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Evaluation of sensibility in leprosy—comparison of various clinical methods

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Summary In order to determine whether various sensibility tests, not in common use at our hospital, are appropriate for the neurological screening of leprosy patients, an extended nerve function assessment (NFA) was done on 50 in- and outpatients who had been diagnosed as suffering from leprosy (100 hands and feet). The nerve function assessment battery consisted of Semmes–Weinstein monofilament testing (SWMT), moving 2-point discrimination (M2PD), Pinprick (PP), position sense (PS), vibration sense (VS) and voluntary muscle testing (VMT). In addition the SWMT was performed on 637 hands and 634 feet of 'field patients' in order to get a better indication of the prevalence of sensory impairment as measured with the SWMT. The SWMT has been shown to be a sensitive test of peripheral nerve function, therefore the other tests were compared with the SWMT. Results are reported separately for the ulnar, median and posterior tibial nerve. Test sites were the pulp of the distal phalanx of the index finger, the little finger and the big toe. Correlation between the SWMT and each of the other tests proved statistically significant; the closest correlations were between the SWMT, M2PD and PP for both ulnar and median nerves ($r > 0{\cdot}7$, F test > 100, $p < 0{\cdot}0001$). It is argued that the first tests to show nerve function impairment (NFI) are the M2PD and the SWMT. VS and PS were also absent in a significant proportion of patients. Arguments are presented that this may indicate advanced NFI. Results are compared with other data currently available in the literature.

Introduction

Peripheral neuropathy is the direct or indirect cause of almost all impairments, disabilities and deformities of leprosy sufferers. Potentially much of the nerve function impairment (NFI) in leprosy can be treated successfully if treatment is started during the early stages of the NFI. Effective anti-inflammatory drugs like prednisolone are now widely available, often under field conditions. Several investigators have shown that prednisolone treatment can be prescribed safely to hospital outpatients[1] or even to 'field patients',[2]

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provided that certain basic precautions are taken. Effective treatment for nerve damage is therefore potentially available for those patients who need it, provided they can be identified while their NFI is still reversible. Because of this, the diagnosis of early, reversible NFI is of utmost importance to the patient.

This paper discusses several simple clinical tests that are potentially useful in the diagnosis of early sensory NFI.

The testing protocol was carried out at Green Pastures Hospital (GPH), a 100-bed mission hospital in Pokhara, West Nepal, run by the International Nepal Fellowship (INF) under its Leprosy Control Project (LCP), which is a joint project with His Majesty's Government/Nepal (HMG/N). GPH is the main leprosy referral hospital for the West of Nepal.

Methods

STUDY QUESTIONS

1 How appropriate are moving 2-point discrimination (M2PD), pinprick (PP), position sense (PS) and vibration sense (VS) tests for the neurological screening of leprosy patients?
2 How well do the results of these tests correlate with the results of the more established method of nerve function assessment in leprosy, the Semmes–Weinstein monofilament test (SWMT)?
3 Can any pattern be discovered in the various test results that may be predictive of 'less severe' or 'severe' NFI, i.e. that might predict a good or bad prognosis for recovery?

OUTCOME MEASUREMENTS

Question 1

The proportions of hands and feet tested that showed abnormal test results for the tests mentioned above.

Question 2

Regression coefficient, F test, correlation coefficient (r) and 'squared r' were used to express significance of linear relationship and closeness of correlation.

Question 3

The chance of getting a positive or negative test result for each of the other tests given a positive or negative result in one test.

PATIENTS

Patients were chosen without any specific selection criteria except that they had no missing limbs or digits, or stiff contractures of the fingers, that would make testing of the volar surface of the distal phalanx difficult. No randomization was applied because the

purpose of the study was to compare results of different testing methods within the same patient.

All patients had an established diagnosis of leprosy and were classified according to the Ridley–Jopling classification. Details of diagnosis and classification at GPH have been published elsewhere.[3] The patients were either taking or had been released from WHO–MDT.

NERVE FUNCTION ASSESSMENT (NFA)

NFA was done by 1 of 3 trained physiotechnicians and 3 medical students who had been thoroughly familiarized with testing techniques. The NFA battery consisted of Semmes–Weinstein monofilament testing (SWMT), moving 2-point discrimination (M2PD), pinprick (PP), position sense (PS), vibration sense (VS) and voluntary muscle testing (VMT). If any test site could not be tested for any reason, a missing value was recorded. The VMT data will not be discussed further in this paper.

