

## Peripheral Nerve Function Assessment

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### INTRODUCTION

Leprosy is essentially a disease of the peripheral nervous system.<sup>24,28,49</sup> It has therefore been encouraging to see an upsurge in interest in the detection and treatment of peripheral neuropathy in leprosy – commonly called ‘nerve damage’ or ‘nerve involvement’ – in recent years. Apart from early detection of leprosy and prompt treatment with multidrug therapy (MDT), nerve function assessment (NFA) and steroid treatment of any impairment detected is the main method of primary prevention of impairment and disability.<sup>46</sup> Since most deformity, activity limitation (disability) and ultimately, even psychosocial problems in leprosy result from nerve damage, NFA has a very important role to play in leprosy control programmes.<sup>47,96</sup> The purpose of this chapter is to review the existing methods to detect and monitor peripheral nerve damage, with a particular reference to field programmes.

### RELATIVE IMPORTANCE OF DIFFERENT KINDS OF NEUROPATHY

Leprosy may result in damage of sensory, motor and autonomic nerve fibres. Motor nerve impairment has been recognised as an important problem in leprosy, because it often leads to visible impairment (deformity). Regular testing of voluntary muscle strength was already suggested in the sixties.<sup>42</sup> It has been adopted on a worldwide scale as a measure of neural function and is often the only outcome parameter reported.<sup>52,70,84,88</sup> Although the importance of motor function in daily life is beyond dispute, the importance of sensory

function is often underestimated. Moberg put it very clearly when he called sensibility “the eyes of the hands”.<sup>67</sup> The importance of sensibility to the patient cannot be overemphasized. A patient with insensitive feet is at constant risk of injury, while those with insensitive hands are often severely disabled.<sup>25</sup> The role of protective sensation of eyes, hands and feet has been repeatedly emphasised.<sup>83,95</sup> Loss of protective sensation in eyes, hands and feet is responsible for much of the long-term morbidity caused by leprosy. The usefulness of sensibility testing of leprosy patients with graded nylon monofilaments was reported by Naafs & Dagne as early as 1977.<sup>69</sup> Autonomic nerve damage is important because the resulting dryness of the skin and possibly also the changed microvascular physiology are additional risk factors for injury.

Histopathological evidence shows that small unmyelinated and myelinated fibres are affected at an early stage of the disease.<sup>66,81</sup> Assessment of modalities mediated by such fibres, which include autonomic function, temperature and pain sensation, would therefore be theoretically advisable. However, these are difficult to measure reliably and are currently impossible to quantify with instruments suitable for field use. Several studies have shown sensory function to be more frequently affected than motor function.<sup>75,78,90</sup>

### Recent vs. Late

The dilemma often faced is “is this NFI ‘recent’ or ‘old’?” The implication being that recent NFI should be treated with corticosteroids, while it is assumed that old NFI would no longer

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respond. It is common practice to call NFI that occurred *within* the last six months 'recent' and beyond six months 'old'.<sup>9,52</sup> Support for this cutoff has recently been obtained in a controlled, randomised trial in Nepal and Bangladesh (Richardus *et al.*, in preparation).

### Mild vs. Severe

If treatable forms of neuropathy were detected and treated at an early stage, i.e. when they are still 'mild', the prognosis is likely to be better than when treated at an advanced, severe stage. The question is "How do we know whether a given patient has early or advanced neuropathy?" 'Early neural impairment' is a different concept from 'recent NFI'. Patients with 'recent NFI' who fail to respond to steroid treatment may in fact have had advanced neuropathy. Early detection of NFI calls for regular nerve function assessment (NFA), so that changes can be noted early in time. It also requires sensitive testing instruments, so that early changes in nerve function would not go unnoticed. In compression neuropathy it is possible to predict severity from the results of testing several different modalities of peripheral nerve function.<sup>32,41</sup> Whether this is also true for leprosy neuropathy can only be answered by prospective studies of the prognostic value of various NFA instruments. However, under field conditions, the best we can hope for is the use of a sensitive instrument that would detect neuropathy at an early stage. If appropriate normal values are available, then instruments measuring thresholds (e.g. monofilaments and (moving) two-point discrimination) will be more sensitive than methods that rely on supra-threshold stimuli (e.g. ballpen and pin prick testing).

