A comparison between two methods of aesthesiometric assessment in patients with hand–arm vibration syndrome

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Hand–arm vibration syndrome (HAVS) is caused by prolonged exposure to vibration. The diagnosis and assessment of disease severity are subjective at present. The aim of this study was to determine sensorineural dysfunction in patients with HAVS using two methods of aesthesiometric assessment. We recruited three groups of age-matched subjects: 20 subjects diagnosed as having HAVS, 15 manual workers and 15 sedentary workers. We measured both two-point discrimination and depth sense perception using an aesthesiometer. We found that the two-point discrimination wheel was more accurate than the depth sense perception wheel at detecting levels of sensorineural dysfunction in subjects with HAVS. The increased sensitivity of the two-point disc would suggest that it should be used in preference to the depth sense disc for the assessment of sensorineural dysfunction in patients with HAVS.

Key words: Aesthesiometry; depth sense perception; hand–arm vibration syndrome; two-point discrimination.

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Introduction

Hand–arm vibration syndrome (HAVS) is a progressive disease brought on by excessive exposure to vibration over a prolonged period. There are three components to the syndrome:

1. Circulatory disturbances (vasospasm and finger blanching—thus leading to the typical ‘white finger’).
2. Sensory and motor nerve damage (tingling, numbness and loss of dexterity).
3. Musculo-skeletal disorders (changes in the structure of the joint, bone or muscle).

The diagnosis of HAVS is based upon the presence of symptoms, either singularly or in combination with an occupational history of vibration exposure, and the exclusion of other known causes of conditions that can mimic HAVS. Disease severity is graded using the Stockholm Workshop scale [1,2] and previously by the older Taylor–Pelmear scale [3]. These scales are based upon subjective findings, and there is still debate as to the most appropriate objective method of assessment of disease severity.

No single test can accurately determine disease severity in patients with HAVS, and therefore it has been recommended that a number of complementary tests be used [4].

Cold provocation thermography (CPT), finger systolic pressure measurements and isotope studies have all been used to determine the severity of the vascular aspect of the disease, although it has been shown that CPT fails to differentiate between the varying stages of disease severity as classified using the Stockholm Workshop scale [5–7]. Assessment methods for determination of peripheral neurological deficit have included vibration perception, temperature threshold measurements, electrophysiological studies, and aesthesiometric threshold testing with two-point discrimination (TPD) and depth sense perception (DSP) [8].

The aim of this study was to evaluate the effectiveness
of two different modalities of aesthesiometry (TPD and DSP) to assess its role in determining dysfunction in digital sensibility that may occur in patients with HAVS.

Materials and methods

Twenty consecutive patients with HAVS (median age 49 years, range 25–61 years) who were referred to our vascular laboratory for assessment, 15 age-matched sedentary workers (median age 48 years, range 20–51 years) and 15 age-matched manual workers (median age 47 years, range 31–59 years) were recruited. All subjects examined were men. TPD and DSP testing were performed using a wheel aesthesiometer. None of the control subjects had a history of hand disorder, pertinent medical problems or vibration exposure. Subjects with HAVS underwent a thorough history (using a specifically designed questionnaire) and examination to confirm the presence of symptoms suggestive of HAVS and a history of vibration exposure, as well as to exclude other known causes of Raynaud’s phenomenon and other conditions known to mimic HAVS. Haematological, biochemical and immunological investigations were undertaken to confirm causes of secondary Raynaud’s phenomenon. Further investigation to confirm the presence of carpal tunnel syndrome was only undertaken if clinical examination was suggestive of the condition. The HAVS patients were either chainsaw users, miners or road workers who had used pneumatic tools. All patients with HAVS were classified as either stage 2 or 3 on the Stockholm Workshop sensorineural classification. The number of years each subject with HAVS was exposed to vibration was recorded (median 31.5 years, range 10–46 years). All the patients with HAVS and all the control subjects underwent aesthesiometric assessment by a single examiner to determine TPD and DSP. This followed a 12 h period of abstinence from exposure to vibration in order to remove any temporary vibration-induced shift in sensory threshold of the fingers. The aesthesiometer used was developed from Renfrew’s initial design and was similar to the one used by Corlett [16].

