Supporting occupational health and wellbeing professionals

Nerve Conduction Studies (NCS) in workers exposed to Hand-Transmitted Vibration (HTV)

Referral Criteria and Interpretation of Results

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The aim of this document is to assist occupational health practitioners to determine if, and in what circumstances, it may be necessary to refer for Nerve Conduction Studies (NCS) in workers exposed to hand-transmitted vibration (HTV).

The report covers a basic understanding of NCS, recommends a set of referral criteria for those exposed to HTV along with a broad précis on the interpretation of results. This should assist occupational health practitioners informing decisions on diagnosis, management and workplace restrictions in cases of suspected Carpal Tunnel Syndrome (CTS) in vibration exposed.

The document should be read in conjunction with SOM HAVS SIG publication ‘Carpal tunnel syndrome and work with hand-held vibrating tools.’

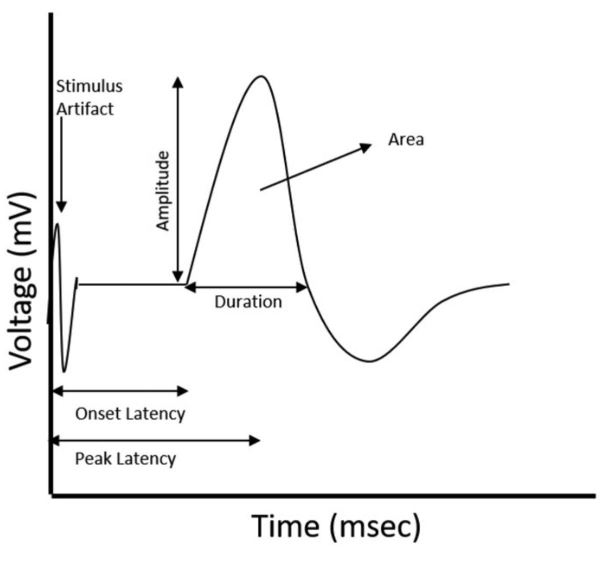
BACKGROUND

The referral for Nerve Conduction Studies (NCS) as part of health surveillance has both cost and time implications and is not generally regarded as part of routine health surveillance of vibration exposed employees. However the role of NCS in the assessment of employees exposed to HTV has both potential benefits and drawbacks.

In addition, whilst NCS can assist in the diagnosis, grading and differential diagnosis of suspected CTS not all clinicians support this utility.[1,2,3] Studies by Lew and Atroshi suggest that NCS has a sensitivity of about 75%.[4,5] Edwards and Frampton deployed a six domain questionnaire to identify those scoring above a predetermined CTS 'threshold' and demonstrated a reduction in the need for NCS by nearly 50% with a significant potential cost saving.[6] Violante noted that epidemiological studies of occupational CTS often report asymptomatics with electrophysiological evidence of median neuropathy and many symptomatics that did not.[7]

Notwithstanding these caveats, atypical clinical cases do arise and the likelihood of CTS may need to be ruled in, or ruled out, given the multiple clinical end points that can arise following exposure to HTV e.g. vascular and sensory HAVS, CTS or co-morbid combinations of compressive neuropathies.[8]

Figure 1: Action potential (DaSilva et al)[9]



BASIC GUIDE TO NERVE CONDUCTION STUDIES (NCS)

The peripheral nervous system transmits rapid impulses via myelinated motor and sensory nerve fibres which can be detected by measuring their action potentials. Slower conduction is via unmyelinated nerve fibres. The physiological direction of transmission e.g. in motor nerves towards a muscle and in sensory nerves towards the spinal cord is referred to as orthodromic. In nerve conduction studies an electrical stimulus applied to a nerve containing both motor and sensory fibres can fire in both directions, orthodromic and antidromic (opposite of physiological) and then measured by suitably placed surface electrodes.

Orthodromic motor responses are referred to as compound muscle action potentials (CMAP) and antidromic as F-waves thus providing information about the distal and proximal portions of motor nerves. Sensory conduction is usually recorded by an antidromic electrode placed over the distribution of the cutaneous nerve under test giving rise to a sensory nerve action potential (SNAP). Whilst there are various conventions on placement and distance of recording electrodes, the resulting recordings allow for the measurement of a latency period (DSL; distal sensory latency, DML; distal motor latency) prior to an action potential (see *Figure 1*) and along with distance travelled by an impulse allows the calculation of a conduction velocity (CV).

Whilst numerous other values may be reported in neurophysiology reports these provide the mainstay of interpretation and are sufficient for understanding by the occupational health practitioner.