SENSIBILITY TESTING

Semmes–Weinstein monofilament test (SWMT)

Patients were tested using the standard set of 5 'coloured Semmes–Weinstein monofilaments' as described by Bell–Krotoski.[4] The score per site varies from 0 to 5. A score of 5 was given when the thinnest monofilament in the test series was felt; a score of 0 if even the thickest filament was not felt. These filaments (Semmes–Weinstein numbers 2·83, 3·61, 4·31, 4·56 and 6·65) give a force ranging from about 70 mg to 300 g when applied in such a way that it bends slightly.[5] For the foot the thinnest filament used was 200 mg, while an extra filament of about 10 g was added in between the 4 g and 300 g filaments, because 10 g (SW filament no. 5·07) has been found to be the level of 'residual protective sensibility' in the foot.[6,7] The result was recorded using the colour code for the respective monofilament for each of the sites mentioned below. The 70 mg and 200 mg filaments were applied 3 times, because they tend to slip more easily than the thicker filaments. If the patient felt any of the touches the result was recorded as positive for that site. The thicker filaments were usually only applied once. The maximum score per site was 5. The following sites were tested:

Ulnar nerve: the pulp of dig. V.

Median nerve: the pulp of dig. II.

Posterior tibial nerve: the volar surface of the big toe.

Moving 2-point discrimination (M2PD)

Moving touch sensibility of the ulnar, median and posterior tibial nerves was tested with the M2PD test as described by Dellon.[8] Two prongs of a small testing device specifically marketed for testing static and moving 2-point discrimination, the Disk-Criminator™,*

* Available through P.O. Box 13692, Baltimore, Maryland, 21210, USA.

were moved from proximal to distal over the volar/plantar surface of the distal phalanx, giving as little pressure as possible. Randomly 2 or 1 prongs were applied and the patient was asked whether he felt 1 or 2 prongs. The smallest distance between the prongs that was still detected by the patient as 2 prongs was recorded in millimetres for that site. The smallest distance tested was 2 mm. The test sites were the same as for the SWMT.

The score was calculated as '15 minus the minimum distance between the 2 "prongs" of the testing device (in millmetres) that was still perceived as 2 points'. The maximum score was therefore 13, if the patient could still feel 2 separate points at an interprong distance of 2 mm. If the testing device was not felt at all, the score was recorded as 0. If the device was felt, but only as 1 moving point, a score of 1 was given.

Pinprick (PP) score per nerve

Pain sensation was tested using standardized wooden toothpicks. The toothpick was applied randomly with the sharp end or the blunt end and the patient was asked to indicate whether he felt 'sharp' or 'blunt'. The sites to be tested with the PP test were the same as the sites for the SWMT test. The score per site was the number of correct responses out of 5 trials.

Position sense test

'Proprioception' or position sense was tested in the same digits as the SWMT. While the middle phalanx was fixed between the thumb and the index finger of the examiner, the examiner gently moved the distal phalanx either up or down from the neutral position. The patient was asked to indicate whether he felt his finger/toe go up or down. The score per site was the number of correct responses out of 5 trials. The maximum score was therefore 5 for each site.

Vibration sense test

Vibration sense in the nerves and sites described under the SWMT were tested using a 128 Hz tuning fork. A supramaximal stimulus was given to the tuning fork and then the prongs were immediately applied to the volar–plantar surface of the distal phalanx of the digit to be tested. The patient was asked to describe what he felt. Any description of a vibrating, 'electrical' or similar sensation was taken as a positive test (score 1). If the tuning fork was felt without any special sensation, the test was negative (score 0).

NERVE FUNCTION IMPAIRMENT (NFI)

A patient was diagnosed as having NFI using the following criteria:

SWMT: a score for any site of 3 or less;
M2PD: a score of 10 or less for any site on the hand and 9 or less on the big toe;
PP: a score for any site of 0 or 1 (values of 4 and 5 were counted as normal, while the values 2 and 3 were left out of the analysis);
PS: same as for PP;
VS: a score at any site of 0.

Table 1. Proportions of nerves with abnormal test results (i.e. nerves with NFI) as detected with each of the NFA methods (n = 100)

nerve	SWMT*		M2PD*	PP*	PS*	VS*
	GPH†	FIELD‡				
Median	10	23	16	5	2	2
Ulnar	26	31	42	23	10	11
Posterior tibial	29	37	69	36	10	21

* SWMT = Semmes–Weinstein monofilament test, M2PD = Moving 2-point discrimination, PP = pin prick, PS = position sense, VS = vibration sense.
† GPH = Green Pastures Hospital.
‡ n = 637 hands and 634 feet.

The criteria for the SWMT and the M2PD are based on normal values found in a normative study conducted recently by a team from our hospital (to be published elsewhere).[9]

STATISTICAL METHODS

The significance of the difference between the various proportions was tested using the standard normal deviate (SND) for unpaired samples and McNemar's paired χ^2 test for paired samples as described by Armitage.[10] The significance of an association between 2 tests was tested with an F test (linear regression). A p-value of less than 5% was used as level of statistical significance. The 95% confidence interval is given of the most important proportions or ratios, e.g. 4·19 (2·14–8·25) means that there is a 95% chance that the ratio actually lies between the values 2·14 and 8·25%. Predictive values for positive and negative tests were calculated according to Armitage. Analysis was done using Epi Info software, version 5·01.[11] The terms 'sensitivity' and 'specificity' are not used in the correct sense, because no 'true diagnosis' or 'golden rule test' is available for NFI in leprosy. The meaning, however, is the same, but is used in a qualitative rather than quantitative sense.

