Use of sensorineural tests in a large volume of medico-legal compensation claims for HAVS

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Background
The Department of Trade and Industry set up a contract to examine miners and ex-miners claiming compensation for hand–arm vibration syndrome (HAVS). They had been exposed to hand-transmitted vibration. Over 100 000 have now been examined using sensorineural tests as part of that process.

Aims
The purpose of this paper was to examine the internal consistency of the vibrotactile threshold test (VTT) and the thermal aesthesiometry test (TA).

Methods
In 18 centres across the UK, nurses were trained to perform the measurement of VTT and TA in a controlled standardized manner. These tests were to aid the staging of the neurological component of the Stockholm Workshop Scales. The staging of this component was modified by dividing stage 2SN into 2SN (early) and 2SN (late). The test results and an automatic neurological staging were presented to the examining doctor following the clinical examination. The results of these sensorineural tests were held on a central database. The results and analysis of the first 57 000 tests are reported.

Results
The correlations within the VTT and TA scores were consistent with reliable measures. However, these correlations were not of such strength as to allow reliance on the results of a single test when making an assessment of the severity of neurological damage.

Conclusions
Different end organs and nerve fibres should be tested when making an assessment of damage in the sensorineural component of HAVS. The correlations demonstrated for the VTT and TA suggest that they are of value in assessing these claimants and would be for other vibration exposed workers.

Keywords
Hand–arm vibration syndrome; HAVS; neurological component; sensorineural tests; staging.

Introduction
In the court case of ‘Armstrong and others’, the British Coal Corporation was found to have been negligent when exposing its employees to hand transmitted vibration (HTV). On the 31 December 1997, the British Coal Corporation ceased to exist and the Department of Trade and Industry (DTI) took over all of its liabilities.

When the appeals were completed, it fell to the DTI to arrange a medical specification for the examination of a large number of claimants.

The DTI and the claimants’ solicitors steering group (CSG) agreed to a single medical examination for the assessment of hand–arm vibration syndrome (HAVS). They also agreed to the use of the Stockholm Workshop Scales (SWS) [1,2] to determine the extent of any damage due to vibration.
The only criterion stipulated by the DTI was that the process had to be fair to the claimant and to the tax-payer. However, it was stressed that the process had to be capable of producing similar results across the UK. This need for standardization was central when the Medical Assessment Process (MAP) was created. The detail of the MAP has been described elsewhere. [3] So far, 100 000 claimants have been examined in 18 centres spread across the UK. This analysis covers the first 57 120.

In the past, assessment of claimants for compensation has tended to be totally dependent on the history provided by the individual. This has obvious dangers in the litigation situation.

In order that total reliance was not placed on the recall of symptoms by the claimant, a number of tests were included in the MAP. The introduction of the neurological component in the Stockholm Workshop Scales opened the way for the assessment of the neurological damage caused by exposure to vibration. In the MAP, the sensorineural component of the Stockholm Workshop Scales was modified to recognize that the symptom of tingling was as important as numbness, as shown in Table 1.

If there is a loss of sensory perception it should be possible to demonstrate this loss and assess its extent. A variety of tests have been used in the assessment of this loss but in the studies published the population samples have tended to be small. The available tests are not specific for vibratory damage but combined with a history of occupational exposure to vibration they can be a strong tool when presented with an unverifiable history [4–6].

As there is a lack of a gold standard to diagnose any stage of HAVS and as no single test has sufficient specificity or sensitivity previous workers have recommended the use of a battery of tests to make the staging as accurate as possible [7–9]. The vibrotactile thresholds test (VTT) [10,11] and thermal aesthesiometry (TA) [12,13] were two of the recommended tests.

The sensation of touch, vibration, joint position and motion are transmitted by the mechanoreceptors and nerve fibres in the fingers. Tests detect abnormalities in the transmissions. Their value is in assessing the severity of nerve damage and thus improving the neurological staging.

The tests in the MAP were called standardized tests because criteria standards were defined and supported by normative data. In the MAP the standardized tests were the VTT, TA, Purdue pegboard test [14,15], Jamar grip strength [16] and a cold provocation test (CPT).

Raw scores on the VTT and TA were converted by the software into a points system; these points were then combined with equal weighting to generate a neurological stage. The neurological component of the SWS was changed to include the division of stage 2SN into 2SN early and 2SN late. The latter stage was awarded greater

compensation. The appropriate combined score for each stage is shown in Table 1.

This paper is concerned with the use of the VTT and TA tests to assess neurological damage arising from HAVS. The audit of the vascular tests has been reported elsewhere [17].

