

Carpal tunnel s

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EPIDEMIOLOGY

Carpal tunnel syndrome is the most common entrapment neuropathy encountered in electro-diagnostic laboratories. It is due to compression of the median nerve in the carpal tunnel. From the number of electrophysiologically confirmed cases in Canterbury, UK, the annual incidence is 120 per 100 000 for women and 60 per 100 000 for men (Bland & Rudolfer 2003). The incidence rises with age in men, but peaks in the 45–54 age group in women. Population surveys reveal a prevalence of 0.6–2% in men and up to 9% in women (De Krom *et al.* 1992; Atroshi *et al.* 1999). However, this sex ratio varies widely in the literature, from an excess of women of 23 : 1 in Korea to 2 : 1 in the UK.

The relationship between carpal tunnel syndrome and work conditions is controversial. Early epidemiological studies pro-

duced divergent results, perhaps because they were methodologically flawed – the diagnoses were not supported by objective testing, the degree of exposure at work was based on self-reporting, and concurrent medical illnesses, which may have predisposed workers to the carpal tunnel syndrome, were not considered. However, the National Institute for Occupational Safety and Health has reviewed rigorously conducted studies and concluded that repetitive wrist movements, high-force hand-grip, and the use of vibrating tools are all associated with an increased prevalence of carpal tunnel syndrome (NIOSH 1997). The social costs in terms of medical expenses, lost productivity and compensation are significant: this syndrome results in more days lost at work (median 32 days per case) than any other work-related injury or illness.



Figure 1 Intraoperative picture showing compression of the median nerve at the wrist (arrow) with proximal swelling of the nerve.

PATHOPHYSIOLOGY

The exact pathophysiology is unclear but mechanical injury is an important component. In patients with idiopathic carpal tunnel syndrome, the median nerve is compressed in the confined space of the carpal tunnel by adjacent tissue or raised interstitial fluid pressure (Fig. 1). The early descriptions were of cases secondary to trauma, but any process – neoplasm, infiltrative disease, infection, arthritis – that leads to raised intracarpal pressure may produce the characteristic signs and symptoms. Although the syndrome can develop due to deformities as a consequence of fractures of the carpal bones or radius, and some cases have been reported in families with a congenitally narrow carpal tunnel, there is great overlap in the size of the tunnel between affected and normal individuals. Canal size alone does not and cannot explain the susceptibility of some patients to the syndrome, and it is not a useful diagnostic test.

A square wrist shape (Table 1) and a high body mass index (BMI > 29) are both associated with carpal tunnel syndrome (Werner *et al.* 1994). A relationship has also been found with

syndrome

hand configuration; the mean palm and third digit length were shorter and the palm width wider in patients with the disorder compared with normal controls (Chroni *et al.* 2001).

Experimental peripheral nerve compression causes reduced epineural blood flow and impaired axonal transport; with increasing pressure intraneural vascular injury and endoneural oedema occur (Werner & Andary 2002). Histological examination of synovial biopsies from patients who have undergone surgical decompression shows a marked increase in fibroblast density, collagen fibre size and vascular proliferation which suggests injury to the subsynovium (Ettema *et al.* 2004). The response to this type of nerve injury is conduction block and ectopic impulse production involving both efferent fibres (fasciculations) and afferent fibres (pain, numbness) (Werner & Andary 2002).

CLINICAL FEATURES

The typical symptoms are intermittent numbness in the territory innervated by the median nerve, but sensory symptoms can and

often do occur beyond this area. The sensory symptoms, which typically are worse on awakening and can disrupt sleep, are usually relieved by shaking or wringing the hand. In more advanced cases patients notice clumsiness or weakness on prolonged grip which is improved with rest (American Academy of Neurology 1993). Thenar weakness, and less commonly wasting, is found in severe cases. Patients more often have symptoms in the dominant rather than in the non-dominant hand, but over half have bilateral disease demonstrated on nerve conduction – usually worse in the dominant hand (Bland & Rudolfer 2003).

