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REVIEW ARTICLES OF TOPICS

Is there Light at the End of the Tunnel? Controversies in the Diagnosis and Management of Carpal Tunnel Syndrome

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Abstract Carpal tunnel syndrome is a common disorder responsible for considerable patient suffering and cost to health services. Despite extensive research, controversies still exist with regards to best practice in diagnosis, treatment, and service provision. Current best practise would support the use of history, examination and electro-diagnostic studies. The role for ultrasound scanning in diagnosis of carpal tunnel syndrome is yet to be proven. It appears magnetic resonance image scanning has a role where a rare cause for carpal tunnel syndrome may be suspected and also in the detailed reconstruction of the anatomy to aid endoscopic procedures. Treatment options can be surgical or non-surgical and patient choice will dictate the decision. For non-surgical interventions many options have been trialled but until now only steroid use, acupuncture, and splinting have shown discernable benefits. Open surgical decompression of the carpal tunnel appears to be more simple and cost-effective than minimally invasive interventions. For those patients who reject surgery, splinting, acupuncture, and steroid injection can play a role. Recent work looking at different service delivery options has shown some positive results in terms of decreasing patient waiting time for definitive treatment. However, no formal cost-effectiveness analysis has been published and concerns exist about the impact of a stream-lined service on surgical training. In this review, we look at the different diagnostic and treatment options for managing carpal tunnel syndrome. We then consider the different service delivery options and finally the cost-effectiveness evidence.

Keywords Carpal tunnel syndrome · Electro-diagnostic studies · Non-operative treatment endoscopic surgery · Cost-effectiveness

Wherever a peripheral nerve traverses a fibro-osseous tunnel, it is at risk of entrapment. The most common site is the carpal tunnel that accounts for 90% of entrapment neuropathies [2]. The patient complains of an unpleasant tingling, pain or numbness in the distal distribution of the median nerve [55]. The prevalence of carpal tunnel syndrome (CTS) in the UK is 7–16%, and the surgical decompression rate is 43–74 per 100,000 [2]. Economic consequences include the direct financial implications of management and the indirect burden of absenteeism from the workplace. The median number of days away from work for CTS is among the highest at 27 days. In the US in 1995, between 400,000 and 500,000 patients underwent surgical decompression. This equates to an economic cost of in excess of $2 billion [2].

The management of CTS is complex and involves multiple stakeholders including the patient, their employer, the primary care physician, the surgeon and the health service provider. Although CTS is responsible for a significant number of outpatient appointments, investigations and interventions, controversy still surrounds its management. Effective management of CTS requires a highly sensitive diagnostic test and a definitive treatment option. Despite the relative simplicity of the condition,

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controversies exist in diagnostic tests, treatment options and modalities of service delivery. These problems are compounded by increasing patient expectations and budget constraints.

Diagnosis of Carpal Tunnel Syndrome

Currently the diagnosis of CTS involves a combination of a detailed clinical history, accurate examination and, where appropriate, electro-diagnostic studies (EDS) [50]. However, the contribution of each of these factors makes to the eventual diagnosis remains a contentious issue. The interventions should be acceptable to the patient, cheap to deliver and easy to provide. With the development of newer investigative procedures such as ultrasound and magnetic resonance imaging (MRI), this diagnostic uncertainty is set to continue.

A key problem relating to the diagnosis of CTS is the lack of a diagnostic gold standard to which the value of other potential diagnostic techniques can be compared [20]. With such a high reported incidence of CTS, it is clear that an accurate and efficient diagnostic protocol would have significant financial implications for the health service in managing this condition [4].

Clinical Signs

Historically, clinical provocative tests such as Phalen's and Tinel's have been used to aid in the diagnosis of CTS. A wide range of sensitivities and specificities have been reported in the literature for both tests [28].

Phalen's test is said to be positive when flexion at the wrist for 60 s leads to pain or paraesthesia in the distribution of the median nerve [46]. These tests have quoted sensitivities of 10–90% and specificities of 33–100% [2]. A detailed systematic review of over 3,000 cases reported a sensitivity of 68% and specificity of 73% for Phalen's test and concluded that it was a useful test, but false negatives should be expected [38]. Tinel's test is said to be positive when tapping over the volar surface of the wrist causes paraesthesia in the fingers innervated by the median nerve [6]. Tinel's is generally thought to be less sensitive than Phalen's; however, specificities have been recorded as high as 100% [2].