Results

We chose 50 patients for the study—6 female, 44 male—i.e. 100 hands and 100 feet. There was no significant difference in test results between left and right, or between male and female. The mean age was 40·6 (SD 12·3, range 16–65, median 41·5).

Table 1 and Figure 1 show the proportions of abnormal test results, i.e. nerves with NFI, as detected with each of the NFA methods. The highest proportions of abnormal test results were found for the M2PD (16%, 42% and 69% for the median, ulnar and posterior tibial nerve, respectively). The difference between the SWMT and M2PD results were not significant for the median nerve (McNemar's test, $z = 1{\cdot}73$, $p > 0{\cdot}05$). However, the differences were highly significant for the ulnar and posterior tibial nerves ($z = 3{\cdot}41$ and 6·58, respectively, $p < 0{\cdot}001$). The lowest, but still not insignificant proportions were found for the position sense and vibration sense tests. Overall the posterior tibial nerve was the most frequently affected nerve.

The significant linear relationship and correlation between the SWMT results and the results of each of the other NFA methods is shown in Table 2. The closest correlations

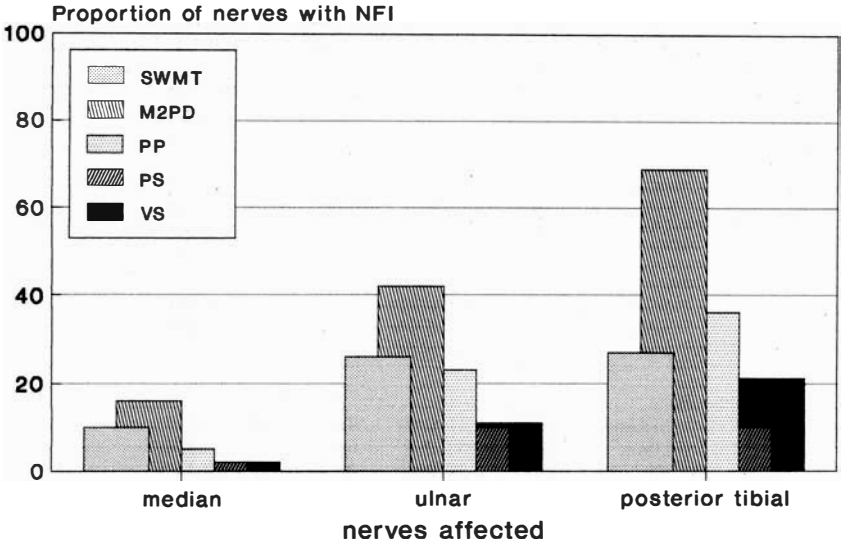

Figure 1. Proportions of nerves with NFI detected by various sensibility tests.

were between the SWMT and M2PD and PP for both ulnar and median nerves and SWMT and VS for the median nerve only ($r > 0{\cdot}7$, F test > 100, $p < 0{\cdot}0001$). A similar pattern of correlation was found between the M2PD and the other tests, but mostly the correlation coefficients were slightly lower (data not shown).

Table 3 shows the chance of finding NFI with each of the other tests if one of the tests shows NFI. The high predictive value of the absence of vibration sense or position sense is separately illustrated in Figures 2 and 3.

The chance of getting normal test results with each of the other tests if one of the tests is normal is shown in Table 4. The predictive value was high for normal results of the pinprick test, the moving 2-point discrimination test and the Semmes–Weinstein monofilament test. This is illustrated separately in Figures 4, 5 and 6, respectively.

Discussion

The importance of the early detection of NFI is based on the assumption that early detection will lead to improved treatment prognosis. Until now scientific evidence for this assumption is lacking. Our ability to detect peripheral neuropathy obviously depends on the sensitivity of the instruments used during the nerve function assessment (NFA). Sensory testing in the field is usually done with the 'ballpen test', as recommended by Jean Watson.[12] This test, along with the 'field VMT', certainly brought a great improvement to many field programmes where no NFA was done at all, but they are probably not sensitive enough to detect less severe NFI. In one study only 61% of patients with foot ulcers had sensory NFI according to the ballpen test, while 95% tested positive using a single SW monofilament (no. 5.07).[7] The variance of test results on repeated testing with the ballpen has been shown to be very large.[5] It should be remembered, though, that the ballpen test was originally introduced to determine whether or not a patient had WHO