The diagnosis is straightforward in people with classical features, but atypical presentations are well recognized. These include dry palms, finger swelling, loss of dexterity and 'stiffness' of the fingers. The syndrome can also present as painless thenar atrophy, or ulceration of the tips of the index and middle fingers. Tingling of the whole hand, and acroparaesthesiae (tingling, pins and needles, burning, numbness) of all the digits are common, but symptoms confined to the ulnar digits are rare, as are

Table 1 Provocative tests and physical findings in the carpal tunnel syndrome (adapted from D'Arcy & McGee 2000)

| TEST | DEFINITION OF ABNORMAL FINDING | SENSITIVITY (%) | SPECIFICITY (%) |
|---------------------------|--|-----------------|-----------------|
| Closed-fist sign | Paraesthesia in the distribution of the median nerve with the patient maintaining fist closure for 60 s | 61 | 92 |
| Flick sign | The patient demonstrates a flicking movement of the wrist and hand when describing their attempts to relieve their symptoms | 93 | 96 |
| Hand elevation test | Symptoms occur when patients raise their hands over their heads for up to 2 min | 76 | 96 |
| Phalen's test | Paraesthesia in the distribution of the median nerve on sustained flexion of both wrists at 90° for 60 s | 10–91 | 33–86 |
| Pressure provocation test | Paraesthesia in the distribution of the median nerve when the examiner presses with their thumb on the palmar aspect of the patient's wrist at the level of the carpal tunnel for 60 s | 28–63 | 33–74 |
| Square wrist | Wrist ratio > 0.70. The wrist ratio is the anteroposterior dimension of the wrist divided by the mediolateral dimension (measured at the distal flexor crease) | 69–74 | 73–76 |
| Tinel's sign | Tapping the distal wrist crease over the median nerve results in paraesthesia in the distribution of the median nerve | 23–60 | 64–87 |

Phalen's and Tinel's signs are the most popular provocative tests but their utility is rather variable

symptoms affecting the palm but not any of the fingers (Stevens *et al.* 1999). A self-administered 'hand diagram' can be used to classify the level of certainty of the diagnosis into classical, probable, possible and unlikely; the patient is provided with a picture of a hand and is asked to mark the areas that are affected and indicate the quality of the symptoms (Katz *et al.* 1990).

Phalen's and Tinel's signs are the most popular provocative tests but their utility is rather variable (D'Arcy & McGee 2000). A review of a range of physical signs and provocative tests concluded that none were of sufficient diagnostic accuracy to exclude or confirm the diagnosis (Table 1).

The median nerve is susceptible to compression at sites other than in the carpal tunnel: for example, it may be compressed by the pronator teres, or the anterior interosseus branch may be affected in isolation (Rosenbaum & Ochoa 2002).

Clearly, physical examination is important in looking for conditions that mimic or that are associated with this syndrome (Witt & Stevens 2000) (Table 2).

Most cases are idiopathic but a number of conditions are associated with carpal tunnel syndrome, most frequently diabetes mellitus, rheumatoid arthritis, thyroid dysfunction, pregnancy and the use of oral contraception (Rosenbaum & Ochoa 2002). Less common disorders are listed in Table 3. Patients with a long history of diabetes are more likely to develop the syndrome, perhaps because the neuropathic nerve becomes more vulnerable to compression and associated tendon abnormalities are more common. Screening patients with carpal tunnel syndrome who are not

Table 2 Neurological differential diagnoses of the carpal tunnel syndrome

| |
|------------------------------|
| Congenital thenar hypoplasia |
| Proximal median neuropathy |
| Ulnar neuropathy |
| Radial neuropathy |
| Peripheral neuropathy |
| Brachial plexopathy |
| Thoracic outlet syndrome |
| Cervical radiculopathy |
| Motor neuron disease |
| Syringomyelia |
| Myelopathy |

Table 3 Disorders associated with the carpal tunnel syndrome.