The purpose of this paper is to provide summary data of the process and examine the internal consistency of the VTT and TA tests. Where multiple tests are used to create a composite score, internal consistency is assessed to ensure that all elements of a multiple item are measuring the same underlying condition.

**Methods**

One hundred and ninety-five examining doctors underwent a 2 day training course which included an assessment.

One hundred and eighty-four nurses, following 1½ days training, performed the VTT and TA using a strictly controlled format.

**Medical Assessment Procedure**

After form filling on arrival, the claimant took one of two possible paths, as follows.

**Path 1**

The examining doctor completed:

1. the occupational history questions;
2. the symptomatology questionnaire;
3. the past medical history questionnaire;
4. the clinical examination of the patient.

The nurse performed vibrotactile thresholds test, thermal aesthesiometry and CPT. At this point the results of the VTT, TA and CPT tests were presented to the doctor. The doctor then completed the conclusion section.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Criteria</th>
</tr>
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<tbody>
<tr>
<td>0SN</td>
<td>Vibration exposure but no symptoms</td>
</tr>
<tr>
<td>1SN</td>
<td>Intermittent numbness and/or tingling with a sensorineural score of ≥3, ≤6</td>
</tr>
<tr>
<td>2SN (early)</td>
<td>Intermittent or persistent numbness, and/or tingling, reduced sensory perception with a score of ≥6, ≤9</td>
</tr>
<tr>
<td>2SN (late)</td>
<td>As 2SN (early) but with a score of ≥9, ≤16</td>
</tr>
<tr>
<td>3SN</td>
<td>Intermittent or persistent numbness and/or tingling, reduced manipulative dexterity and an SN score of ≥19</td>
</tr>
</tbody>
</table>
This was similar to path 1, except that the nurse performed the VTT and TA prior to the doctor examining the claimant. The CPT was always performed after the examination by the doctor. These test results were not presented until the doctor had completed their examination.

**Medical Assessment Process**

**Occupational history**
The doctor took a history of exposure to vibration from all sources.

**Symptomatology questionnaire**
Avoiding the use of leading questions the claimant was asked about his problems with his hands. All the reported symptoms and signs affecting the hands and arms, both vascular and neurological were recorded. Following further questioning the doctor had to decide if the claimant was describing a genuine history of loss of dexterity in a warm environment. If the doctor did not think there was such a loss it was a requirement that the doctor recorded the reasons for this decision and the activities the claimant could perform in a warm environment.

**Past medical history questionnaire**
A detailed past medical history, including medication, smoking and alcohol habits, to help with the differential diagnosis of other causes of peripheral neuropathy was taken.

**Clinical examination**
The doctors were required to examine the claimant, paying particular attention to abnormalities in cervical spine, shoulders, elbows, wrists and hands, specifically looking for signs of arthritis, circulatory problems, trophic changes, connective tissue problems or muscle wasting. Blood pressure was taken in both arms as were the radial and ulnar pulses. Allen’s test to assess the vascular status [18] and Adson’s test to search for a possible thoracic outlet diagnosis [19] were performed. Phalen [20] and Tinel tests [21] were carried out to check if there was evidence of carpal tunnel syndrome.

The claimant’s dexterity was assessed by the Purdue pegboard test and grip strength by the Jamar grip strength dynamometer.

**Tests by the nurse**
The VTT was chosen because vibration is known to stimulate a variety of mechanoreceptors, end organs and nerve fibres. Meissner corpuscles or fast adapting 1 (FA1) respond to frequencies between 5 and 60 Hz, while Pacinian corpuscles or fast adapting 11 (FA11) react to frequencies between 50 and 400 Hz. These signals are transmitted by the large myelinated A alpha and A beta fibres [22].

With the TA, cold and warm receptors in the skin of the finger tips are examined. Messages from the cold receptors are transmitted by the small myelinated A delta fibres while those from the warm receptors use the unmyelinated C fibres [22]. The ‘pulse method’ as opposed to the Marstock method was used. The temperature neutral zone (TNZ) was calculated by subtracting the cold threshold from the warm threshold.

Both tests have been in regular use by Mitsui Babcock since 1990 and Rolls-Royce since 1995. Previous publications have described the use of such a scoring system but the populations have been relatively small [4–6].

In all centres the VTT and TA tests were performed by nurses in an environment controlled at 22 ± 2°C. The Institute of Sound and Vibration Research (ISVR) supplied and was responsible for the calibration of the equipment for the VTT and TA. In both tests the flexor surface of the skin over the distal phalanx of the index and little fingers was tested covering the median and ulnar nerves. With the VTT a constant downward pressure of 1 N was maintained. The thresholds were measured at 31.5 Hz to examine the Meissner corpuscles and 125 Hz for the Pacinian corpuscles.