Table 2. Correlation between SWMT results and results of the other nerve function assessment methods respectively, using linear regression

nerve	r†	95%ci	r^2	F‡	β§
M2PD					
Median	0·73	0·62–0·81	0·53	111	0·216
Ulnar	0·8	0·72–0·86	0·64	176	0·252
PT*	0·57	0·42–0·69	0·33	47	0·203
PP					
Median	0·77	0·67–0·84	0·59	142	0·641
Ulnar	0·82	0·74–0·87	0·67	179	0·684
PT	0·68	0·56–0·78	0·47	86	0·621
PS					
Median	0·56	0·41–0·68	0·32	45	0·607
Ulnar	0·65	0·52–0·75	0·43	72	0·668
PT	0·41	0·23–0·56	0·17	20	0·44
VS					
Median	0·73	0·63–0·81	0·54	114	4·76
Ulnar	0·64	0·51–0·74	0·41	68	3·27
PT	0·61	0·47–0·72	0·38	59	2·5

* PT = posterior tibial.
† r = correlation coefficient.
‡ F test results are all highly statistically significant ($p < 0{\cdot}001$).
§ β = regression coefficient.
Other abbreviations, see Table 1.

disability grade 1 (anaesthesia), and *not* to screen for early NFI. Reliability of the ballpen test may well be improved by careful testing giving standard instructions like 'only use the weight of the ballpen as pressure' or, 'give as little pressure as possible' (Jean Watson, personal communication). Some evidence of this was recently presented from Ethiopia and Nepal. Lienhardt *et al.*[13] found the coefficients of agreement (Kappa statistics) to be between 0·54 and 0·74 (max. value = 1) for ballpen testing in the hands of 'trained observers'.

A range of simple but useful neurological tests is available that can be used under field conditions. A detailed protocol and suggested scoring system for the use of these tests was published by Pearson as early as 1982.[14] As yet no prospective studies have been reported using this protocol or a similar testing protocol. The use of a more extensive and sensitive NFA battery may shed more light on the sequence in which different nerve function modalities get affected in leprosy. This may well have prognostic consequences.[15] The sequence in which modalities disappear and reappear after treatment in nerve injuries and compression syndromes has been well described.[8,16] But there seems to be no general consensus among leprologists concerning this issue. Some investigators have found touch tests to be 'the least sensitive among perception tests,[17] while others have found that fine touch is lost 'early',[18] or before temperature discrimination,[19] and that there is a 'close correlation of manual (Semmes–Weinstein monofilament) and electrophysiological tests of the upper extremity.[20,21] Good correlation between graded nylon filament results and motor conduction velocity measurements was also reported by Naafs & Dagne.[22]

Table 3. Predictive value (percents) or chance of getting a positive test result (NFI) for each of the tests on the top row, given a positive result of the test in the first column

nerve	n*	SWMT	M2PD	PP	PS	VS
VS						
Median	2	100	100	100	100	
Ulnar	11	91	100	100	55	
PT†	21	86	100	100	42	
PS						
Median	2	100	100	100		100
Ulnar	10	90	100	90		60
PT	10	80	90	100		80
PP						
Median	5	100	100		40	40
Ulnar	23	87	96		43	48
PT	36	75	92		24	53
M2PD						
Median	16	44		33	13	13
Ulnar	42	55		58	26	26
PT	69	36		59	14	30
SWMT						
Median	10		70	63	20	20
Ulnar	26		88	87	39	38
PT	29		93	100	31	62

* n = the number of nerves found to have NFI according to the results of the test in column 1.

† PT = posterior tibial.

Other abbreviations, see Table 1.

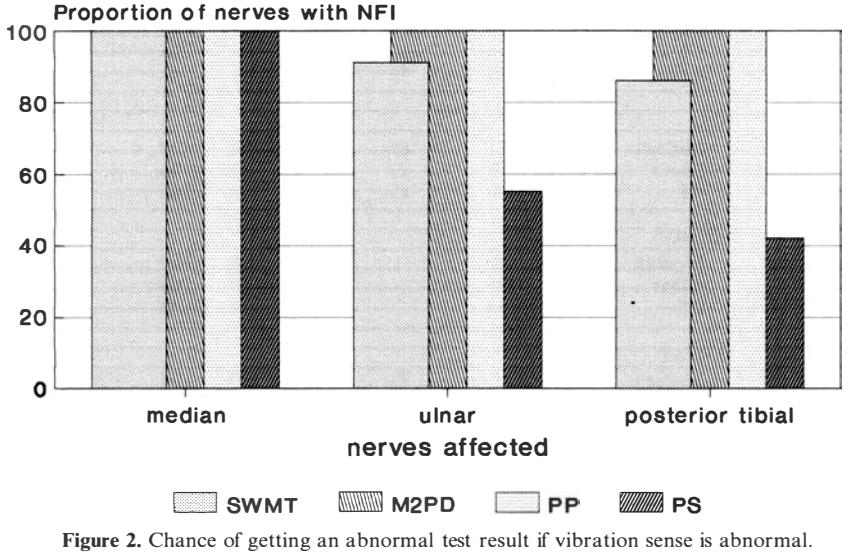

Figure 2. Chance of getting an abnormal test result if vibration sense is abnormal.