| | |
|--------------------------|------------------------|
| Amyloidosis | Mononeuritis multiplex |
| Carpal tunnel lipoma | Multiple myeloma |
| Collagen disease | Multiple sclerosis |
| Diabetes mellitus | Neurofibromatosis |
| Dyschondroplasia | Peripheral neuropathy |
| Ganglion | Plantar fasciitis |
| Gout | Polycythaemia |
| Herpes zoster | Raynaud's phenomenon |
| Hodgkin's disease | Renal failure |
| Leukaemia | Sarcoidosis |
| Median artery thrombosis | Tuberculosis |

known to be diabetic has been recommended although this has a low yield (Katz & Simmons 2002).

INVESTIGATIONS

Nerve conduction studies (NCS) are helpful in diagnosing and assessing the severity of the carpal tunnel syndrome (Table 4) (Bland 2001). The original diagnostic studies, conducted in referral centres, had a high proportion of severe cases so the predictive value of NCS may be lower in a primary care setting among patients inevitably with milder forms of the disorder. Generally accepted techniques include median sensory nerve conduction across the wrist, comparison of median and ulnar sensory nerve conduction, and motor recording from the thenar muscles (American Association of Electrodiagnostic Medicine 2002). Of course, comparison with the contra-lateral median sensory nerve may be misleading if the patient has bilateral disease. Various supplementary tests have been advocated but there is the risk of increasing the probability of false positives with additional testing (Rivner 1994).

Not all physicians or surgeons request nerve conduction because of the costs, delay and inaccessibility. Indeed, the need for confirmatory NCS to support the diagnosis has been challenged. Some surgeons have reported good results following surgical release in patients with normal NCS results, and in those who have not undergone electrophysiological testing at all (Braun & Jackson 1994; Concannon *et al.* 1997). It has been argued that over reliance on abnormal NCS may deprive patients of prompt

Table 4 A neurophysiological system for grading the severity of the carpal tunnel syndrome

| | |
|---------|---|
| Grade 0 | Normal |
| Grade 1 | Very mild, abnormal nerve conduction only demonstrable with most sensitive tests |
| Grade 2 | Mild, sensory nerve conduction velocity slowing, normal terminal median nerve motor latency |
| Grade 3 | Moderate, preserved sensory action potentials, distal motor latency < 6.5 ms |
| Grade 4 | Severe, absent sensory action potentials, distal motor latency < 6.5 ms |
| Grade 5 | Very severe, distal motor latency > 6.5 ms |
| Grade 6 | Extremely severe; unrecordable sensory and motor action potentials |

treatment. Favourable response to treatment, and operative findings, have been proposed as an alternative gold standard, but for trial and epidemiological purposes the combination of clinical features and electrodiagnostic study is recommended for confirming the diagnosis (Rempel *et al.* 1998; American Association of Electrodiagnostic Medicine 2002).

False negative NCS occur in cases where the symptoms are due to disorder of small unmyelinated fibres which are not tested on routine nerve conduction. NCS may also be normal where nerve compression causes intermittent nerve ischaemia without permanent demyelination. Furthermore, the 'normal' range of many parameters is generally set as the mean \pm 2 standard deviations, but many biological values such as conduction latencies, sensory nerve and motor amplitudes do not follow a Gaussian distribution (Robinson *et al.* 1991). Applying these cut off points to skewed data would result in misclassification.

High-resolution ultra sonography is a promising diagnostic tool which may complement or even compete with electrophysiological study in the assessment of patients suspected of having carpal tunnel syndrome (Nakamichi & Tachibana 2002; Wong *et al.* 2004; Ziswiler *et al.* 2005). Superficial peripheral nerves can be insonated using transducers at a frequency of 7–12 MHz (Fig. 2). The cross sectional area of the median nerve, which appears as a hypoechoic oval or round structure, is measured with electronic callipers at multiple levels. A combination of measurements of the nerve at different levels such as the carpal tunnel inlet and outlet gives the best sensitivity and specificity (Wong *et al.* 2004). Magnetic resonance imaging (MRI) can also demonstrate abnormalities such as swelling/flattening of the median nerve, hyperintense nerve signal and bowing of the flexor retinaculum (Jarvik *et al.* 2002) (Fig. 3). Currently, ultrasound is more widely used be-

