The carpal tunnel is a bony canal covered on the palmar side by the flexor retinaculum. On the ulnar border the flexor retinaculum attaches to the pisiform and hook of the hamate and on the radial border to the scaphoid tubercle and ridge of the trapezium. The median nerve passes through the carpal tunnel together with eight flexor tendons of the long fingers and the tendon of the flexor pollicis longus. The bony walls of the carpal canal and the rigid flexor retinaculum have no capacity for expansion. Anything that reduces the dimensions of the tunnel or increases the volume of its contents will predispose to carpal tunnel syndrome.\textsuperscript{1,2} Many conditions have been associated with carpal tunnel syndrome, but most cases are idiopathic.\textsuperscript{2} Carpal tunnel syndrome can be caused by abnormal anatomical structures such as anomalous muscles\textsuperscript{3} or a persistent median artery.\textsuperscript{4} Other causes are trauma, swellings (ganglion, lipoma), inflammatory diseases (rheumatoid arthritis) and metabolic disturbances (diabetes, thyroid disorders, pregnancy).\textsuperscript{1} Obesity is a risk factor for carpal tunnel syndrome.\textsuperscript{1,4} Carpal tunnel syndrome can also be associated with certain occupations involving handgrip with high forces or vibrating tools, especially when those tasks require repetitive movements of the hands.\textsuperscript{1} However, in another study, working in repetitive or non-repetitive occupations did not cause, accelerate or aggravate carpal tunnel syndrome.\textsuperscript{4} A genetic predisposition for carpal tunnel syndrome has also been reported.\textsuperscript{3}

In the general population, the prevalence of carpal tunnel syndrome ranges between 2 and 4%.\textsuperscript{5,6} Carpal tunnel syndrome is more common in women. The incidence peaks in women in their late 50s and in men between 45 and 54 years of age. In both sexes, the incidence peaks again in the late 70s.\textsuperscript{5,6}

Symptoms of carpal tunnel syndrome can range in severity from transient sensory disturbances to irreversible thenar wasting and sensory loss. Patients woken by paraesthesias or pain in the distribution of the median nerve have carpal tunnel syndrome until proved otherwise.\textsuperscript{2} On physical examination, wasting of thenar muscles should be looked for and the strength of the abductor pollicis brevis muscle should be tested. It should be examined whether the area of sensory disturbance involves the distribution of the median nerve. Several clinical tests can be used to diagnose carpal tunnel syndrome, such as Tinel’s sign, Phalen’s test, reversed Phalen’s test, Durkan’s compression test\textsuperscript{12} and the hand elevation test.\textsuperscript{13} The diagnosis can be made based on clinical findings and electromyography.\textsuperscript{1}

In the US, costs of surgical treatment are lower than those of non-surgical care.\textsuperscript{14} Surgery is also more effective, but non-surgical treatment can still be proposed in patients with moderately severe carpal tunnel syndrome.\textsuperscript{15,16} Steroid injections and splinting can be tried first, and when these fail surgery can be advised. Immediate surgical release is indicated in those patients showing constant numbness, evident motor weakness or increased distal latency with electromyographic testing.\textsuperscript{1}

\textbf{Open Carpal Tunnel Release}

The patient is placed supine with the arm extended on a padded arm table and the forearm supinated. General, endovenous, plexus or, preferably, local anaesthesia can be administered.\textsuperscript{2} A pneumatic tourniquet can be applied at the upper arm or forearm. With local anaesthesia, patient comfort is greater when a forearm tourniquet is used.\textsuperscript{3}

When planning the surgical incision, a few landmarks are useful in order to cut the flexor retinaculum on the ulnar side of the median nerve and to avoid injury to neurovascular structures. Kaplan’s cardinal line is drawn from the apex of the thumb–index web to the hook of the hamate. The deep palmar arch lies under the cardinal line.
and the superficial palmar arch is located between the cardinal line and the proximal palmar crease. Palpation of the hook of the hamate will prevent an excessively ulnar incision. The surgical incision is in the palm, in line with the central axis or radial border of the ring finger. It starts proximal to Kaplan’s cardinal line and ends distal to the distal wrist crease. The incision can be extended into the distal forearm if needed, but a 2–4 cm-long incision confined to the palm is now recommended for standard open carpal tunnel release (see Figure 1).

When making the skin incision, care must be taken to protect the terminal cutaneous branches. Because there is no internervous plane in the palmar region, four cutaneous nerves are at risk, i.e. the palmar cutaneous branch of the median nerve, the palmar cutaneous branch of the ulnar nerve, branches from the nerve of Henle and transverse branches of the palmar cutaneous branch of the ulnar nerve.