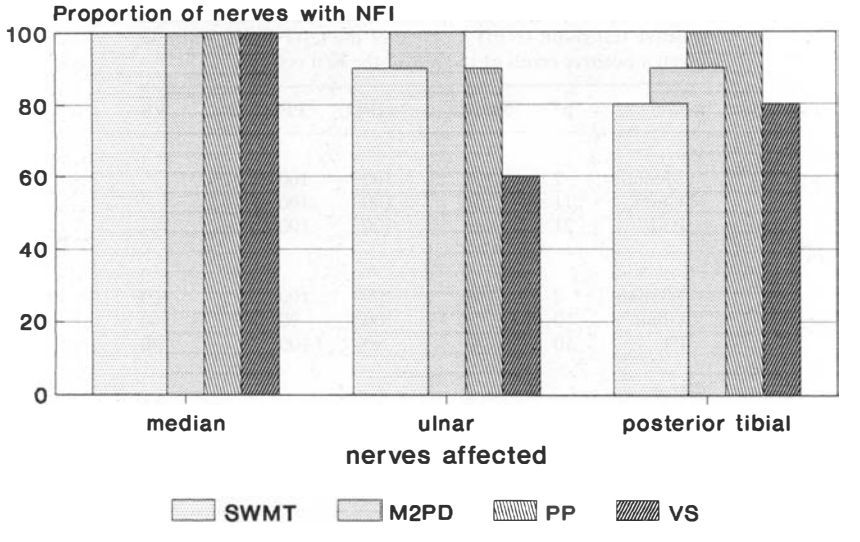

Figure 3. Chance of getting an abnormal test result if position sense is abnormal.

Table 4. Predictive value (percentages) or chance of getting normal test results for each of the tests on the top row, given a normal result for the tests in the first column

	n*	SWMT	M2PD	PP	PS	VS
VS						
Median	98	92	86	97	100	
Ulnar	89	82	65	85	95	
PT†	79	86	39	71	97	
PS						
Median	95	92	85	97		100
Ulnar	85	98	67	85		95
PT	86	79	35	63		87
PP						
Median	90	97	89		100	100
Ulnar	70	94	77		99	100
PT	42	100	45		100	100
M2PD						
Median	84	96		100	100	100
Ulnar	58	95		98	100	100
PT	31	94		86	97	100
SWMT						
Median	90		90	100	100	100
Ulnar	74		74	94	99	99
PT	71		40	82	97	96

* n = the number of nerves with a normal function according to the results of the test in column 1.

† PT = posterior tibial.

Other abbreviations, see Table 1.

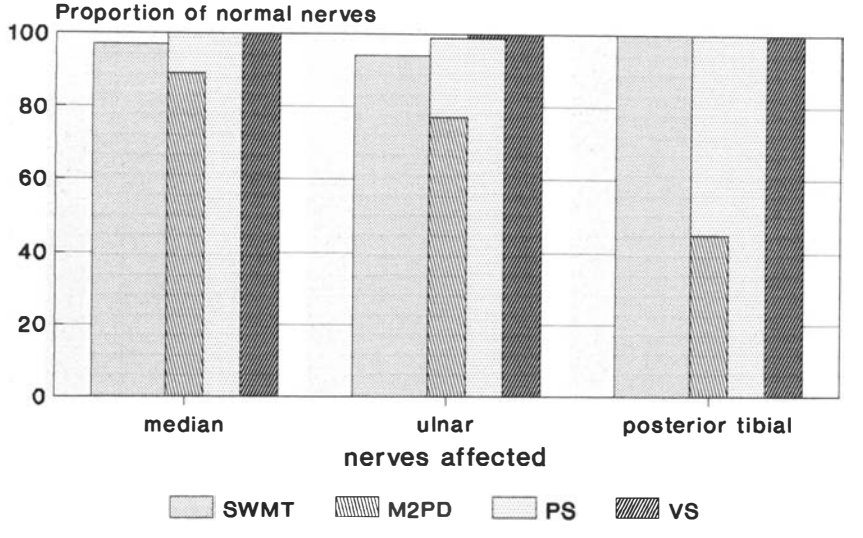

Figure 4. Chance of getting a normal test result if the pinprick test is normal.