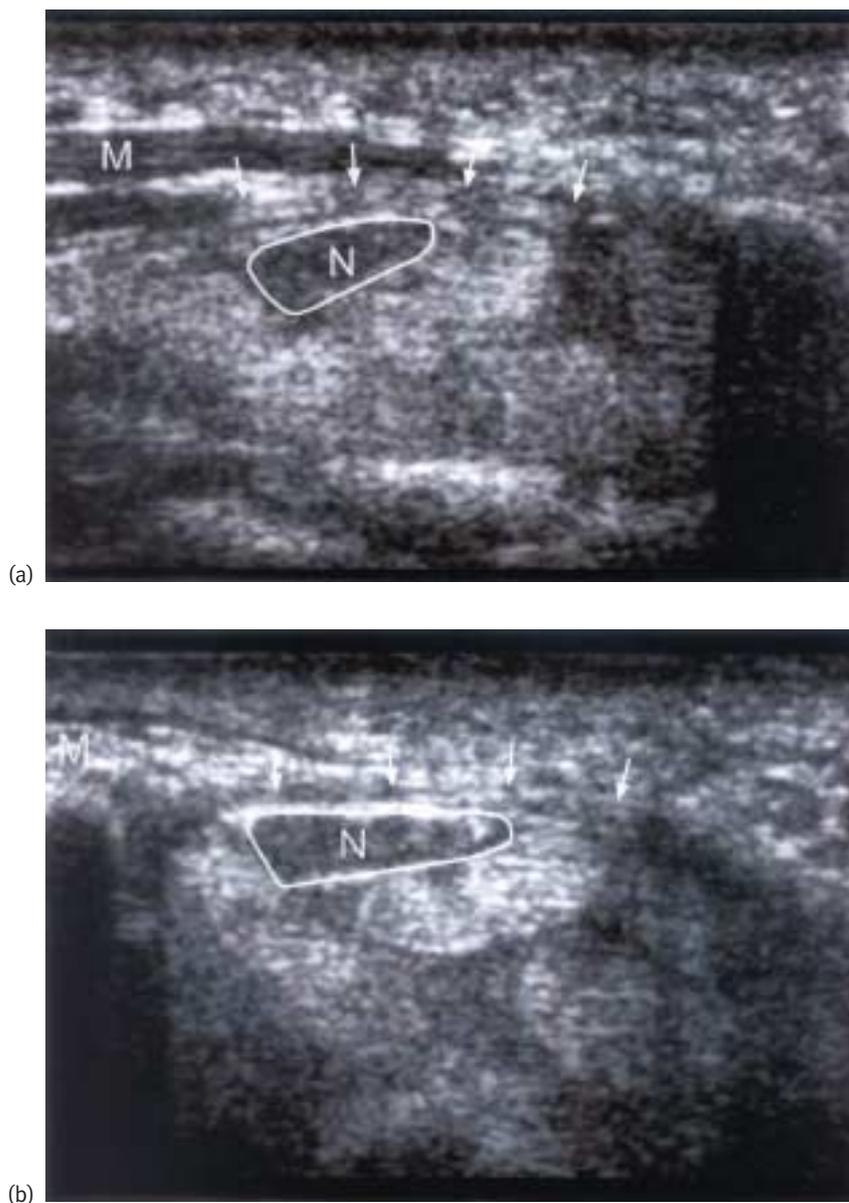


Figure 2 (a) transverse ultrasound examination of the wrist at the level of carpal tunnel inlet. Normal calibre (8.8 sq.mm) of the median nerve (N, margin outlined). The flexor retinaculum is indicated by arrows. M = thenar muscle. (b) transverse ultrasound examination of the wrist at the level of carpal tunnel inlet. Midly enlarged (11.6 sq.mm) median nerve (N, margin outlined). The flexor retinaculum is indicated by arrows. M = thenar muscle.