The wheel aesthesiometer is mostly made from plastic (as it is a poor conductor of heat and therefore only a small amount of heat is transferred from the examined finger to the instrument), apart from a supporting base and a rotatable knob, which are made of metal. The aesthesiometer is composed of three basic components: a plastic box, to blind the subject from the actual stimulus of the wheel; a metal base that supports and stabilizes the machine; and a stimulus disc. There are two types of stimulus disc:

1. A DSP wheel. This disc consists of a single ridge of variable height from 0 to 2 mm. This disc allows measurement of pressure threshold, indicated by the minimum stimulus perceived.

2. A TPD wheel. This disc consists of a single ridge of a standard height that gradually diverges into two ridges, reaching a maximum distance between the ridges of 8.74 mm at 180° around the wheel. This disc allows the determination of a digital spatial discrimination threshold whereby the finest digital resolution is recorded.

Both wheels were used in the study in order to determine which disc was the more sensitive for disease assessment.

The digit being tested is supported by a plastic slide with a v-shaped cut-away portion that is positioned between the side of the box and the disc (Figure 1). This enables the subject being tested to hold the finger in the correct position. Either of the two stimulus discs is mounted onto a metal spindle. Turning of the knob results in the disc being turned in the same manner. A circular protractor, which rotates as the knob is being turned, acts as a marker for the stimulus level of the disc. A horizontal line in the centre of a clear plastic window provides the set level at which the protractor should be read. A metal spring mounted on the supporting base and placed between the base and the box ensures that the same pressure is always applied by the finger to the stimulus disc by providing resistance to the movement of the box (Figure 2).

The protocol of examination was adhered to for each patient, and is described below.

Testing using the DSP wheel

The disc is placed in the machine so that the highest part of the ridge (2 mm) is exposed and correlates to a figure of 180°. The subject places the right thumb on the wheel so that the pulp of the finger is touching the wheel. The wheel is then turned, and the subject is instructed to state the point when the ridge can no longer be felt (down threshold) and again when the ridge first reappears (up threshold). At each point, the protractor reading is noted.

Testing using the TPD wheel

The stimulus disc is set so that only one ridge is felt. The finger is again placed so that the pulp of the distal phalanx is placed against the wheel. The subject is asked to state when two ridges are first detectable (divergence), and again when only one ridge can be felt (convergence). All 10 digits were tested three times, and the mean values for each hand were used for subsequent analysis. Protractor readings in degrees were converted to the measurement in millimetres which corresponded to the ridge height or distance between the two ridges of the respective wheels, using a conversion chart specific to each wheel.
Statistical analysis was performed using the Kruskal–Wallis test, with a P-value of <0.05 considered statistically significant. Results are expressed as median and interquartile ranges.

### Results

#### DSP wheel

No significant difference was found between the values obtained for the down thresholds of both hands and the up threshold of the right hand of the HAVS group, the manual worker group or the sedentary worker group (P > 0.05). The up threshold of the left hand was significantly poorer in the HAVS group (median value 1 mm, IQ range 0.92–1.19 mm) compared with the manual worker group and the sedentary worker group (0.59 mm, 0.49–0.72 mm and 0.49 mm, 0.39–0.72 mm, respectively; P < 0.01) (Figure 3). No significant difference was determined between values from the manual group and the sedentary group.

#### TPD wheel

The convergence thresholds obtained in both hands were significantly poorer in the patients with HAVS compared with both the manual and sedentary workers (left hand: 1.68 mm, 1.36–2.54 mm versus 3.04 mm, 2.80–3.28 mm and 2.80 mm, 2.29–3.04 mm, respectively, P < 0.01; right hand: 1.35 mm, 0.73–2.34 mm versus 2.92 mm, 2.17–3.52 mm and 2.32 mm, 2.02–2.71 mm, respectively, P < 0.01). The divergence thresholds obtained in both hands were significantly poorer in the patients with HAVS compared with both the manual and sedentary workers (left hand: 4.02 mm, 3.37–5.04 mm versus 2.92 mm, 2.71–3.10 mm and 2.68 mm, 2.11–3.46 mm, respectively, P < 0.01; right hand: 4.22 mm, 3.76–5.49 mm versus 2.74 mm, 2.38–3.04 mm and 2.26 mm, 1.84–3.46 mm, respectively, P < 0.01). There was no significant difference between the thresholds for the manual workers and the sedentary workers (Figure 4).

The sensitivities, specificities, positive predictive values and negative predictive values of both the TPD wheel and the DSP wheel are shown in Table 1.

