Vibration injury to the hands was first reported in 1911 in workers using compressed air tools [1]. Since then, mechanization has become more widespread, with a corresponding rise in the incidence of vibration injuries. Employers, legislators, machinery and tool manufacturers, and physicians in general have all been slow to recognize and effectively address the problem. Fortunately, some tool manufacturers in recent years have modified their tools to partially attenuate vibration transmission, and legislators have introduced safety guidelines, e.g. Health & Safety Executive (HSE) HS(G)88, and regulations to encourage recognition and reduction of the risk from vibration exposure at work. The recently published EU Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from vibration (hand–arm and whole-body) [2], with specified exposure action and limit values, is very welcome. This, together with an HSE regulation to follow in 2005, will increase public knowledge and should result in less vibration-induced injuries.

Workers’ compensation schemes allowing vibration injury claims are ongoing, and lawyers have become increasingly interested and active on behalf of clients [3–5]. However, the uncertainty of diagnosis and lack of uniformity in the examination of subjects exposed to hand-transmitted vibration continue to be a matter of concern to many occupational and family physicians, employers, lawyers, and not least the worker who has developed symptoms. Numerous clinical and laboratory tests have evolved and become available over the years to assist physicians to evaluate the three components of hand–arm vibration syndrome (HAVS)—vascular, sensorineural and musculoskeletal—as defined by an international group who met in London in 1983 [6]. The tests vary from very simple to highly sophisticated, and their use is dependent on many factors, e.g. examination or screening time, the circumstances, need, availability and cost. Hence, inevitably, there has been a lack of uniformity on the tests that examining physicians use.

The initial screening examination of a subject may be limited satisfactorily to the use of a history questionnaire to determine the symptoms and the nature of the vibration exposure, a clinical examination of the upper torso and some simple subjective tests. However, there is a need to exclude other possible causes of the symptoms and to verify the preliminary diagnosis. In these circumstances, blood analyses and the use of sophisticated subjective and objective tests in a hospital or special clinic are necessary to make an authoritative diagnosis and to grade severity accurately. Such an evaluation is essential for cases seeking compensation if both parties in the dispute are to be well served. Most patients referred to a hospital usually circulate between vascular, orthopaedic or hand surgeons, rheumatologists, neurologists and perhaps others, each one in turn offering an opinion on the presumed occupational disease without any clear understanding of the patient’s occupational environment or vibration exposure. Although consultants in these various specialities, by virtue of their specialist knowledge, have a contribution to make on the interpretation of the results of diagnostic tests conducted within their departments, the ultimate consultant to finalize the diagnosis of HAVS should be an experienced occupational physician or vascular surgeon with a special interest in this occupational disease. Regrettably, few countries in the world have centres of excellence staffed by occupational physician specialists for the examination of cases with vibration injuries. Because of the need to process quickly the >120 000 coal miners claiming compensation, the UK Department of Trade & Industry (DTI) established between 1998 and 2001 some 18 regional assessment centres, staffed predominantly by family physicians and ancillary staff. Unfortunately, anomalies in the screening process and the limited use of laboratory tests—all subjective except one vascular test, which was abandoned.
before the clinics closed—left much to be desired. Consequently, the accuracy of diagnosis of HAVS and the evaluation of its severity are questionable, as are the data for analysis.

From the wealth of international literature published on the assessment of HAVS patients, the DTI, their physicians and researchers failed to recognize or ignored the methodology and excellence of practice in a hospital-based centre in Toronto, Canada. HAVS patients seeking compensation or specialist assessment have been attending the Department of Occupational and Environmental Health, St Michael's Hospital, Toronto, since the mid-1980s, and a range of clinical tests, both subjective and objective, used to assess them have been evaluated. In a diagnostic facility, the results of multiple tests enable a diagnosis to be made and the severity of HAVS patients to be graded. These would suggest that the vascular tests should include some or all of the following: Doppler and Duplex studies (to check the patency of the arteries in the upper limbs, and also lower limbs if indicated, and the blood pressure ratios between the arm and digital vessels); plethysmography (to evaluate the pulse wave forms in the digital arteries pre- and post-cold stress at 10°C); finger systolic pressure measurement (to compare the blood pressure of an affected digit pre- and post-cold stress with the thumb, which is usually but not always less affected by vasospasm, or with the brachial artery); and cold provocation tests (immersion of the digits in cold air or water at 10–15°C for 5–10 min with recording of the skin temperature to note any reactive hyperaemia while immersed and delay in recovery afterwards).