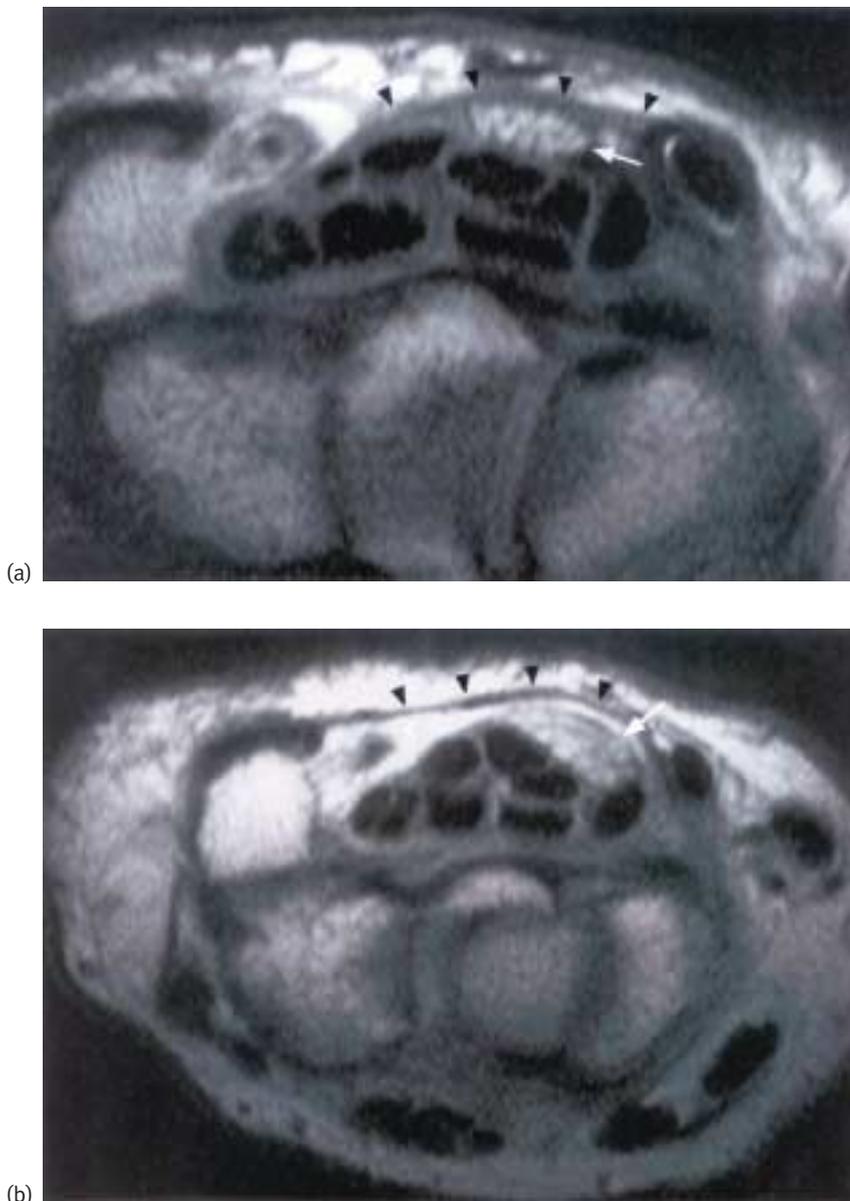


Figure 3 (a) axial intermediate-weighted MR image of the wrist at the level of carpal tunnel inlet demonstrating a normal calibre median nerve (arrow). The flexor retinaculum is indicated by arrowheads. (b) axial intermediate-weighted MR image of the wrist at the level of carpal tunnel inlet demonstrating an abnormal median nerve (arrow) in a patient with carpal tunnel syndrome. The flexor retinaculum is indicated by arrowheads.

cause it is cheaper, faster and more accessible than MRI. Both techniques have the additional advantage of demonstrating the contents of the carpal tunnel and any anatomical variations of the median nerve, but they are not yet a routine part of evaluation.