NEUROPATHOLOGY AND NERVE INJURIES: DEFINITIONS

Neurapraxia

A mild nerve compression such as nerve injury or acute entrapment neuropathy leading to demyelination with remyelination usually occurring in days to weeks. This can have an initial impact on conduction velocity and distal latencies.

Axonotmesis

More severe and prolonged compression leads to damage to the distal nerve axon with poorer likelihood of recovery or taking months. This can cause reduced or absent amplitudes along with slowing conduction velocities and latencies. Complete disruption to axons is called neurotmesis.

Other considerations

Diffuse polyneuropathies may show features of both myelin and axon damage in NCS results. Also, there is often a combination of myelinopathy and axonopathy with more severe nerve entrapments and as such results of specific NCS metrics can help classify cases into mild, moderate and severe (see section on interpretation and severity).

Finally, it should be noted that standard NCS tests the larger diameter and fastest conducting sensory fibres which comprise only 20% of the whole nerve and as such do not help to exclude a peripheral receptor level neuropathy such as occurs in HAVS.[10] There is some limited evidence to suggest smaller diameter fibres may also damaged in severe CTS.[11,12]

NERVE CONDUCTION STUDIES IN VIBRATION-EXPOSED WORKERS

Where fractionated nerve conduction velocity has been performed on symptomatic vibration-exposed subjects a bimodal distribution of nerve conduction velocity was found pointing to effects at both the level of the carpal tunnel and more distally at palmar or finger level.[13] Other studies have found delayed sensory nerve conduction in the digits.[14,15] By contrast, the study by Lander et al using standard NCS demonstrated that the predominant neurological abnormality identified in workers using vibrating tools were neuropathies of the ulnar and median nerve that were proximal to the hand.[16] This contrasts with an earlier study using fractionated antidromic NCS of digital, digital to palm, palm to wrist and wrist to elbow segment sensory nerve conduction velocity of median nerve (n =56 controls 43).[17] The study showed slowing across both carpal tunnel (wrist to palm) and digital segments with the slowing in the digital segment correlating with late stage HAVS (Stockholm sensorineural: stage 0SN 10% and 56% 3SN). Fractionated NCS is usually not available to the occupational health practitioner, but this type of multilevel testing has the potential to play a future role in both differential diagnosis and staging of HAVS.

The limitation of standard NCS alone for detecting the site of injury, either because of the variety of diameters in sensory nerve fibres that pass through the carpal tunnel, or because the injury is in the more distal smaller fibres and receptors in the palms and fingers, suggests it has little value in the routine surveillance of vibration exposed. Sanden et al followed up a vibration exposed cohort of manual workers and controls over 21 years and found no exposure response relationship and concluded that NCS may not be a sensitive method for detecting smaller vibration-related pathological changes.[18] Giannini et al summarised the dilemma succinctly following an electrophysiological study of forestry workers as 'vibration-induced neural involvement can be considered neither pure digital neuropathy, nor definite CTS.'[19] Therefore where there is a clinical suspicion of CTS in vibration exposed there is a case for recommending both standard NCS and receptor level QST, particularly when CTS, if found is usually amenable to treatment.[20] In addition, a diagnosis of the dual pathology of CTS and HAVS should only be made after full assessment and treatment of the CTS if present. In this case an assessment of the stage HAVS has reached can at best be presumptive and only confirmed following the treatment of CTS.

Another benefit of targeted NCS in vibration exposed is the elimination of other proximal compressive neuropathies such as Cubital Tunnel Syndrome (CuTS) that may contribute to sensory symptoms in the hand. Cubital tunnel syndrome is the second commonest compressive neuropathy in the upper limb and should be discounted in vibration exposed who report nocturnal symptoms predominantly confined to the ulnar supplied fingers. It should be added here that epidemiological evidence for a causal attribution of CuTS to vibration is very limited. Karkosy et al investigated vibration exposed workers by neurophysiology and electromyography (n=167) and found a high prevalence of upper limb compressive neuropathies and found 42.5 per cent had CuTS.[21] Yet a further retrospective study by the same lead author[22] of 154 foundry workers using chipping hammers and grinders reported 41 cases of 'distal' type neuropathy and 21 cases of compressive neuropathy more consistent with the findings by Lander.[16]