El Miedany et al. [16] carried out a case control study comparing 232 patients with clinically diagnosed CTS against 182 asymptomatic controls. The patients underwent EDS to look for underlying CTS and high resolution ultrasounds to look for other pathologies. They found that provocative tests such as Tinel's and Phalen's were actually more sensitive and specific for the diagnosis of tenosynovitis than for the diagnosis of CTS. The sensitivity for Tinel's was 46% in tenosynovitis compared with 30% in CTS, and for Phalen's was 92% in tenosynovitis compared with 47% in CTS.

With such a disparity in the literature regarding the accuracy of provocative tests, it is easy to see how a clinician may have difficulties in interpreting the significance of a positive or negative result. This may contribute to a greater reliance on EDS as a diagnostic gold standard [20]. Whilst provocative tests may assist in diagnosing CTS, their low positive predictive value makes them insufficient to diagnose CTS alone and as such they should be considered in conjunction with a good clinical history and EDS where appropriate [15].

Electro-diagnostic Studies

EDS are based on the discovery that median nerve conduction times are slowed across the wrists of hands with symptomatic CTS ([54] 1956). Various diagnostic criteria have been suggested including prolonged motor and sensory latencies of the median nerve and reduced sensory and motor conduction velocities [56]. The optimal diagnostic criteria however remain uncertain [34].

As mentioned earlier, the diagnostic uncertainty associated with clinical signs may lead to clinicians non-selectively referring patients for nerve conduction studies with the belief that it represents a diagnostic gold standard [40]. However, EDS have their own diagnostic hurdles. False negative and false positives can occur even when the most sensitive methods of EDS are used [34, 42]. Inadequacies of EDS have been partly blamed on a lack of standardised diagnostic criteria with reports of 16–34% of clinically defined CTS being missed with EDS [61], and sensitivities ranging from 49 to 84% [30]. With this in mind, blanket referrals for EDS are an expensive and inefficient approach to the diagnosis of CTS and may lead to continued diagnostic uncertainty [5].

Graham [20] looked at the value added by EDS in diagnosing patients with clinically defined CTS. They recruited 143 patients and used a structured questionnaire that focused on symptoms, history and clinical examination. This questionnaire had previously been validated by comparing its ability to diagnose CTS to that of a panel of expert clinicians [19]. They reported that for the majority of patients, EDS did not change the probability of diagnosing the condition. This was an interesting discovery and supports and emphasis on clinical history and examination in identifying patients with CTS.

Kamath and Stothard [26] carried out a prospective study involving 107 patients to assess whether a similar structured health questionnaire would be able to diagnose CTS with similar sensitivities and specificities to EDS. They used symptom relief after surgery as the diagnostic

gold standard and reported equivalent sensitivities and positive predictive values (PPV) between their questionnaire (sensitivity, 85%; PPV, 90%) and EDS (sensitivity, 92%; PPV, 92%). They concluded that such a questionnaire could be used to fast track those patients who scored highly for surgery, bypassing usual outpatient referrals and EDS. This goes against the recommendations of the American Academy of Orthopaedic Surgeons, who recommend EDS for all patients being considered for surgery [30].

Ultrasound

The first studies demonstrating the efficacy of ultrasound in the diagnosis of CTS were performed by Buchberger et al. [7–9]. They reported that thickening of the median nerve, flattening of the nerve within the carpal tunnel and bowing of the flexor retinaculum were all features diagnostic of CTS. Many studies have attempted to define the optimal criteria by which ultrasound measurements can be used to define CTS. The most predictive measurement is cross-sectional area; however, there is still much debate with regards to the level within the carpal tunnel that this measurement should be taken and furthermore what constitutes an abnormal value [51, 60, 62].