Similarly, based on the experience from Toronto, the sensorineural tests should include: depth sense and two-point discrimination using Von Frey or Semmes–Weinstein monofilament hairs, callipers, plastic blocks or wheels with split levels and widening grooves [7,8]; and one or more of the following subjective tests: finger tip vibration threshold measurement (8–500 Hz) with vibrometer instrumentation [9]; thermal hot/cold perception, using Minnesota thermal discs [10] or instrumentation [11]; and current perception threshold (detection of a 0–10 mA current at 5, 250 and 2000 Hz) [12]. An objective nerve conduction test should also be conducted to confirm the presence and severity of a neuropathy, which in HAVS patients often affects both median and ulnar nerves.

A paper on the early case material from the St Michael's Hospital clinic with an analysis by statistical clustering algorithm of 364 patients according to the results of their tests was presented at an international workshop in Nagoya, Japan, and subsequently published in 1994 [13]. A Stockholm staging (history) for each hand, based on the history information alone, was first recorded. Following a review of all the test results, the hand severity impairment was determined and the Stockholm staging (diagnostic) was recorded. The tests conducted on these patients included Adson’s, Allen’s, plethysmography of the digits, finger systolic blood pressure (FSBP%) using the thumb as the reference, cold water immersion of the hands (10 min at 10°C), depth-sense aesthesiometry, two-point discrimination, grip strength, Tinel’s, Phalen’s, vibrometer perception threshold, current perception threshold and nerve conduction.

All subjects who had been exposed to significant hand–arm vibration away from work, who had suffered significant injuries or diseases including constitutional white finger, or who were female were excluded, leaving 173 men available for the cluster analysis by an SAS FASTCLUS procedure. The results from each hand were used separately and the cluster analysis was used to determine how many clusters could be found using the vascular tests alone, and the sensorineural tests alone in each hand.

The agreement between the history and the diagnostic Stockholm staging was found to be low. For the vascular component, agreement was only 35% and the history staging was more severe than the diagnostic staging in 39%. For the sensorineural component, the corresponding percentages were 37 and 17%, respectively. Hence, the patient’s history alone is not sufficient to stage severity, as patients may not disclose all their symptoms or may exaggerate some, particularly when compensation is being sought. Furthermore, the assignment of an individual to a Stockholm stage can be influenced by the personal judgement of the physician, so an assessment method linked to laboratory test results is required. This is especially so when workers’ compensation and litigation are an issue.

The results of the cluster analysis showed that the subjects could be classified, using the vascular tests, into four clusters with the right hand and three with the left. Using the sensory test results, four clusters were obtained with both hands. The mean values of the diagnostic tests in the vascular and sensory test clusters differed between the two groups, as did the severity. This confirmed that although there is an association between the vascular and sensorineural components of HAVS, the two components appear to occur and progress independently of each other. It is not valid to presume, as some physicians still do, that if there is no sensory impairment, abnormal vascular test results are false-positive results and vice versa.

Another result from the analysis was that, within the sensory group clusters, the ranking order in the depth sense, two-point, current perception, vibrometer and grip strength tests was found to be comparable in order of increasing severity in the respective hands. Thus, this group of tests would seem to be evaluating impairment and severity on the same basis. If the cluster analysis had been limited to these tests, the number of clusters would
have been no more than three. However, when the Tinel’s, Phalen’s and nerve conduction tests were incorporated, a more severe cluster four emerged. The inclusion of the results of these tests, designed to evaluate the function of myelinated nerve fibres, in the cluster analysis added a new dimension to the sensorineural grading, thus indicating the need for a fourth sensorineural grade.

These findings suggest that abnormality in all the components does not need to be present for a diagnosis of HAVS to be made. Most patients will be aware of finger blanching, but some will complain of sensorineural symptoms only. The sensible health-educated patient will avoid cold exposure and reduce the frequency of finger blanching. However, he (or she) is less able to reduce sensory impairment, so the sensorineural component of HAVS causes the greater disability. As indicated earlier, the components may progress independently, but they may also recover when hand-transmitted vibration exposure is discontinued. The vascular symptoms usually recover more quickly than the sensorineural, and grip strength is normally the last to do so. The younger the patient and the less severe the impairment in a component, the better the prognosis.