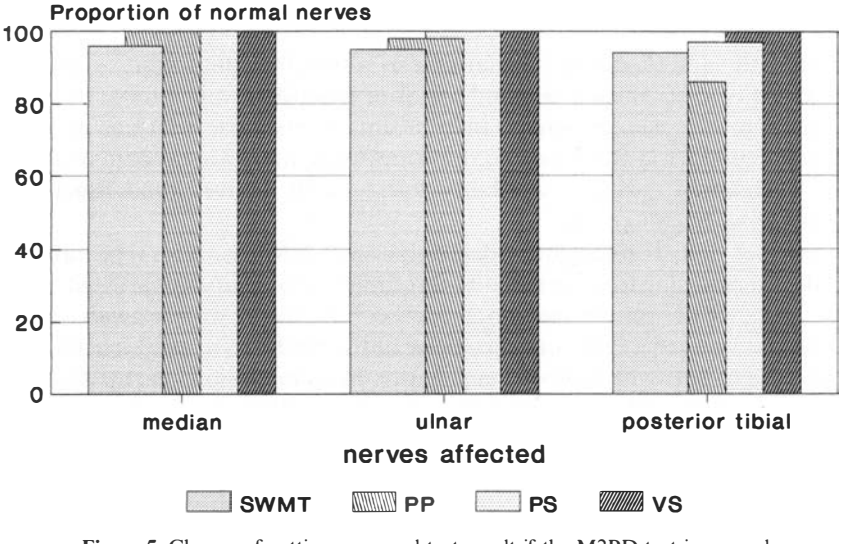

Figure 5. Chance of getting a normal test result if the M2PD test is normal.

SEMMES–WEINSTEIN MONOFILAMENTS AND MOVING 2-POINT DISCRIMINATION

The use of graded nylon monofilaments has been found to be a sensitive and repeatable method to detect less severe nerve damage in leprosy and to monitor the treatment response of NFI.[5,7,18,20,22–24] The main problem is the limited availability of standardized filaments. Other practical problems with this test include: loss of the filaments or failure to replace them after they become bent, the extra time involved in this more elaborate test, and the difficulty of finding a quiet place, free from distraction, in many field situations.

It has been claimed (in nonleprosy patients) that there may not be a good enough

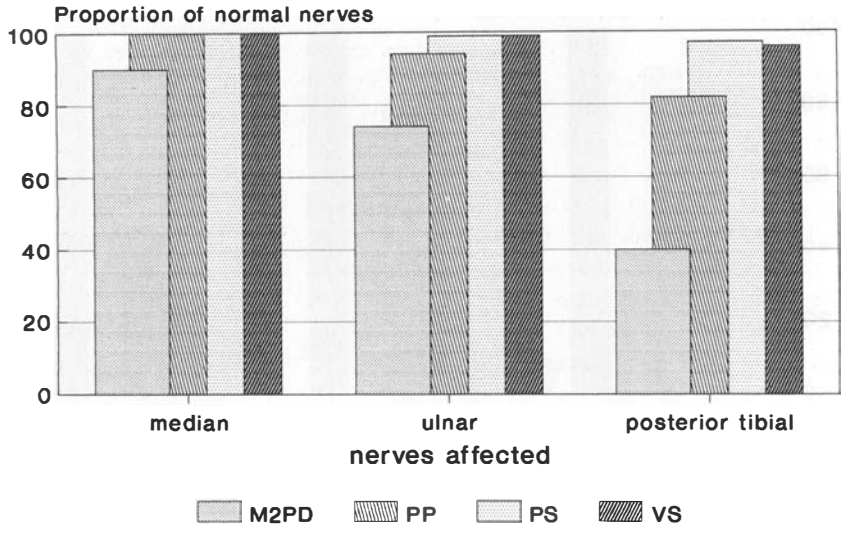

Figure 6. Chance of getting a normal test result if the SW monofilament test is normal.

correlation with hand function.[8] The latter is of course very important because, from the patient's point of view, the actual hand and foot function is much more important than passive touch-test thresholds. Judith Bell[25] claims a very close relationship between the SWMT and actual hand function. To our knowledge there are no data available in the literature correlating 'passive' sensibility testing with 'active' hand function tests in subjects suffering from leprosy.

It seems that there is sufficient evidence that the SWMT is valid, repeatable, sensitive and specific for assessing touch sensibility thresholds, provided standardized filaments are available and that the proper technique is used.[26] As far as we are aware, however, no quantiative data on sensitivity and specificity of the SWMT are available that have been determined in patients with leprosy neuropathy. In compression neuropathy the SWMT correlates very well with measurements of sensory fibre conduction and electronic vibrometry.[27] The 'coefficient of variation' (SD divided by the mean) of measured application force was less than 10% in 2 separate studies.[5,26] This was confirmed recently by our own normative study (to be published elsewhere). We chose the SWMT, therefore, as a reference test against which to compare other clinical tests of sensibility. In a recent study by Dellon *et al.*[28] testing healthy volunteers with a new computer-linked electronic device called the pressure-specifying sensory device (PSD),* static 1-point discrimination was found to have the lowest threshold for pressure perception (0·1 g/mm^2) when compared with moving 1-point and static and moving 2-point discrimination.