A recent prospective study comparing the diagnostic utility of ultrasound versus EDS found equivalent sensitivities between the two techniques [41]. The study involved 85 patients with clinically mild CTS who reported symptoms suggestive of CTS but without objective motor deficit or sensory impairment in the areas supplied by the median nerve. Sensitivities for EDS and ultrasound were 67.1% and 64.7%, respectively; however, if both EDS and ultrasound were considered together, the sensitivity increased to 76.5%. This suggests a role for ultrasound as a diagnostic adjunct to the established EDS. The study also highlights the diagnostic shortfalls of these investigations with 23.5% of patients with clinically diagnosed CTS remaining undetected.

Karadağ et al. [27] reviewed 99 wrists of 54 patients and were able to demonstrate high concordance of EDS and ultrasound in defining CTS severity ($P<0.001$) when compared with a detailed symptom questionnaire and clinical examination. They were able to use ultrasound to classify severity of CTS as normal, mild, moderate and severe according to cross-sectional area of the median nerve.

Magnetic Resonance Imaging

MRI indicators of CTS include swelling of the median nerve and increased signal intensity on T2-weighted images [31, 49]. The usefulness of median nerve flattening remains controversial with some papers suggesting that flattening is a positive indicator of CTS [49], and others advising that CTS was more likely in patients who showed no median nerve flattening [31]. With the increased popularity of endoscopic procedures for CTS, it is becoming increasingly necessary to establish the underlying anatomy in order to prevent potential damage to the median nerve in cases where the anatomy is abnormal [29]. Rare pathological causes of CTS such as ganglion, haemangioma or bony deformity are more likely to be uncovered with imaging modalities, and their presence may alter planned surgical intervention [52].

A prospective cohort study by Jarvik et al. [24] attempted to further delineate the role of MRI in the diagnosis of CTS. They reviewed 105 patients and followed the patients for 1 year specifically looking at the ability of MRI to identify those patients likely to benefit from surgery and to compare its diagnostic usefulness to that of EDS. They demonstrated that both MRI and EDS were able to predict those patients who would benefit from surgical intervention; however, neither technique correlated well with patient's perceived severity of symptoms. They did show some evidence to suggest that there is a patient preference for MRI over EDS with 76% of their patients reporting EDS to be unpleasant compared to 21% finding MRI unpleasant.

Imaging provides anatomical information whilst EDS gives information on impairment of nerve fibre function and is able to rule out polyneuropathies and nerve conduction problems elsewhere in the body. With this in mind it is probable that the future of imaging will be in a supplementary role to the already established EDS in cases where anatomical clarification is required or where the results of EDS are equivocal.

Treatment of Carpal Tunnel Syndrome

Treatment of CTS should provide significant improvements in symptoms and value for money whether this be with regard to surgical or non-surgical interventions.

Non-surgical Treatment

Various non-surgical treatment options have been offered to patients with mild to moderate symptoms of CTS. Although significant short-term benefit has been achieved with oral steroids, splinting, ultrasound, yoga and carpal bone mobilisation, the long-term efficacy of such treatments is unclear [45].

The greatest focus of non-surgical research has been around steroid injection. A systematic review by Marshall et al. [39] using data from 141 patients with CTS demonstrated greater clinical improvement in symptoms 1 month after injection compared to placebo (RR, 2.58; 95% CI, 1.72–

3.87); however, it failed to show any significant symptom relief beyond 1 month. It was also unable to show greater therapeutic benefit at 2 or 8 weeks when compared to patients treated with oral anti-inflammatory medication and wrist splinting.

Multiple alternative non-surgical techniques have been trialled. A recent randomised control trial reported acupuncture to be an effective treatment for patients with mild to moderate CTS [63]. In the trial, 77 patients with mild to moderate CTS confirmed by EDS were assigned randomly to either a 4-week course of oral steroids with 2 weeks of 20-mg prednisolone daily followed by 2 weeks of 10-mg prednisolone, or eight sessions of acupuncture over the same time period. Although both groups reported a subjective improvement in their symptoms at 2 and 4 weeks ($P<0.01$), there was no statistically significant difference between the two groups. Interestingly, the study revealed that acupuncture led to a significant decrease in distal motor latency in subsequent EDS compared to those patients taking oral steroids. This demonstrates that an improvement in median nerve function can be both subjectively and objectively measured following acupuncture therapy [63]. The authors however made no mention of attempts to blind the EDS technicians to treatment groups and, with such a short follow-up period, more information with regards to long-term benefits of acupuncture has yet to be established.