Dasgupta et al found 23 cases of ulnar nerve neuropathy out of 66 jack hammer users in a questionnaire and motor nerve conduction study.[23] Sanden et al found no increased prevalence of ulnar nerve abnormalities.[18] Whilst the evidence base to support the case of working with hand held vibrating tools being a risk factor for CTS is significant, the equivalent evidence for other compressive neuropathies remains uncertain. In a recent study Ahmed et al found an overall higher prevalence of compressive neuropathies in patients examined for HAVS and concluded that NCS should be included in HAVS assessment (n= 431, 45% median neuropathy and 7% ulnar neuropathy) acknowledging that previous studies on ulnar neuropathy were comparable with non-exposed.[8]

One advantage of the addition of NCS in vibration exposed is in differentiating between the potential location of any neurological damage i.e. along the nerve trunk or at the receptor level.[24,25] The presentation of sensory symptoms in vibration exposed do not necessarily follow a typical pattern of either a regional entrapment or a peripheral neuropathy. For example, if the median or ulnar nerves are compressed at the wrist then vibrotactile thresholds (large myelinated fibres and mechanoreceptors), possibly cold thresholds (small myelinated fibres) and nerve conduction velocities may all be abnormal. However, if nerve conduction studies are normal but vibrotactile and thermal thresholds are abnormal, this points to the damage being at the receptor level. In this context the combination of NCS and sensorineural tests in a vibration exposed individual with sensory symptoms are more than just a test of severity but a tool of differential diagnoses supporting a diagnosis of HAVS.[25] Stromberg et al previously suggested that severe sensory HAVS was reflected in results of vibrotactile thresholds but not in neurophysiological results[26].

POINT-OF-CARE NERVE CONDUCTION STUDIES (POC NCS)

The advent of devices for point-of-care nerve conduction studies (POC NCS) offers a solution to the problem of time and costs in the health surveillance setting.[27] Various devices are commercially available (e.g. NEUROmetrix® ADVANCE™ and Mediracer®) which measure various neurophysiological parameters. To measure severity, it is preferable to choose a device that measures sensory and motor latencies with their amplitudes and has an F-wave functionality. Whilst having the same potential for false positives and negatives as conventional NCS their accuracy by comparison has been reviewed in a meta-analysis of median neuropathy concluding clinically relevant accuracy (n = 448, sensitivity 88%; specificity 93%).[28] However, the American Academy Orthopaedic Surgeons (AAOS) currently report only limited evidence in support of these hand-held devices.[29] Yet it has been shown that NCS when used in vibration exposed the prevalence of median and ulnar neuropathy proximal to the hand is greater than presumed by history and examination alone.[16] Descatha et al used POC NCS and found physical examination, either alone or combined with appropriate symptoms, did not sufficiently predict CTS in a working population (n=1108) and suggested using specific symptoms as a screening tool, and only NCS as confirmation.[30]

REFERRAL CRITERIA

With the caveats outlined above a set of referral criteria has been devised.

1. Where there is doubt over differential diagnosis of sensory HAVS, CTS or CubTS.
2. Where the diagnosis is suggested by history but there is a reluctance to pursue treatment options or accept workplace restrictions or modifications.
3. To grade CTS and act as an adjunct to advice on workplace restrictions and inform recommendations for referral and treatment plans.

The National Institute for Health and Care Excellence (NICE) on CTS specialist assessment and management includes advise on NCS referral:

https://cks.nice.org.uk/topics/carpal-tunnel-syndrome/management/management/

INTERPRETATION OF RESULTS

Whether conventional laboratory NCS or clinic POC NCS is carried out, the occupational health practitioner should have a rudimentary understanding of test results. Whilst neurophysiologist or test generated results are normally reported there are some key parameters that the practitioners should be aware of. In addition, the separation into mild, moderate or severe CTS is useful in the context of advising on the type of initial clinical management and interim advice on continuing exposure. Both motor conduction and the sensory conduction are required to distinguish CTS severity. Laboratories report against their normative data which can vary between centres depending on methodologies used (e.g. electrode positioning and distances measured including the direction orthodromic or antidromic).

Age, sex, height and weight can also influence results such that using standard reference tables can impact sensitivity and specificity.[31] For example, age can have a significant effect on conduction velocity which can vary from 50 m/s to 70m/s in adults declining after 40 years of age. As well electrode placements and distance measured, the size and temperature of the hand, the equipment used and recording techniques all impact the results (usual position for the active electrode in motor studies is the abductor pollicis brevis (APB) for median nerve and adductor digiti minimi (ADM) for ulnar nerve and for sensory studies digit 2/3 and digit 5 respectively and normally indicated on the report). Sometimes onset latency is reported and sometimes peak latency.

