Clinic-based nerve conduction studies reduce time to surgery and are cost effective: a comparison with formal electrophysiological testing

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ABSTRACT

INTRODUCTION Carpal tunnel syndrome is the most common compression neuropathy affecting the upper limb. Clinical diagnosis is not always clear and electrophysiological testing can be indicated when considering a patient for decompression surgery. The downside of electrophysiological testing is cost and increased time to surgery. Newer methods of performing nerve conduction studies in clinic have become available.

MATERIALS AND METHODS We investigated the use of a clinic-based, handheld, non-invasive electrophysiological device (NC-stat®) in 71 patients with suspected carpal tunnel syndrome presenting to our hand clinic in a district general hospital. We compared this to a similar cohort of 71 age-matched patients also presenting to our unit in whom formal nerve conduction studies were performed at a local neurophysiology unit. Our outcome measures were time from presentation to carpal tunnel decompression, the cost of each pathway and the practicalities of using the device in a busy hand unit.

RESULTS AND CONCLUSIONS The NC-stat® proved to be a successful device when compared with referring patients out for more formal nerve conduction studies, shortening the time from presentation to surgery from 198 days to 102 days ($p < 0.0001$). It was also cost effective with a calculated saving to the hospital of more than £70 per patient. The device is easy to use and acceptable to patients and no adverse effects were noted.

KEYWORDS

Carpal tunnel syndrome – Nerve conduction studies – Clinic-based – Carpal tunnel decompression

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The prevalence of carpal tunnel syndrome (CTS) in the general population has been reported as 3%¹ and accounts for a large number of presentations to a hand clinic. Traditionally, diagnosis has been made on the patient's history and clinical examination by a hand surgeon, supplemented and confirmed by electrophysiological investigations only in equivocal cases. As well as confirming diagnosis, nerve conduction studies (NCS) also provide additional information regarding severity and progression and an exclusion of concomitant peripheral nervous system abnormalities.^{2,3}

Surgery for CTS is high volume, quick turnover day surgery, performed under local anaesthetic. Carpal tunnel referrals have therefore become popular with all healthcare providers and have manifested themselves in one-stop clinics and protocol-driven pathways. These are often staffed by allied health professionals such as nurse consultants, extended scope practitioners and general practitioners. Due to the implementation of protocols used by the multidisciplinary team, many hand units perform NCS on every patient who is considered for surgery. The growing trend towards litigation has also increased the number of patients referred for NCS. The increasing need for an objective record of

nerve function preoperatively led the American Academy of Orthopaedic Surgeons to modify its guidelines in 2007, recommending NCS in all patients being considered for decompression surgery.⁴

Electrophysiological testing is usually not universally available, especially in a district general hospital setting, and hence referral to a larger unit is required. This occurs at inconvenience to the patient (time, travel and expense) and further cost to the hospital. In the current climate of increased patient choice and greater financial constraints on NHS trusts, these are important factors to consider. Handheld or portable nerve conduction devices have been previously evaluated and have been shown to be reproducible and reliable in CTS.^{5–7} The NC-stat® (NeuroMetrix® Inc, Waltham, Massachusetts, US) is a non-invasive, portable, validated electrophysiological device that can perform NCS on the median and ulnar nerves rapidly and reliably.^{8–11}

The aim of this study was to assess the application of clinic-based NCS using this device on patients referred to a UK district general hospital with suspected CTS. Given the current political and financial pressures on the NHS, we

focused on any potential cost savings this device could create and the length of time it took for the patients to have their operations. These results were then compared with a second group of patients who received formal electrophysiological testing performed by a neurophysiologist.

Materials and Methods

All patients presenting to our orthopaedic hand clinic in a medium-sized district general hospital (catchment area of 360,000) who had a suspected diagnosis of CTS after history and examination were offered NCS in clinic. Those with known or suspected complex neurological conditions were excluded from the study. There were no other exclusion criteria.

Those patients who accepted to have NCS performed in clinic were allocated to Group 1 and their outcomes were recorded. The outcomes of this group were later compared to a retrospective cohort of the same number of consecutive patients who had been sent for NCS to the nearby regional neurophysiological unit (as had been our previous protocol).

The device used to perform all the clinic-based NCS was a portable handheld nerve conduction system, NC-stat®, shown in Figure 1.

Once a decision to perform NCS was made, the reasons for the investigation were explained and an explanation into exactly how the device works was given to the patient. The NCS was then carried out in a nurse-led clinic (trained and supervised initially by a company representative) either on the same day as the consultation or at the next available clinic. The system utilises disposable, single-use electrode pads that are carefully applied to the patient’s skin around the forearm and wrist (Fig 2).