In the TA the rate of change of the temperature was 1°C/s. The ‘pulse method’ as opposed to the Marstock method was used. The temperature neutral zone (TNZ) was calculated by subtracting the cold threshold from the warm threshold.

**Scoring system**
Following publication of the Institute of Sound and Vibration Research (ISVR)/Health & Safety Executive (HSE) research report No. 197 in 1998 [23] it was possible to introduce a new scoring system. The VTT and TA were given equal strengths as shown in Table 2.

**Final staging**
The automatic neurological staging was presented to the doctor. At this point the doctor completed the Conclusion section and had to decide if the claimant suffered from HAVS. If a diagnosis of HAVS was not made, the test scores were irrelevant. If the diagnosis was of HAVS the doctor could either accept the software generated staging or vary it within strictly controlled limits. If the final staging was varied a justification had to be recorded.

As the standardized tests were not thought to be
reliable at stage 1SN, this stage could be awarded: (i) if there was a good history of exposure to vibration and symptom history even when the VTT + TA score was <3; (ii) if the claimant was staged at 1V or higher as during a vaso-spastic attack, numbness and tingling would be experienced.

Stage 2SN was thought to cover a very wide range of neurological damage from claimants with relatively minor handicap to those with severe sensory loss but without a dexterity problem in a warm environment. For this reason the software used the combined VTT + TA score to divide this stage into 2SN early and 2SN late as shown in Table 1.

Assessment of dexterity loss in a standardized manner caused many problems. A number of tests were reviewed. The Purdue pegboard test was deemed to be the most suitable as it included a time factor and had published age related normative data. However, the subjectivity of this test was high and very dependent on the cooperation of the claimant.

Genuine stage 3SN cases were thought to have severe persistent neurological damage. The assessment of this stage undoubtedly caused the greatest difficulties. Before an award of a stage 3SN there had to be a loss of dexterity in a warm environment, VTT + TA score of ≥9, and an abnormal Purdue pegboard test. As the maximum single test score per hand was 8, the score of 9 required evidence of damage in both tests.

The completed MAP report was finally authorized by the examining doctor.

### Auditing

Auditing of the MAP reports was an integral part of the MAP process. The results of every MAP examination were held on a database. There was internal auditing by the contract company and external auditing by four senior doctors with experience of HAVS—the Medical Reference Panel. Centre results underwent statistical analyses, the results being compared with the national results.

There was regular auditing of individual doctors and nurses.

### Statistical methods

Means and standard deviations were used to summarize the data for each measure. To examine the distributions, the 20th, 40th, 60th and 80th percentiles were calculated. Bivariate (Pearson product moment) correlations were used to examine the relationships between the measures.

An issue that arises with sample sizes of this magnitude is that virtually all relationships and comparisons are highly statistically significant, although they may not be clinically significant. For this reason, we do not describe statistical significance in the conventional sense, using $P$-values.

### Results

The sample comprised 57,120 males, with a mean age of 55.6 years (SD = 12.1) and a mean number of years of exposure to vibration of 22.3 (SD = 10.2). All had been employed by British Coal.

Table 3 shows the means, standard deviations and percentiles for the individual tests and Table 4 shows the Pearson correlation matrix between the standardized tests.

For the thermal aesthesiometry tests the correlations are all high and similar to one another, ranging from 0.77 to 0.80, the only exception being the correlation of right hand little finger and left hand index finger, which are considerably lower (although still high), at 0.69.

For the vibrotactile tests, the correlations show a similar set of relationships, although there is a greater range in the size of the correlations, from a maximum of 0.90 to a minimum of 0.59. With the vibrotactile tests, there is a tendency for the correlations amongst similar measures to be higher. The correlations between measures on the same hand are higher than the correlations between hands.

### Discussion

The principal sensorineural tests, VTT and TA, both showed good internal consistency. However the correlations found were not of such a strength to allow reliance on the results of a single test when making an assessment of the severity of neurological damage in an individual case. Neither test, even with this huge database, could be shown to be markedly superior to the other test.