After incision of the skin and subcutaneous fat, the underlying flexor retinaculum is identified as a transversely orientated fibrous tissue layer that is contiguous radially with the thenar muscles and ulnarily with the hypothenar fat pad. Anatomical variations of thenar and hypothenar muscles exist and muscle fibres frequently cross the line of incision on the flexor retinaculum. The flexor retinaculum can have a muscular aspect without a clear separation between the thenar and hypothenar muscles. In these circumstances muscle fibres have to be cut in order to visualise the flexor retinaculum (see Figure 2).

At the distal edge of the flexor retinaculum is a fat pad containing the branches of the median nerve and the superficial palmar arterial arch. The flexor retinaculum is cut along its ulnar border (see Figure 3). The proximal portion, near the distal wrist flexion crease, is less thick and can be divided with scissors after first freeing the adjacent tissues palmarly and dorsally (see Figure 4). The flexor retinaculum should be incised approximately 3 cm distal of the flexor crease. It is advised to inspect the motor branch of the median nerve and the superficial palmar arterial arch before releasing the tourniquet and closing the wound. Some do not explore the motor branch during open carpal tunnel release and find it is not necessary to release the tourniquet and obtain haemostasis prior to wound closure.
Besides the palmar cutaneous nerves, other structures at risk during open surgery are the ulnar nerve and artery, the superficial palmar arch and the motor branch of the median nerve. Kaplan’s cardinal line is useful to avoid injury to the superficial palmar arch and the motor branch of the median nerve may show anatomical variations. The classic configuration is that it arises from the ulnopalmar aspect of the radial division of the median nerve, just distal to the flexor retinaculum. In about 20% of cases it originates a few millimeters proximal to the distal edge of the flexor retinaculum. The course of the motor branch can be extra-, sub- or transligamentous. An extraligamentous course is the most common. The safest way to open the flexor retinaculum is to the ulnar side of the median nerve, although motor branches from this side may arise proximally in the carpal tunnel or distal to the tunnel.

During open carpal tunnel release adjuvant procedures can be performed, such as neurolysis of the median nerve, synovectomy, repair of the flexor retinaculum and opening of the canal of Guyon.

Internal neurolysis is a technique in which the epineurium of the median nerve is split and the fascicles are separated to relieve interfascicular scarring. This procedure has been advised in patients with constant sensory loss and/or thenar atrophy. However, clinical studies have failed to show any benefit of internal neurolysis and it has fallen out of favour. Epineurotomy, a release of the epineurium of the nerve without separating the fascicles, is not more successful than simple decompression. Results may even be worse after neurotomy or internal neurolysis.

Routine tenosynovectomy did not provide better results than carpal tunnel release alone. It may increase the risk of haematoma and adhesions between the nerve and tendons, and is only indicated in cases of proliferative or invasive tenosynovitis.

Reconstruction of the cut flexor retinaculum has been proposed to avoid bowstringing, but the outcome was not different from that of simple carpal tunnel release.

Patients with carpal tunnel syndrome can have symptoms outside the median nerve distribution. Because these symptoms are likely to resolve after carpal tunnel release alone, it is not necessary to open the canal of Guyon as an adjuvant procedure.

Post-operative splinting can be applied to avoid bowstringing or entrapment of the median nerve in scar tissue. However, these complications are rare and splinting following open release of the carpal tunnel has been shown to cause more pain and scar tenderness the first month after surgery. The patients should be taught to exercise the wrist and fingers and avoid simultaneous wrist and finger flexion. Other authors found no difference between patients who were splinted for four weeks and patients who were allowed immediate motion of the wrist following open carpal tunnel release. In patients who are encouraged to use their hand immediately after surgery, sick leave has been shown to be less, which may have economic consequences.

Surgery can be performed on patients anticoagulated with warfarin. Although recommended by only a few surgeons, simultaneous bilateral surgery can be performed without too many problems for the patient, and costs are considerably less than with consecutive bilateral release. Open carpal tunnel release increases the volume of the tunnel. Post-operatively, grip strength is decreased, but recovers within three to nine months. Usually there is a rapid improvement of sensory disturbances and immediate relief of nocturnal paraesthesias.

Endoscopic Carpal Tunnel Release and Minimally Invasive Carpal Tunnel Decompression

Two techniques have been described for carpal tunnel release: the single-portal technique and the two-portal technique. The advantage of endoscopic surgery is that the soft tissues superficial to the flexor retinaculum are not divided. This avoids injury to the palmar cutaneous nerves and may explain the lower rate of painful incisions compared with open release. In addition to less immediate post-operative pain, it may allow patients to return to work sooner. However, endoscopic carpal tunnel decompression is not possible in all hands, and in some patients the procedure has to be converted to an open release.