NCS using the median nerve electrode pads was performed on both upper extremities of each patient, recording bilateral investigations to allow comparison. If, as in some cases, there was a mixed or unclear presentation, ulnar nerve electrode pads were used in addition, again bilaterally. The data were recorded by the machine and relayed telephonically to an electronic database stored by Neuro-Metrix® in the US. This database compares the data with

Figure 1 NC-stat® device used for clinic-based nerve conduction studies; when returned to its cradle, the data can be sent telephonically to an electronic database for interpretation

Figure 1 A single-use median nerve electrode for use with NC-stat®

Table 1 Comparison of waiting times for a decision to surgery, time on waiting list and total time from presentation to surgery in the two groups

	Mean time to decision for CTD (standard deviation)	Mean time on waiting list for CTD (standard deviation)	Mean total time from presentation in clinic to CTD (standard deviation)
Group 1: NC-stat® <i>n</i> =45	29.2 days (20.8)	73.5 days (10.6)	102.7 days (24.8)
Group 2: Referral <i>n</i> =45	122.8 days (32.4)	77.0 days (11.8)	198.8 days (35.3)
Statistical significance	<i>p</i> <0.0001	<i>p</i> =0.1514	<i>p</i> <0.0001

normal ranges and returns results electronically within minutes (by email or fax). These results were reviewed by the senior author (PD). If the results were consistent with CTS, patients were offered direct entry onto the waiting list for carpal tunnel decompression (CTD) or a further clinic appointment to discuss the results. If the results were not consistent with CTS, further investigations or referrals were organised as indicated.

NC-stat® technique

The electrode pads supramaximally stimulate the patient's median and ulnar nerves, 3cm proximal to wrist crease. Motor parameters measured include the distal motor latency (latency to initial negative deflection), compound muscle action potential amplitude (baseline to negative peak) and F-wave (median latency from at least ten F-responses). Sensory parameters measured include the distal sensory latency (latency to negative peak, median: wrist to third digit proximal interphalangeal joint, ulnar: wrist to fifth digit proximal interphalangeal joint) and the sensory nerve action potential amplitude (measured from negative peak to positive peak). Digital thermometers embedded in the device allow normalisation of data to a standard temperature (32°C) and all nerve conduction parameters are corrected

for patient age (five-year increments) and height (one-inch increments) prior to determination of abnormalities.

Once the adhesive electrodes have been placed on the patient's forearm and the device has been attached, a reading is given in approximately two minutes. Each appointment with a trained nurse therefore lasts roughly ten minutes per patient, with an additional ten minutes if ulnar nerve testing is appropriate.

Our main outcome analyses were waiting times for NCS, time to surgery and a cost analysis of the two different pathways. These parameters were all based on figures correct and available at the time of the writing of this paper. Statistical analysis was performed using a Mann-Whitney U test for unpaired non-Gaussian data using 95% confidence intervals.

Results

Over a 40-week period, 77 patients attended our hand clinic with suspected CTS. The mean age was 55 years (range: 19–90 years) and of these patients 27 were male and 50 female. Six patients with suspected or known complex neuropathies were excluded and referred directly to the regional centre for formal electrophysiological testing. The remaining 71 patients were offered NCS in clinic. All 71 patients agreed to be tested using the device (Group 1). We then compared their outcomes to 71 consecutive patients who had been sent for formal NCS to our local neurophysiological unit (Group 2). The outcomes of all 148 patients are illustrated in Figure 3. In Group 2 there were 31 males and 40 females with an average age of 59 years (range: 25–86 years).

In Group 1, 43 out of the 71 patients (61%) had a diagnosis of CTS (mild: 12, moderate: 9, severe: 22) confirmed by NC-stat® and underwent decompression surgery. The remaining 28 patients (39%) had normal or inconclusive tests and were not offered decompression surgery. Twelve of these patients were referred for electrophysiological testing at the regional centre because the NC-stat® data suggested a more proximal lesion (*n*=7) or the study was inconclusive (*n*=5). Of these, two were recommended for surgery following formal electrophysiology testing and were added to the waiting list for CTD. The remaining ten were not diagnosed with CTS and were managed differently or referred to a more appropriate specialty as indicated by their subsequent suspected diagnosis.

Table 1 Cost analysis between the two groups based on expenditure from our two cohorts of patients. For simplicity the analysis has been calculated per 100 patients before and after the initial purchase cost of the NC-stat® device has been recovered by the saving.

	First 100 patients	Subsequent 100 patients (after cost of NC-stat® is recovered)
Group 1: NC-stat®	NC-stat®: £3,995 Electrodes (£29 x 290): £8,410 Clinic nurse (£70 x 15.5): £1,085 20% extra referral rate (£210 x 20): Total cost:£17,690 £176.90 per patient	Electrodes (£29 x 290): £8,410 Clinic nurse (£70 x 15.5): £1,085 20% extra referral rate (£210 x 20): Total cost:£13,695 £136.95 per patient
Group 1: NC-stat® Group 2: Referral	Total cost:£21,000 £210 per patient	Total cost:£21,000 £210 per patient

In Group 2, 44 of the 71 patients (62%) sent to the regional centre for formal electrophysiology testing were diagnosed with CTS. There is no statistical difference in the diagnosis of CTS between the two groups.

