transient CTS (pediatric patients, pregnancy, hypothyroidism etc.).

Most conservative treatments begin providing relief within 2 to 6 weeks and reach the maximal benefit at 3 months[20]. Alternative management approach can be considered if there is no response after 6 weeks.

Wrist immobilisation during night and intermittently during day produces relief in up to 80% patients within days. Splints, particularly useful in patients who have a positive Phalen's test, work primarily by maintaining MCP joint in neutral position keeping the lumbricals out of tunnel. Studies have shown Splinting to be equally effective whether used continually or only at night. Splinting can relieve symptoms and improve functional status within 2 weeks with the effects lasting for 3 to 6 months, eliminating the need for surgery for some patients with mild CTS.

Activity modification, an integral part of initial management, is aimed to avoid repetitive strenuous activities. Ergonomic modifications at work place like ergonomic keyboards are supposed to be helpful.

Local corticosteroid injections for CTS have been utilized for years to alleviate symptoms. The effectiveness and duration of benefit from these injections have not been clearly defined along with very little information regarding the optimal corticosteroid to use, dosage, or location of the injection. The reappearance of symptoms after corticosteroid injection ranges from 8%to 100% [21]. Patients with the most severe CTS are least benefited from steroid injections. Celiker[22] compared steroid injections to NSAIDs and splinting in an unblinded, randomized trial. No statistical difference between corticosteroid injection alone versus NSAIDs and splinting was observed during the short follow-up periods. Local corticosteroid injections appear to be

superior to oral steroids for up to 3 months. No studies show benefit from steroid injection greater than 3months.

Oral prednisone at a dose of 20 mg/d for 2 weeks improves symptoms and function in patients with CTS, but is less effective than steroid injections[23]. Treatment for 2 weeks is as effective as treatment for 4 weeks; the effects tend to wane after 8 weeks in both cases.

Surgical Measures

Patients with severe CTS i.e. with findings such as thenar atrophy, diminished hand function, and median nerve denervation should be referred for surgery without delay. This recommendation is based on expert opinion, however, as most clinical trials comparing surgical vs nonsurgical treatment exclude those with severe CTS[24].

Carpal tunnel release has been performed by various methods including open method, limited open method and endoscopic methods. The different methods have their own drawbacks and benefits. The primary aim of all these methods is to limit the post-operative weakness and recurrence rates and avoid complications. The post-operative weakness due to tendon subluxations following release of carpal ligament (so- called Volar wrist pulley) is a major post-operative concern.

Traditionally, the open release is performed through wrist-palm incision, which involves deep dissection releasing palmar fascia and carpal ligment longitudinally. With the improved understanding, early diagnosis and increased need for aesthetic surgery 'palm-only' incision technique has evolved whereby incision is given only in the region of palm.

Limited open carpal tunnel release: Using a 'palm-only' mini incision (<2 cms) distal end of carpal ligament is released under direct vision followed by proximal release using variously designed guides [25].

Endoscopic technique: Endoscopic technique overcomes complications associated with open techniques like scar tenderness, prolonged healing time, pillar pain and weakened grip strength. However, it is not advised in patients with wrist stiffness, proliferative synovitis and space occupying lesions that obliterate the view of canal. When all the treatment modalities for CTS are compared, it has been found that surgical treatment for CTS is more effective than conservative method or injection technique[26]. Especially with long term benefit, the surgical technique has been found to be superior to injection method which gives only short term relief. No significant difference in the outcome has been found comparing endoscopic to open carpal tunnel release. Active motion exercises of the wrist and fingers should be encouraged post-operatively in all patients as wrist immobilization following carpal tunnel release has not been found to be any benefit.

A Cochrane database review[27] was done recently to assess the effectiveness and safety, and more specifically, in relieving symptoms, producing functional recovery (return to work and return to daily activities) and reducing complication rates, of the endoscopic techniques of carpal tunnel release compared to any other surgical intervention for the treatment of CTS. In this review, with support from low quality evidence only, it was found that Open Carpal Tunnel Release(OCTR) and Endoscopic Carpal Tunnel Release(ECTR) for carpal tunnel syndrome are about as effective as each other in relieving symptoms and improving functional status, although there may be a functionally significant benefit of ECTR over OCTR in improvement in grip strength. ECTR appears to be associated with fewer minor complications compared to OCTR, but no difference in the rates of major complications was observed. Return to work was observed to be faster after endoscopic release, by eight days on average.

Complications associated with carpal tunnel release are mostly minor –e.g. a painful or hypertrophic scar, stiffness, swelling, and pain or tenderness on either side of the incision—and resolve within a few months. Other commonly encountered complications may be injuries to motor and/ or palmar cutaneous branch of median nerve, pillar pain, injury to superficial palmar arch, incomplete carpal tunnel release, tendon adhesions, infection, wound hematoma, finger stiffness, reflex sympathetic dystrophy, weak grip strength and recurrence. The most common complication following open carpal tunnel release surgery is pillar pain followed by laceration of the palmar cutaneous branch of median nerve. Incomplete release is the most frequently reported complication of endoscopic release. Patients can expect significant symptomatic improvement within 1week of surgery, and most patients return to normal activities in 2 weeks. Evidence suggests that from 3% to 19% of patients may have persistent or recurrent symptoms even after carpal tunnel release, with up to 12% requiring surgical revision[28]. Recurrent carpal tunnel syndrome has been reported to occur in 7-20% patients[29]. Revision surgery involves neurolysis of median nerve, fat or muscle transfer and vein wrapping, however the results are not satisfying.

SUMMARY

Carpal tunnel syndrome, the most common and prevalent surgically correctable compression neuropathy, is caused by median nerve compression at wrist. The diagnosis is primarily clinical, based on detailed patient history and physical examination and confirmed by electrophysiological studies. Treatment options available range from conservative measures such as splinting and steroids to surgical release, which may be open or by endoscopic route.

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