In our study the SWMT appeared slightly less sensitive than the M2PD in picking up leprosy NFI. The proportion of nerves testing positive with the M2PD, i.e. showing NFI, was consistently the highest of all tests (Figure 1). In a subsequent study, however, this

* Available through NK Biotechnical Engineering Company, P.O. Box 26335, Minneapolis, Minnesota 55426, USA.

was no longer the case (to be published later). The predictive value of a normal SWMT result was less good than that of the M2PD and the PP. Until studies with even more sensitive electronic testing instruments become available, the question of which instrument is the most sensitive in screening for leprosy neuropathy may well remain unanswered. But the monofilaments are very easy to use and results have been shown to have only limited interobserver variability.[5] This feature makes the SWMT particularly suitable for serial testing, such as in the monitoring of NFI treatment.

The M2PD was introduced by Dellon as a test of the quickly adapting fibre system which mediates 'moving touch' and is therefore claimed to be a test of 'functional sensibility'. The test can be done with a paperclip if necessary, but for this study we used the instrument specifically marketed for static and moving 2-PD testing, the Disk-Criminator™. Both static and moving 2-PD have been criticized for their inability to produce repeatable pressure stimuli in an electronic testing setup.[29] However, the fact that the normal values found by different investigators, particularly for the M2PD, have been very consistent and with little variance, it seems that this criticism may not be valid in the clinical testing situation.[8,9,30]

In the current study we found a very good correlation between SWMT and M2PD, particularly in the hand. In compression neuropathy the M2PD is only affected much later than the SWMT.[27] It has been suggested by Lundborg *et al.*[31] that the reason for the latter may be that 2-point discrimination involves higher cortical integration, which needs only a minimum of peripheral input for correct interpretation. One explanation for our observation might be that the SWMT does not actually selectively stimulate the slowly-adapting fibre system (static touch) and the M2PD does not only selectively stimulate the quickly-adapting fibre system (moving touch), as has been claimed,[8] but each test cross-stimulates mechanoreceptors of both systems. It has been shown that handheld instruments for sensibility testing always produce a whole range of stimulus frequencies.[29] Another explanation for the observed good correlation between the 2 tests might be that in leprosy neuropathy individual fascicles are affected, producing a 'patchy' pattern of impairment. This may equally affect touch thresholds as well as innervation density (moving 2-point discrimination), and therefore give a good inter-test correlation (Dr A. Lee Dellon, personal communication).

The difference between the M2PD and the SWMT was the largest on the foot (69% *vs* 29%) and it may be that the M2PD is less reliable for testing sensibility there. In a recent study we found the coefficient of variation to be as high as 50% for normal values of M2PD on the foot.[9] A possible explanation could be that the higher cortical integration, required for interpretation of 2-point discrimination, is less well developed for the sole of the foot than for the fingertips. Weinstein suggested that this would be the reason behind the lack of correlation that he observed between static 2PD and monofilament thresholds, which are apparently registered at a lower cerebral level.[32] Callous on the footsole may be another reason why M2PD may be more affected than the pressure sensibility.

A normal M2PD result had the highest predictive value for finding normal results with the others tests. Our data therefore suggest that M2PD may be a very sensitive test of NFI in leprosy. This supports the finding of Lewis that (static) 'two-point discrimination was lost early'.[18] However, it was found that M2PD was the test most difficult to explain to the patients and the most prone to misunderstanding of those used in this study. Therefore the clinical usefulness, particularly the intra- and interobserver reliability, will still need to be confirmed in a follow-up study.

PINPRICK

Pinprick (pain) sensation is mediated by 'free nerve endings' of small myelinated and unmyelinated fibres. But again a prick with a pin or toothpick will cross-stimulate all other touch receptors as well. It has been observed to be often present while static touch sensibility is either diminished or absent.[18] In the present study we found a very strong correlation between SWMT and PP results (Table 2). This directly contradicts the findings of Oommen *et al.*[33] who found no association between the loss of touch perception and the loss of pain perception in 76 ulnar nerves of 38 patients. It is not possible to explain this discrepancy because Oommen *et al.* do not give any details of their testing techniques or of their criteria for 'loss of perception'. A normal PP result had a high predictive value for a normal SWMT result (Figure 4), while the SWMT was often still normal when the PP was already affected. The PP may thus be a useful screening test for NFI in leprosy, especially under field conditions. It is easy to carry out and was found to be easily understood by the patients.