Other non-surgical interventions such as magnet therapy, exercise or chiropractic treatment failed to show any significant improvement in symptoms when compared to placebo or control [45].

Surgical Treatment

Surgical options for CTS involve division of the transverse carpal ligament to increase the space in the carpal tunnel [53].

A systematic review of four randomised control trials [17, 18, 21, 37] compared the efficacy of surgical treatment of CTS against non-surgical interventions including splinting and steroid injection [59]. Data from three of the trials [18, 21, 37] involving 295 patients gave information on improvement at 3 months. The pooled data demonstrated more favourable outcomes for those patients who had undergone surgery (RR, 1.23; 95% CI 1.04–1.46). Two of the studies [17, 18] were able to show this clinical improvement was sustained at 1 year (RR, 1.27; 95% CI, 1.05–1.53). The authors concluded that whilst a better response is evident in the surgically treated groups, this was most evident when compared to splinting and that there was insufficient evidence to confirm a better response from surgical intervention over and above steroid injection [59].

A randomised parallel-group trial recently published in the Lancet has added further evidence to support surgical intervention [25]. The authors compared surgical intervention to a rigorous non-surgical programme involving repeated hand therapy sessions, educational information, hand exercises and therapeutic ultrasound for those patients who were not improving at 6 weeks. Information from 101 of the randomly assigned patients showed significant improvement in symptoms for both treatment groups at 1 year. Improvements in the surgical group were more significant than the non-surgical group at 3 months and these improvements were sustained up to 1 year. This demonstrates that surgery is beneficial to patients even when compared to an intensive multi-modal non-invasive approach. A voluntary crossover of 39% of non-surgical patients in this study to surgical care further supports this. However, before advocating a ‘surgery for all’ policy we should consider the 61% of patients in the non-surgical group who showed significant improvement in symptoms and did not require surgery at 1 year.

Much attention has been paid to the relative merits of open versus laparoscopic surgery in the treatment of CTS. Both techniques have been shown to offer a large degree of symptom relief and improvement in health related quality of life [3]. Early studies in the US showed endoscopic surgery to be more costly but more effective than open surgery [13, 58]. Studies in the UK have failed to demonstrate a significant improvement in outcomes in the minimally invasive technique compared to the open procedure [3, 36]. At present, there is no strong evidence supporting the need for replacement of the standard open carpal tunnel release by existing alternative surgical procedures [53].

A surgical technique involving the Knifelight (Stryker, Kalamazoo, MI) combines the advantages of the open and endoscopic methods without the need for endoscopic setup [22]. Studies have shown significant post-operative improvements in pain relief, patient satisfaction and work performance at 3 and 6 months after surgery [22]. Furthermore, it has been shown to have significant advantages over open procedures by reducing pillar pain and recurrence rates as well as leading to a shorter post-operative recovery period [12].

Delivery of Service and Cost-effectiveness

All across the world, economic constraints continue to put pressure on the ability of the health providers to deliver effective efficient healthcare. Waiting times for hospital treatment in the UK have grown since the inception of the National Health Service (NHS), and it is only in recent history that the trend has reversed. This is in part due to government targets, which currently demand that there will be a maximum allowed wait from referral to treatment of no

more than 18 weeks [35]. All health services are accountable to the contributor and the allocations of resources should be directed to maximising health gains against budget constraints [32]. This necessitates assessment of service cost-effectiveness.

In an effort to increase access to definitive treatment for CTS several new service delivery formats have been trialled. Newey et al. [43] audited the clinical outcomes and effect on waiting times of a nurse-led management service for CTS. It involved a single-person-pathway clinic with Consultant supervision, and 395 local anaesthetic procedures were performed on 305 patients over a 2-year period. Comparable outcome scores with published literature were achieved, with complication rates of 2.5% and only 1.3% of patients complaining of no resolution of symptoms. The waiting list was reduced from 105 weeks to 6 weeks. In response, Clarkson and Neil-Dwyer [14] raised concerns about the adequacy of complication monitoring and the negative impact on training, and Burke [10, 11] commented on the lack of cost-effectiveness analysis. The authors responded [44] by presenting cost saving for a nurse-led service. This however does not equate to a cost-effectiveness analysis, and its benefit should be treated with caution.