MANAGEMENT

The objectives of therapy are to relieve sensory complaints, prevent progression, limit function-

al disability and enable rapid return to work. A variety of treatments are used even though there is limited formal evidence to support them. For patients whose carpal tunnel syndrome is associated with another potentially causative medical condition such as rheumatoid arthritis or hypothyroidism, management of the underlying disorder alone may relieve the symptoms (Katz & Simmons 2002).

Many clinicians offer carpal tunnel release to patients who do not respond to or relapse after conservative treatment but some have argued that surgery should be the treatment of first choice (Wilson & Sumner 1995; Pal *et al.* 1997; Katz & Simmons 2002). The optimal form of conservative therapy is uncertain because there have been so few head-to-head comparisons of different modalities (Verdugo *et al.* 2003).

Splinting

Normally, pressure in the carpal tunnel is between 0 and 7 mmHg when the wrist is in the neutral position and increases with wrist extension or flexion. Prefabricated splints are designed for primarily nocturnal/daytime wear or for round-the clock use, and vary in size and materials. Splinting in the neutral position results in immobilization of the wrist and offers symptomatic relief (O'Connor *et al.* 2003). A multicentre randomised controlled trial showed that 80% of cases in the surgery group recovered completely or were 'much improved' in the short term vs. 54% in the splinting group (Gerritsen *et al.* 2002). At 18 months, the respective figures were 90% and 75%, but by this time many of the patients in the splinting group had gone on to have decompressive surgery.

Drug treatment

Intracarpal injection of corticosteroid is thought to decrease the volume of any swollen tissue. This provides greater short-term improvement compared with placebo, intramuscular or oral corticosteroid (Ozdogan & Yazici 1984; Wong *et al.* 2001; Marshall *et al.* 2002). The injection is usually made on the ulnar side of the palmaris longus beneath the flexor retinaculum but this does risk needle injury to the median nerve. In recent trials, the needle has been positioned *proximal* to the carpal tunnel, 4 cm proximal to the distal wrist crease, with good short-term results (Dammers *et al.* 1999). A disadvantage of all forms of injections is that that while symptoms improve or are abolished in the majority

when assessed at around 1 month, recurrence is common in the longer term (Gelberman *et al.* 1980). Patients with symptoms for more than a year, thenar wasting, distal motor latencies over 6 ms and absent sensory action potentials have the poorest response and highest likelihood of relapse. The optimal number of injections is unknown but physicians limit the number in view of the adverse effects of corticosteroids.

For oral drugs, only prednisolone at a dose of 10–25 mg daily for 2 weeks, is superior to placebo in providing short-term subjective improvement (O'Connor *et al.* 2003). Pyridoxine (Vitamin B6) is a popular treatment and stems from the belief of an association between carpal tunnel syndrome and pyridoxine deficiency, but there is insufficient evidence to support its use. At high dosage it may even be harmful because there are anecdotal reports of peripheral neuropathy (Dalton & Dalton 1987). Diuretics and nonsteroidal anti-inflammatory drugs are ineffective (O'Connor *et al.* 2003).

Surgery

Open carpal tunnel release by splitting the transverse carpal ligament is the standard surgical procedure. It is performed under local anaesthesia as a day case. In the UK the decompression rate is 71/100 000 per annum which is half that of the United States (Burke 2000). An additional procedure called internal neurolysis is sometimes used (epineurotomy plus division of the nerve into multiple fascicular groups). Endoscopic carpal tunnel release is a newer technique; supporters claim there is less wrist and scar discomfort and more rapid recovery of grip strength. Observational data show that surgical release results in 80–97% of patients noting marked improvement or complete symptomatic relief. The Cochrane review reported that both the standard procedure and endoscopic release appeared to be equally efficacious and cost-effective in the short term (Scholten *et al.* 2004). However, it found conflicting evidence as to whether endoscopic release leads to earlier return to work or full activities of daily living. Overall complication rates were similar but endoscopy was associated with more transient nerve sequelae such as numbness, while open surgery resulted in more wound complications (Scholten *et al.* 2004).