The disadvantage is the great potential variability in the stimulus strength (more or less pressure given on the pin), which actually influences the patients' perception of 'sharp' or 'blunt'. This could be overcome by the use of weighted sliding, or spring-loaded pins as described by Palande & Bowden,[34] and Jain *et al.*[35] Availability may again be a problem with these instruments, as is the use of metal needles, because of the risk of a perforating injury, with an associated risk of infection. The use of a pointed wooden pin, such as a tooth pick, is therefore preferred over an actual pin.[15]

POSITION SENSE AND VIBRATION SENSE

In a recent study by Jennekens,[15] 33% of the examined leprosy patients had an abnormal position sense of 1 or more digits in 1 or more limbs. 'It reflects a severe impairment of the distal, thick sensory fibres.'[15] In our data this percentage was 19% (data not shown). This difference could be because the patients studied by Jennekens were inpatients, with advanced leprosy only, while our group contained both in- and outpatients and both advanced and 'less severe' cases. The fact that an abnormal PS reflects severe NFI is illustrated by our finding that if the PS is abnormal, there is a very high chance that the other tests will also be abnormal. Whether an abnormal PS is also a bad prognostic sign for the chance of recovery after treatment of NFI is currently being investigated in a prospective study at our hospital. The test was found to be easy to perform and easy to understand by the patient and does not need any instrumentation.

Electronic vibrometry is currently widely accepted as a very sensitive method of assessing nerve function.[36–40] We are aware of only one systematic study where vibration perception was measured to assess peripheral nerve function in leprosy.[7] In this study Hammond & Klenerman found that vibrometry, using a handheld biosthesiometer, is a sensitive method of detecting sensory impairment in the feet of leprosy patients. In our study VS was affected in a similar proportion of nerves as the PS. The predictive value of an abnormal test result was equally high as for the PS, indicating that loss of vibration perception to a handheld tuning fork (a strong stimulus) may also be a sign of advanced NFI.

It would be very worthwhile to further investigate the value of controlled electronic vibratory stimuli in the diagnosis of less severe NFI in leprosy. There is a need for a

sensitive, reliable instrument for the diagnosis of NFI in leprosy, against which the sensitivity and specificity of other simple clinical tests can be calculated.

One important sensory modality that was not included in our study for operational reasons is temperature discrimination. This is an important modality in leprosy neuropathy as it has been claimed that it is affected in the early stages of the disease,[33,41] but temperature discrimination is difficult to test reliably because of the difficulty of maintaining constant temperatures for 'hot' and 'cold', particularly in hot climates and under field conditions. Schreuders & Kuipers[42] tried to use the WHO-supplied portable temperature testing device (the Thermal Sensibility Tester) for testing temperature discrimination on the hand, but it was found that 24–50% of healthy Thai people could not distinguish the difference between the hot and the cold tip of the device. If a more reliable instrument becomes available this modality should certainly be tested, as temperature sensibility plays an important role in protective sensibility. Burns are one of the most frequently sustained injuries in patients with leprosy NFI.

Considerations for practical application

The aim of this study was to examine whether the abovementioned tests are suitable as screening tests for leprosy neuropathy, *not* whether they are suitable for field use, in the hands of multi-purpose health workers. To determine their operational suitability, further studies will need to be carried out.

When applying the above tests in clinical practice, we usually test more than the 3 sites used in this study. A minimum of 3 sites per tested nerve is common; for the sole of the foot 5–10 may be used.

According to the above results it seems unnecessary to use all 5 of the tests described when screening a leprosy patient for NFI. A combination of the M2PD and the SWMT, or alternatively the PP if no standardized filaments are available, virtually excludes sensory NFI if both tests are normal and indicates definite NFI if both tests are abnormal. If at least 1 of the tests is abnormal there is an indication to perform some additional tests. Finding absence of vibration perception or position sense indicates severe sensory nerve damage and possibly a poor treatment prognosis, but the latter will still need to be confirmed in a prospective study.

Meanwhile no effort should be spared to train health workers in nerve function assessment techniques, using the locally most appropriate methods, to detect impairment as early as possible.

Conclusions

1 Correlation between the SWMT and each of the other tests proved statistically significant; the closest correlations were between the SWMT, M2PD and PP for both ulnar and median nerves.
2 The proportion of nerves testing positive with the M2PD (i.e. showing NFI) was consistently the highest of all tests.
3 Our data suggest that the M2PD is a sensitive screening test of NFI in leprosy. However, care should be given to ensure that the patient understands the test well.

4 When screening patients for NFI a combination of the M2PD with either the SWMT or PP is likely to be highly sensitive and specific.
5 There was evidence that absence of position sense and /or vibration sense indicated advanced damage to the nerve trunk and this may therefore be a sign of 'severe' NFI.

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