In this study all the equipment came from a single...
Table 3. Summary statistics for the standardized tests

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Percentiles</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>20</td>
<td>40</td>
<td>60</td>
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<tr>
<td><strong>Neutral zone</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Left hand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Index</td>
<td>24.8</td>
<td>12.5</td>
<td>13.2</td>
</tr>
<tr>
<td>Little</td>
<td>28.9</td>
<td>12.6</td>
<td>16.6</td>
</tr>
<tr>
<td><strong>Right hand</strong></td>
<td></td>
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<tr>
<td>Index</td>
<td>27.5</td>
<td>12.5</td>
<td>15.6</td>
</tr>
<tr>
<td>Little</td>
<td>31.1</td>
<td>12.3</td>
<td>19.2</td>
</tr>
<tr>
<td><strong>Vibrotactile tests</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Left hand</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31.5 Hz</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Index</td>
<td>1.4</td>
<td>2.6</td>
<td>0.2</td>
</tr>
<tr>
<td>Little</td>
<td>1.9</td>
<td>3.1</td>
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<tr>
<td>125 Hz</td>
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<td><strong>Right hand</strong></td>
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<td></td>
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<td></td>
<td></td>
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<tr>
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<td>0.2</td>
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<tr>
<td>Little</td>
<td>2.1</td>
<td>3.3</td>
<td>0.2</td>
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<tr>
<td>125 Hz</td>
<td></td>
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<tr>
<td>Index</td>
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<td>9.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Little</td>
<td>7.4</td>
<td>10.5</td>
<td>0.8</td>
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</table>

Table 4. Matrix of correlation coefficients

<table>
<thead>
<tr>
<th></th>
<th>Neutral zone</th>
<th>Vibrotactile tests</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Left hand</td>
<td>Right hand</td>
</tr>
<tr>
<td></td>
<td>Index</td>
<td>Little</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
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</tr>
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<tr>
<td></td>
<td>Little</td>
<td>0.69</td>
</tr>
<tr>
<td>Vibrotactile tests</td>
<td>Left hand</td>
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</tr>
<tr>
<td></td>
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<td>0.29</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Little</td>
<td>0.38</td>
</tr>
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<td>Right hand</td>
<td>31.5 Hz</td>
<td>Index</td>
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<tr>
<td></td>
<td>Little</td>
<td>0.33</td>
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</tr>
<tr>
<td></td>
<td>Little</td>
<td>0.39</td>
</tr>
</tbody>
</table>

The table of correlations shows the relations between the different measures.
source and was calibrated in a similar fashion. The nurses were trained to use the equipment in an identical manner and underwent regular auditing of their performance.

The doctor's diagnosis of the presence or absence of HAVS was the most important decision. This was based on the history of exposure to vibration and the presence of symptoms compatible with such a diagnosis. All the doctors completed the same training course and were subject to stringent auditing, reducing the chance of errors.

There is no doubt that this population was exposed to harmful vibrations but the lack of any useful data on vibration dosage of the individual claimants is a weakness inherent in this type of study. Another problem was the fact that the claimants may have been exposed to a variety of the 300 types of vibratory tools used in the mining industry during the relevant period.

The crucial need for standardization across the country resulted in the examining doctors' power to override the built-in software being strictly limited. This built-in rigidity, while an advantage from the point of view of standardization, was a weakness in certain situations and would not be suitable for all occasions. However, it has allowed >100,000 claimants to be examined in a relatively short time and up to 1000 claimants processed in a week in a regulated manner.

To our knowledge the population sample was vastly greater than any other published study. This size and the other unique features in this study make comparison with other studies difficult. We are unaware of any previous study which has specifically looked at the internal consistency of the VTT and TA tests.

A potential weakness of this report is that the study population was comprised entirely of claimants. The medico-legal environment may result in encouraging exaggeration by the claimant whereas in the occupational setting the worker may minimize the symptoms. However, as the principal findings of this paper relate to the correlation between measures we do not anticipate any bias in the results.

We believe that the findings in this study should allow confidence in the use of the VTT and TA in the investigation of vibratory damage to the neurological system in exposed workers.

The pathophysiology of HAVS remains obscure. An interesting finding was that, while most claimants had abnormalities in both the VTT and TA, there were occasions where one test was normal while the other grossly abnormal. At this time we can only conjecture that a possible cause was that claimants had a variety of trades, used tools with varying frequency spectra and acceleration values.

The tests used in this study require an individual's co-operation. Ideally, truly objective neurological tests would be advantageous. At present the only available objective test is neurophysiological investigation. While this may be useful in isolation in carpal tunnel syndrome it is not useful in HAVS [24].

Conclusions
The conclusion is that the different end organs and fibres should be tested when making an assessment of damage in the sensorineural component of HAVS. The strong internal consistency of the VTT and TA tests is further evidence that these tests are reliable indicators of the underlying neural damage.

The correlations demonstrated for the VTT and TA suggest that, until truly objective tests can be developed, they were of value in assessing the severity of nerve damage in these claimants and would be for other vibration exposed workers.

Acknowledgements
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References