#### Discussion

HAVS is a condition that has become more prevalent since the latter part of the twentieth century. Since it became a prescribed disease under the National Insurance (Industrial Injuries) Act in 1985, sufferers have been able to claim compensation and disability benefit [9]. At present, there are ~4 million workers using hazardous vibration equipment, and >1 million are exposed to vibration in excess of the Health & Safety Executive’s criterion for action [4]. There are thought to be between 150 000 and 200 000 people with symptoms of HAVS in the UK [10]. HAVS is diagnosed and graded clinically; currently, investigations are only used to support the diagnosis. However, there is a need for sensitive objective investigations to confirm the diagnosis and evaluate disease severity [11,12].

The tactile sensations of touch and pressure are both detected by the same types of receptor. Large numbers of both Meissner’s and Pacinian corpuscles and expanded tip tactile receptors are found within the skin of the fingertips. Meissner’s corpuscles are particularly sensitive to movement of very light objects over the surface of the...
skin, whereas expanded tip tactile receptors are responsible for giving steady-state signals that allow one to determine the continuous touch of objects against the skin. Ruffini’s end-organs, which are found in the deeper layers of the skin, are important for signalling continuous states of deformation of the skin and deeper tissues, such as heavy and continuous touch signals and pressure signals [13].

A study by Takeuchi et al. [14] examined biopsies taken from patients with HAVS. They found that affected individuals had a marked demyelinating neuropathy of peripheral nerves in which a marked loss of nerve fibres had occurred. Perineural fibrosis was also noted, associated with an increase in fibroblast formation and subsequent collagen production. Further studies in animal models have led to the suggestion that neural abnormalities develop in two stages. First, there is a reversible phase that is related to the observation of significant epineural

Figure 3. Comparison of the mean thresholds in the HAVS patients (▲), the manual workers (●) and the sedentary workers (■) using the DSP wheel (median values, IQ ranges). R, right hand; L, left hand; U, up threshold; D, down threshold.

Figure 4. Comparison of the mean thresholds in the HAVS patients (▲), the manual workers (●) and the sedentary workers (■) using the TPD wheel (median values, IQ ranges). R, right hand; L, left hand; D, divergence; C, convergence.
Following recurrent exposure to vibration, an irreversible change develops due to the pathological changes of demyelination and destruction. Renfrew first described his flat aesthesiometer in 1969 and performed studies on patients suspected to have HAVS [15]. He found them to have higher mean thresholds than a control group of doctors and medical students. Further adaptations have since been made to his original design and further studies have been undertaken [16,17]. Bovenzi and Zadini [17] examined 46 forestry workers with evidence of sensory disturbance using both DSP and TPD aesthesiometry. They found aesthesiometric assessment to have a specificity of ~95% and a sensitivity of ~60%. Although they found that aesthesiometric testing was able to differentiate between a normal population group and a HAVS group, their observation of a high false-negative rate resulted in the conclusion that it was unsuitable to confirm objective sensorineural symptoms on an individual basis [17]. The results obtained from our study show a similar specificity to, but a slightly lower sensitivity than, those obtained by Bovenzi. The results further confirm the greater accuracy of the TPD wheel compared with the DSP wheel.

This study has shown that patients with HAVS have significantly impaired TPD with mild impairment of DSP when compared with a control group composed of both manual and sedentary workers. However, the values obtained from our study are less than the mean values obtained for the most severely affected HAVS patients in the study performed by McGeoch and Gilmour [4]. They found significant differences in threshold values between patients with stage 0 and stage 2–3 on the Stockholm Workshop scale. Ongoing studies are being performed to address this question. Despite this, the increased sensitivity of the TPD disc would suggest that it should be used in preference to the DSP disc for the assessment of sensorineural dysfunction in patients with HAVS.

### Acknowledgement

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### References

1. Gemne G, Pykko I, Taylor W, Pelmear PL. The Stockholm Workshop scale for the classification of cold induced

### Table 1. The sensitivities, specificities, and positive and negative predictive values of both the TPD and the DSP wheels

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<tr>
<th></th>
<th>TPD</th>
<th>DSP</th>
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<tr>
<td>Sensitivity</td>
<td>46</td>
<td>41</td>
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<tr>
<td>Specificity</td>
<td>84</td>
<td>94</td>
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<tr>
<td>Positive value</td>
<td>84</td>
<td>82</td>
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<td>Negative value</td>
<td>72</td>
<td>70</td>
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All values are in per cent. Normal limits (mean ± 2 SD) are taken from the control group.