Jarrett and Giddins [23] introduced and reviewed a system of direct access for carpal tunnel surgery. Clinical criteria for referral were established and disseminated to local primary care physicians. A total of 51 patients were seen, and two were refused surgery. All patients who underwent surgical decompression had improvement of their symptoms. Mean waiting list time was reduced by 4 months, and the cost of an out-patient appointment was avoided. However, 18% of patients were dissatisfied with the lack of pre-operative information. Power and Shewell [48] evaluated 33 patients seen by a direct service compared to a cohort of 40 patients referred through normal channels. Unlike Newey et al. [43], primary care physician referred patients who met certain inclusion criteria for EDS. If these were positive then the patient was referred for direct access surgery. They concluded that the waiting time for definitive treatment was decreased.

Limited work exists on the cost-effectiveness of diagnostic procedures, however, Alvarez et al. [1] analysed the cost-effectiveness of the diagnosis of CTS using EDS. They concluded that EDS for all patients with clinically suspected CTS referred from primary healthcare without neurology screening had an acceptable cost-effectiveness ratio. Interestingly, no published cost-effective analysis was found assessing MRI or ultrasound in the diagnosis of CTS. The possible role for MRI in detailed anatomical imaging prior to endoscopic procedures has also not yet been considered in any cost-effective analyses. Logic would dictate that, with limited indications for MRI or ultrasound, these imaging modalities would not be cost effective. It is likely that MRI will make endoscopic procedures less cost-effective and increase waiting times.

More emphasis has been placed on comparisons of cost effectiveness for treatments. Korthals-de Bos et al. [33] assessed the cost-effectiveness of splinting versus surgery for clinically and EDS confirmed idiopathic CTS. Interestingly, they comment that the overall mean costs per patient were very similar but that symptomatic improvement seen was greater in the surgical group (92% versus 70%). Using an acceptability curve they demonstrate a 90% probability that surgery is more cost-effective. This work is supported by Pomerance et al. [47] who performed a retrospective study of 120 EDS proven CTS. They also found that overall costs were comparable for those treated non-surgically compared to those treated surgically. This translated to favourable incremental cost–utility ratio for carpal tunnel surgery.

Lorgelly et al. [36] performed a randomised control trial to assess open versus minimally invasive carpal tunnel decompression. They concluded that minimally invasive surgery was more effective and more costly, but that the increased expense was not justified. In a similar study Thoma et al. [57] concluded that uncertainty still existed with regards to cost and effectiveness of endoscopic procedures. Their study was influenced specifically by whether the procedure was performed in day surgery or main theatres; if an endoscopic procedure was performed within a day theatre, the incremental cost utility ratio became favourable.

Conclusion

Current best practise would support the use of history, examination and EDS, and there may be a role for targeted questionnaires. The American Academy of Orthopaedic Surgeons guidelines advise EDS for all patients being prepared for surgery. This is supported by Alvarez et al. [1] who assessed the financial implications of different diagnostic strategies and concluded that EDS for all patients with suspected CTS demonstrated an acceptable cost-effectiveness ratio. The role for ultrasound scanning in diagnosis of CTS is yet to be proven. It appears that MRI scanning has a role where a rare cause for CTS may be suspected and also in the detailed reconstruction of the anatomy to aid endoscopic procedures.

Treatment options can be surgical or non-surgical and patient choice will dictate the decision. For non-surgical interventions many options have been trialled but until now only steroid use, acupuncture and splinting have shown discernable benefits. There are two main surgical treatment options, minimally invasive or a traditional open procedure.

When a diagnosis has been established open surgical decompression of the carpal tunnel appears to be the most simple and cost-effective intervention. For those patients who reject surgery splinting, acupuncture and steroid injection can play a role.

Recent work looking at different service delivery options has shown some positive results in terms of decreasing patient waiting time for definitive treatment. Service delivery modalities will have to depend on the individual healthcare provider's facilities and organisational ability. No one system appears to be optimal but one-stop clinics do have attractive qualities. No formal cost-effectiveness analysis however has been published and concerns exist about the impact of a stream-lined service on surgical training.

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