With minimally invasive techniques, the carpal tunnel is released through 1–2cm-long skin incisions. This results in less scar formation, just as with the endoscopic methods, but the advantage of minimally invasive techniques is that less equipment is required. Minimally invasive carpal tunnel release can be performed through a single or double incision. Special cutting instruments are available to perform the carpal tunnel release through a longitudinal or transverse incision at the distal edge of the flexor retinaculum or through a transverse incision at the proximal edge. Examples of such instruments used in minimally invasive carpal tunnel release are the Kniefelg, the Indiana Tome and the Safeguard System. Another possible advantage of endoscopic and mini-open procedures is that the interthenar fascia is left intact, which may be important for preserving pinch strength.

Factors Predicting Outcome in Carpal Tunnel Syndrome Surgery

Not all patients have a good result after carpal tunnel surgery. An overall success rate of 75% has been reported. The outcome may be influenced by patient- or surgeon-related factors. Failures after surgery for carpal tunnel syndrome are mostly attributable to misdiagnosis, surgical errors (failure to fully divide the flexor retinaculum) and delay of treatment to a point at which median nerve function is beyond recovery. A minority are caused by nerve and vessel lacerations, infection, painful scarring and complex regional pain syndrome.

Steroid injection may serve as a diagnostic tool and may help to predict outcome after surgery. A patient who responds well to steroid injection has a high probability of responding to surgical management. However, poor relief from injection does not necessarily mean that a patient is a poor candidate for surgery.

Open carpal tunnel release in elderly people has a high satisfaction rate even in those with severe electromyographic abnormalities, but compared with younger patients recovery seems to be slower and incomplete. Nagaoka et al. found that numbness and thenar atrophy did not disappear in patients between 70 and 85 years of age. Because age is a predictor of a less favourable short-term outcome, routine endoscopic carpal tunnel syndrome may not be justified in patients over 65 years of age.
Patients with diabetes have the same beneficial outcome after carpal tunnel release as non-diabetic patients. Only cold intolerance is relieved to a lesser extent.77 Mondelli et al. also found diabetes not to be a risk factor for a poor outcome after carpal tunnel release,79 but others obtained less favourable results with surgical release in diabetic patients than in patients with idiopathic carpal tunnel syndrome.78

The outcome may be influenced by the type of skin incision. A shorter recovery period has been reported with smaller incisions, but return to work was also influenced by the type of medical insurance and early hand therapy.80 Six studies comparing long with short incisions for open carpal tunnel surgery were included in a Cochrane review. Only minor differences were found between the two groups. In three studies, the longer incisions caused slightly more scar pain and tenderness than the shorter ones.81 In one study patients returned to work sooner when a short incision in the palm was used compared with an incision extending into the forearm.82 Zyluc and Strychar observed no significant difference in outcome between a single and a double incision for minimally invasive carpal tunnel release, but found the latter method technically less demanding.83 The two-portal and the single-portal endoscopic techniques may have a different outcome as there is an additional scar in the palm with the Chw technique. Return to work may be quicker for patients treated with the Agee technique.

Mean time off work was 18 days with the Agee technique and 28 days with the two-portal technique.84 However, a randomised prospective clinical trial is mandatory before any conclusions can be made.

The discussion as to whether results are better with open or endoscopic techniques is still ongoing.85 Several reviews have been published,19–22,69–71 from which it can be concluded that both techniques have similar outcomes and risks. With endoscopic procedures, return to work and restoration of grip and pinch strength may occur sooner than with open procedures, but the risk of transient nerve injury and revision surgery is higher.86

In a Cochrane review, the results of minimally invasive techniques were found to be similar to those of endoscopic and open techniques.85 In a recent study with a seven-year follow-up, a higher rate of complications and recurrences was reported with a minimally invasive technique compared with the open technique.82

Conclusion

Outcomes of carpal tunnel release are generally excellent, and surgery – whether open or closed – works if the diagnosis is right.86 There is no strong evidence supporting the need for replacement of standard open carpal tunnel release with existing alternative surgical procedures for the treatment of carpal tunnel syndrome.82 Neither endoscopic nor minimally invasive surgery can solve the problem of pillar pain.87 The open procedure is still the standard treatment method for carpal tunnel syndrome. No special instruments are required and visualisation is better in cases of anatomical variation.
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