Researchers have been looking for a single diagnostic test, and it is surprising that so many do not seem to appreciate that there is no single test, sensory or vascular, that is specific for HAVS. Sensory tests evaluate all causes of neuropathy and the vascular tests all causes of Raynaud’s phenomenon. Therefore, multiple test results are needed, together with skilful interpretation by an experienced physician, if the severity grading of the components of HAVS is to be reliably determined.

In the search for a single diagnostic test, a good deal of work has already been undertaken. It is usual, when evaluating the merits of clinical tests, to consider sensitivity and specificity against a ‘gold standard’—the presence or absence of disease. Often, the most questionable gold standard of a disease is that determined only by the history of the patient, particularly if the disease is a progressive one. It is unfortunate that Raynaud’s phenomenon (blanching of the digits recognized by the subject) is in this category; too many vascular test studies have apparently been confounded and the test procedure devalued by many so-called false-positive results. I believe such results are due to the gradual development of vasospasm during the preclinical state (not recognized by the subject) in cases of HAVS and Raynaud’s disease. The vascular tests that detect vasospasm, e.g. digit plethysmography and cold water immersion, will reveal clinically otherwise unrecognized finger blanching, and if positive, the subject’s history should be declared a false negative rather than the test result as false positive [14,15]. In addition to this anomaly in respect of HAVS cases, the severity and extent of the vasospasm may affect a digit blood pressure vascular test result. The reference thumb

blood vessels may be directly affected by vibration, and reflex vasospasm in the thumb may follow the cooling of another digit. In these circumstances, the FSBP%, using the thumb as a reference digit, may be determined to be normal or less abnormal than expected, so the patient’s severity grading will be underestimated if not verified by pre- and post-cold stress digit plethysmography or a cold provocation vascular test. In most cases, the brachial artery would be a better reference, but its use is still not favoured by some. The standard FSBP% test is also now of questionable value because a recent study has suggested that in HAVS subjects the dermal circulation remains impaired, even after the restoration of arterial blood pressure in the digits [16].

If there is a history of paraesthesia, sensorineural testing is necessary to establish its presence and severity because that history may be unreliable, as indicated earlier. However, it has to be appreciated that all subjective tests for evaluating sensory function in the non-myelinated and small myelinated fibres do not measure peripheral nerve function specifically, since the interpretation of results in this way assumes the integrity of central sensory pathways. Furthermore, abnormal results should always be suspect in compensation cases and examining physicians must avoid being deceived by the apparent good correlation with severity against the Stockholm sensorineural scale in claimants. It would be surprising if it were otherwise, since many claimants may have been briefed beforehand by others to produce a favourable response. Subjective testing on separate occasions to assess repeatability may improve the validity, but this is not always feasible.

The only widely available objective sensorineural test is nerve conduction, which measures the conductive capacity of the largest, myelinated, rapidly conducting fibres in the median and ulnar nerves. Its diagnostic utility is thus limited in conditions that selectively affect autonomic or small diameter fibres, but since hand-transmitted vibration will affect small and large fibres, both need to be evaluated. Nerve conduction testing would be advantageous in compensation cases. It is the standard test procedure for carpal tunnel syndrome, and it should be for HAVS too. Unfortunately, the test results cannot distinguish between the two conditions at the present time, although in HAVS a median together with an ulnar neuropathy is more likely [17]. The two conditions have been shown to differ pathologically [18], and they may co-exist [19]. It is surprising that so many examining physicians are not aware of or do not accept these findings.