Table 1 shows the mean time the patients waited for a decision and the total time to surgery for each group. Those patients who were investigated with clinic-based NC-stat® waited a mean of 96 days less than those who had formal electrophysiology testing. This was statistically significant ($p<0.0001$).

Cost analysis

Group 1: The cost of clinic-based testing with NC-stat® consists of the initial purchase of the machine (£3,995), disposable electrodes (£29 each) of which 203 were used for 71 patients (average of 2.9 per patient) and an extra nurse for one extra clinic per fortnight (£70). Therefore, the total cost of the NCS for the 71 patients in Group 1 was £10,652 (or £150 per patient).

Group 2: The hospital trust is charged £210 per patient for formal NCS at the regional centre equating to £14,910 for 71 patients.

This represents an initial saving of £4,258 for a cohort of 71 patients between the two groups. However, 12 patients in Group 1 required additional formal NCS testing (at a cost of £210 per patient), reducing the cost saving to a total of £1,738 (or £24.48 per patient).

With this saving of £24.48 per patient we have calculated that it will take 163 patients for the purchase cost of the NC-stat® device to be recovered. These results are summarised in Table 2.

In Group 1 the testing was well tolerated in all cases and no adverse effects from using the NC-stat® device or its adhesive electrode pads were noted in any of the patients.

Discussion

Our study has shown that performing clinic-based NCS with the NC-stat® device leads to a considerable reduction in the cost of diagnosing CTS when compared to sending patients to a nearby neurophysiological centre. It also has the potential to significantly reduce the waiting times to surgery for patients with CTS. There are, however, two important factors to consider before recommending this device for wider implementation: first, justification for performing electrophysiology for all patients with the suspected condition and, second, the practicalities of using this particular device in a busy hand clinic.

There is an abundance of evidence to support the belief that NCS is not necessary in patients with a classical presentation of CTS and that electrodiagnostic tests do not change the probability of diagnosing this condition in simple cases.¹²⁻¹⁵ However, the weakness of these studies is that they do not consider those patients being diagnosed by allied healthcare workers (eg hand specialists, generalists, general practitioners, physiotherapists, extended scope practitioners). Nevertheless, these same articles do all acknowledge that NCS can be useful in more atypical cases.

Some surgeons confirm their clinical diagnosis with NCS in all cases and seldom operate without this confirmation.¹⁶ The reason for this is probably due to the lack of a universally accepted consensus and a known variability in sensitivity and specificity of the described clinical tests.¹⁷

More recent literature suggests that history and examination should be used as first-line screening only because there is a poor agreement (51.5%) between the suspected diagnosis and NCS.^{18,19}

On balance, with this information and previously discussed issues, we consider NCS to be a necessary investigation before proceeding to decompression surgery. When this is the case, our study has shown that clinic-based NCS can reduce the patient's journey from presentation to surgery by almost 14 weeks, with significant cost savings of over £73 per patient for the trust. While waiting times and cost savings remain a high priority, this presents a significant ad-

vantage in the management of this common condition.

Since our initial cohort, current experience with the device is providing further improved results. Due to the increase in experience of the clinic nurses and familiarity with using the device, 10 patients can now be tested per clinic (20 per month), which should provide additional savings.

As the system utilises a diagnostic algorithm, interpretation of the results both positive and negative must be considered in conjunction with the history and clinical findings, and this is a necessary note of caution. The use of absolute values in the algorithm may sometimes produce conclusions that are inconsistent with the rest of the test values. Therefore, while the system produces both the numerical values for latency and amplitude and an interpretation, clinician review of the results is still required.

Furthermore, we referred almost 17% of our cases for formal testing as a result of either inconclusive results or a study suggesting a more proximal lesion. Two of these patients were subsequently diagnosed with CTS after formal testing and had CTD surgery suggesting the NC-stat® gave a false negative result 3% of the time. The inconclusive results were attributed to user error and biosensor failure (for which the manufacturer refunded the cost of the wasted electrodes). We suspect that the number of these inconclusive results is likely to be reduced with increased experience of the tester and increased familiarity with the results format but we acknowledge that a 20% referral rate for further NCS to a different unit is high.

Conclusions

Clinic-based NCS cannot replace the skills of a trained neurophysiologist in the investigation and diagnosis of complex or proximal nerve lesions. This study has found the NC-stat® system to be a convenient and welltolerated adjunct to the diagnosis of CTS. As well as offering value for money, the use of this device significantly reduced the time from referral to treatment and smoothed the patient journey through the diagnosis and treatment of this common condition.

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