One recent randomised controlled trial has compared surgery with a single or repeated

Open carpal tunnel release by splitting the transverse carpal ligament is the standard surgical procedure

corticosteroid injections (Ly-Pen *et al.* 2005). Using a primary outcome of 20% improvement in nocturnal paraesthesia, injections produced greater symptom relief than surgery in the short term but at 1 year the efficacy was similar.

A small proportion of patients have persistent or recurrent symptoms after surgery. The reasons include misdiagnosis, incomplete division of the flexor retinaculum, iatrogenic nerve branch injury and perineural fibrosis (Rosenbaum & Ochoa 2002). Re-examination of the diagnosis and surgical re-exploration should be considered in these cases.

Alternative measures

One trial in patients with bilateral carpal tunnel syndrome randomised their wrists to ultrasound treatment on one side and sham treatment over the other side. The rationale was that ultrasound may stimulate nerve regeneration and have an anti-inflammatory effect. At 6 months, the actively treated group reported better subjective relief and had improved nerve conduction responses (O'Connor *et al.* 2003).

In a small study, an 8-week course of Yoga, consisting of 2–3 h of supervised work-outs per week, provided pain relief and improved grip strength compared with splinting alone. Further corroboration is required before these novel treatments can be recommended.

Some patients resort to complementary remedies such as magnet therapy, chiropractic care, acupuncture, hydrotherapy and massage but there are no supporting data.

PROGNOSIS

Studies on the prognostic usefulness of nerve conduction have given conflicting results – absent median sensory and motor responses are considered poor prognostic factors but this has not been universally reproduced (Gelberman *et al.* 1980; Bland 2001). Overall the prognosis is variable; some series report that 79% of untreated patients report improvement or no change in their symptoms, while others find that most patients require

PRACTICE POINTS

- Carpal tunnel syndrome is often present in both hands and occurs more frequently in women.
- High-resolution ultrasound and magnetic resonance imaging are emerging diagnostic tools.
- Splinting, locally injected and oral corticosteroids provide short-term symptomatic relief.
- Diuretics, pyridoxine and non-steroidal anti-inflammatory drugs are ineffective.
- Carpal tunnel release is more effective than splinting, and as effective as injected corticosteroid in the long term (1 year or more).
- Longer duration of symptoms (over 6 months), increasing age, preoperative muscle atrophy, and poor response to steroid injection are associated with a worse response to surgical decompression.

surgery in the long term (Padua *et al.* 2001; Hui *et al.* 2004). Longer duration of symptoms (over 6 months), increasing age, alcohol use, preoperative muscle atrophy, and poor response to corticosteroid injection are all associated with a worse prognosis (Katz *et al.* 2001).

Patients with severe carpal tunnel syndrome do benefit from surgery but the outcome is less favourable and recovery may be incomplete compared with milder cases (Finestone *et al.* 1996). Outcome after surgery is equally good in the elderly and in diabetics (Tomaino & Weiser 2001). In the United States, the involvement of an attorney and any worker's compensation claim are both associated with a poorer prognosis (Katz 2001).

CONCLUSIONS

Our PubMed search revealed 5281 papers on carpal tunnel syndrome over the past 50 years, around half of which were published in the last decade. Despite this surge in the literature, uncertainties and controversies remain. More work is needed to investigate the impact of

preventative measures such as improvement in workplace conditions and ergonomic adaptations. Interpretation of trial data is complicated by variable methodological quality, differences in severity of the symptoms in different trials, different outcome measures and short follow-up. Further well-conducted trials – using objective and patient-orientated measurements – are needed to clarify the best form of treatment for this common and disabling condition.

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