Comparison of symptomatic and contralateral hand and median ulnar differences can often be more useful than normal value tables. Therefore, the occupational health practitioner should always be mindful of the normative values of the reporting laboratory. With these caveats in mind, reproducing tables showing fixed normative values is therefore not appropriate for the purposes of this document other than to list some general adult upper limb by way of example to familiarise practitioners with the type and scale of values reported:[32]

SNAP: ≥ 20 µV*

DSL: peak median ≤ 3.5 ms; peak ulnar: ≤ 3.0 ms

CAMP: ≥ 5 mV

DML: median ≤ 4.2 ms; ulnar: ≤ 3 m/s

CV: ≥ 50 m/s

Median Ulnar Difference, MUD: (e.g. DSL ulnar subtracted from DSL median) ≤ 0.3 to 0.4 m/s

* For example, as well as individual factors laboratory norms may vary e.g. ≥ 10µV to ≥ 15µV and normative median nerve SNAPs are generally reported as higher than ulnar nerve e.g. AANEM 13µV and 9µV (AANEM data https://www.aanem.org/getdoc/9781edf5-f279-4c58-8a1b-24abc61a2c98/Electrodiagnostic-Reference-Values-for-Upper-and-L.aspx).

SEVERITY SCALES AND CASE MANAGEMENT

Whilst CTS severity can be assessed clinically by staging symptom progression[33] without recourse to NCS, some severity scales based on NCS results have been developed. Padua et al in a prospective study in 500 hands with CTS symptoms categorised severity following neurophysiology: extreme CTS (absence of median motor, sensory responses), severe (absence of sensory response, abnormal Distal Motor Latency, DML), moderate (abnormal Sensory Nerve Conduction Velocity, SNCV, abnormal DML), mild (abnormal SNCV, normal DML).[34] A review of normative data used in electrophysiological categorisation systems for CTS and those used in POC NCS have been published.[35,36] Severity scales that incorporate symptoms with NCS results or ones that assist in treatment options have also been devised (Appendix 1).[37,38]

As stated, full neurophysiological testing can be expensive, time consuming and sometimes uncomfortable so a simpler method is to compare ring finger sensory latency (median and ulnar) referred to as the median ulnar difference (MUD) which has been shown to correlate with the severity of CTS[39]. Categorisation into severity may not however provide any longer term prognostic value following optimal surgical treatment.[40] The American Academy of Orthopaedic Surgeons (AAOS) has developed appropriate use criteria (AUC) for the management of CTS using a scoring system (Appendix 1) which has been found to be a practical tool in case management.[41]

The availability of these severity grading tools may assist not only with decisions on treatment options but act as an adjuvant on decision making regarding exposure. For example, with informed consent and an understating of potential risks, milder cases may be able to continue at work using vibrating tools with reduced exposure where feasible whilst awaiting investigations, whereas moderate to severe cases should avoid all vibration exposure until after investigation and treatment as appropriate. Irrespective of severity and attribution of compressive neuropathy in vibration exposed workers an awareness of the ergonomic risks inherent in the use of hand-vibrating tools should also be factored into the advice on workplace exposures.[42]

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APPENDIX 1:
SEVERITY SCALES AND AAOS APPROPRIATE USE CRITERIA AUC

Scale 1 (Sonoo et al)[38]

CTS Severity	Electrodiagnostic findings	Intervention
CTS without median neuropathy at the wrist (MNW)	None	Symptomatic treatment
Mild	Abnormality in comparison studies or median sensory nerve	Symptomatic treatment
Moderate	Prolonged distal motor latency to the abductor pollicis brevis with normal APB CMAP amplitude	Injections/surgery with progression
Severe	Above plus either reduced median to APB CMAP amplitude and/or abnormal needle EMG in the thenar muscles	Surgery if not contraindicated

Scale 2 (Szabo et al)[37]

Severity of CTS	Description & NCS
Stage 1	Transient epineural ischemic episodes cause intermittent pain and paresthesia in the median nerve's field in the hand. These symptoms typically occur at night or following specific activities such as driving a car or holding a book or newspaper, and suggest the presence of nerve transmission disorders.
Stage 2	Constant paresthesia and tingling, corresponding to disturbed intraneural and epineural microcirculation concomitant with intrafascicular oedema. Electrodiagnostic tests usually reveal abnormal sensory conduction.
Stage 3	Sensory and motor function are permanently damaged, and there is atrophy of the thenar eminence. Electrodiagnostic tests are abnormal, and demyelination and axonal degeneration secondary to prolonged endoneural oedema may be present.

3. **Appropriate use criteria: carpal tunnel syndrome management.**
   https://www.orthoguidelines.org/go/auc/auc.cfm?auc_id=224989

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