The Nagoya paper also draws attention to a problem with the 1986 Stockholm scales [20,21] for grading severity, in particular the sensorineural. As mentioned earlier, the cluster analysis indicated the need for a stage 4 SN because of large fibre impairment, as detected by the
nerve conduction test results. Another problem is with the wording of the Stockholm stage 2 SN, ‘intermittent or persistent numbness, reduced sensory perception’, and stage 3 SN, ‘intermittent or persistent numbness, reduced tactile discrimination, and/or manipulative dexterity’. It has to be appreciated that this sensorineural staging was an arbitrary grading not based on evidenced-based clinical findings at the time, hence it is ambiguous and has caused misunderstanding. It needs modification to reduce the present confusion, but as this is unlikely, it should be replaced with a scale recommended by an authoritative clinical body, such as the Faculty of Occupational Medicine. Most patients with reduced sensory perception (tactile sensitivity), supported by abnormal subjective test results, experience difficulty in grasping and picking up pins, needles and small objects. Hence, they will have an abnormal Perdue pegboard test score for the number of pins picked up and placed due to reduced tactile sensitivity rather than discrimination. The Perdue test has been referred to in the literature as ‘evaluating manipulative dexterity’, and if properly conducted, it is designed to measure two types of activity. The first involves the finger dexterity shown to pick up and insert pins, and an abnormal result because of reduced sensory perception would support placement in stage 2 SN. The second activity to be observed is gross movements of the hands, fingers and arms when difficulty is shown in assembling collars and washers, and an abnormal result would support placement in stage 3 SN. Unfortunately, it seems to be the practice for most UK physicians observing the activity of patients with reduced finger sensory perception or those producing an abnormal Perdue pegboard test result to falsely grade claimants into stage 3 SN. Manipulative dexterity testing for stage 3 SN is probably better evaluated using a Moberg test [22] and the Dellon modification [23]. Alternatively, a more practical method is to require the patient to button his shirt and cuffs, tie his shoe laces or tie, and such other tests as the examining physician may find appropriate and easy to use in his clinic. In reality, very few patients with HAVS have suffered with impaired manipulative dexterity in my experience, and it has been my practice to reserve stage 3 SN for those with an abnormal nerve conduction test.

Likewise, the Stockholm vascular scale is faulty in that frequency of blanching attacks is supposed to be used to determine severity in the history staging. The wise, sensible patient, having been advised to modify his lifestyle to avoid cold exposure, will suffer fewer blanching attacks, although the underlying condition may remain severe. Hence, the wording in the Stockholm vascular scale needs to be modified to make the ‘history grading’ determination more relevant. The extent of the blanching should be the only determining factor for staging by the history. For the more valid ‘diagnostic staging’, the severity may be determined from the results of properly conducted objective vascular tests, e.g. Doppler, digit plethysmography and cold water immersion.

Since the 1986 Stockholm International Meeting, the ISO standards committee has been encouraging clinical research, the publication of results and developments in practice. It seems to be preoccupied now in standardizing the methodology of vascular tests, while paying little, if any, attention to the faults in the Stockholm scales. Also, it has not expressed any concern about the anomaly of using the subjective history of finger blanching as a reference ‘gold standard’ rather than a verified diagnostic condition to determine the sensitivity and specificity of vascular tests. This committee would do well to review its mandate and concentrate on non-clinical issues in future, because its recommendations on clinical tests are unlikely to affect clinical practice. Consulting physicians, subject to medico-legal pressures, will determine how and when to modify, improve and upgrade their clinical assessments.

Within the UK, it would be very helpful if National Health Service trusts responsible for hospitals would improve and make their diagnostic facilities available to occupational physician specialists, and support and encourage the multidisciplinary assessment of occupational disease. The D’ITI concept of using referral clinics for the evaluation of HAVS claimants was a step forward, but with their closure, that role should be assumed by hospitals in the major centres using the St Michael’s Hospital, Toronto, model. In the Department of Occupational & Environmental Health, hospital consultants in occupational medicine, dermatology and internal medicine conduct clinics to examine referred patients for occupational health assessments. All the laboratory resources of the hospital are available to them. There is also extensive liaison with other departments, so that patients benefit, and medical students and staff enjoy practical and academic instruction.

The Faculty of Occupational Medicine is at long last about to revise its good practice guidelines on the clinical testing and management of individuals who are exposed to hand-transmitted vibration [24]. A contract has been placed with the HSE group in Sheffield to review the literature and make recommendations. It would be helpful if the review contractors recommend modifications to the Stockholm scales or, better still, propose that the Faculty should adopt new scales that were appropriate for the UK and other countries to use. Impairment scales are being increasingly referred to in litigation cases, so they need to be clearly defined. There is also an urgent need to rationalize issues with respect to HAVS examinations and the use of laboratory tests. Hence, this second report from the Faculty needs to provide more useful direction than the last one. If the concluding recommendations are enlightened, rational
and feasible, the Faculty will earn the gratitude and support of physicians internationally who are interested in evaluating, treating and compensating fairly all workers affected by vibration exposure.

References