Another issue related to the stage of neuropathy is the distinction between impairment *per se* and impairment of protective sensation.<sup>29</sup> Evidence to date shows that it is possible to

have sensory impairment *without* loss of protective sensation.<sup>17,44,54</sup> It is very important to be able to predict whether a patient is at risk of injury due to his NFI or not. Patient education, provision of protective footwear, and even choice of vocation may depend on this. An assessment method that can distinguish between presence and absence of protective sensation is clearly advantageous. However, for screening purposes it may only be possible to test for either normal threshold *or* presence of protective sensation. Where the circumstances permit, I would recommend the former, followed by a more extensive test if impairment is found. Expressed as touch/pressure sensibility and based on cross-sectional data, protective thresholds have been shown to be 2 g for the hand<sup>54</sup> and 10 g for the foot.<sup>17,44</sup> In a prospective study, Rith-Najarian *et al.* found a strong association between the inability to feel the 10 g filament on the feet of diabetic patients and the risk of amputation of the lower extremity.<sup>76</sup> Prospective confirmation of these findings in leprosy patients is needed.

### Graded vs. Non-graded Tests

Non-graded tests are mostly used for screening purposes. The result is simple to interpret: 'Yes' or 'No', 'Felt' or 'Not felt'. Their cutoff should be set at a level that provides the optimum combination of sensitivity and specificity for the screening purpose. A non-graded test can only answer the question "present or not?" In practice, because the biological parameters measured are usually continuous, an in-between category of 'partial' or 'indecisive' is often used. Examples of non-graded tests used in NFA in leprosy are ballpen testing of sensibility, hot and cold testing, pin prick testing of pain sensation and various tests to assess sweating. The main advantage of non-graded tests is that they are usually quicker and cheaper than graded tests and therefore can be

applied to many people in a short time.

The main disadvantage of non-graded tests is that they cannot give quantitative results. They can therefore not distinguish between mild and severe neuropathy, nor are they suitable to monitor progress of NFI during treatment. Often a kind of pseudo-grading is used. For example, if a fixed number of sites on the palm of the hand are tested with a ballpen or single filament, the 'threshold' for impairment is often set at more than one site 'not felt'.<sup>8,29,77</sup> Severity of sensory impairment is thus expressed in terms of extent, instead of a threshold.

#### **Normal (reference) Values**

When graded tests are used with the aim of giving a quantitative result, it is very important that appropriate reference values should be used.<sup>38</sup> Where these are not available, normative studies should be carried out. Normal values for Semmes-Weinstein monofilament testing and moving two-point discrimination have been found to differ between North-America and Asia.<sup>5,51,61</sup> Voluntary muscle testing is an exception to the rule, in that the test is standardised on what the examiner believes to be the normal strength for the person tested. It requires experience to know what is 'normal' in a given population, taking into account age and gender. Therefore, it is advisable to use a scale with clearly distinguishable categories (e.g. strong, weak, paralysed, or strong, weak, reduced range of movement, paralysed), particularly for use by non-specialised staff.

#### **Properties of a Good Test**

A good test should have good measurement properties. A good test should be valid, able to discriminate between groups, reliable, responsive to change and relevant.<sup>37,63</sup> A valid test measures what it is intended to measure. This is often expressed as the sensitivity and specificity of a test, compared to a 'gold standard'

test of what we want to measure. A closely related concept is that of 'discrimination'. A good test should be able to discriminate between people who have a condition and those who don't, or between those who have a severe condition and those in whom the condition is mild.

The 'reliability' or 'reproducibility' of a test is its ability to give the same results if the test is repeated, when the condition measured remains the same.<sup>18</sup> A test is responsive to change if it is able to detect change in what is measured. It is also important that a test is relevant to the investigation and, perhaps more importantly, to the person examined. For example, a test to see if one can discriminate hot from cold may be more relevant to a person with leprosy than a test that measures touch thresholds.

#### **Available Instruments and Tests**

Table 1 below gives an overview of available instruments and tests to assess peripheral nerve function. The list is not comprehensive, but includes the most commonly used methods that do not need advanced or expensive equipment.

#### **Clinical Assessment of Dryness of the Skin**

Assessing dryness with the fingers or back of the hand is a simple but crude test, which can be difficult to interpret on the soles of people walking barefoot or wearing open chappals, particularly in the dry season. It is as such a valid and relevant test of autonomic function, although the sensitivity and specificity are likely to be low. One study compared clinical assessment of dryness with measurement of vasomotor reflexes using laser doppler flowmetry,<sup>2</sup> but the authors did not attempt to calculate sensitivity or specificity. Because the test is crude, the responsiveness to change is also likely to be poor.

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TABLE 1

Instrument/test	Modality assessed	Description	References
<b>Autonomic function</b>			
Assessing dryness of the skin	Autonomic innervation of sweat glands	Use the finger or back of the hands to assess whether an area on the palm or sole feels dry or moist	83,96
Sweat provocation tests	Innervation and/or function of sweat glands	Sweating can be provoked using a direct method (intra-dermal methacholine injection) or indirectly (axon-reflex sweating) with intradermal nicotine	39,62
<b>Sensibility</b>			
<b>Pain</b>			
Pin prick	Pain	Use a sharp object (needle, weighted pins, toothpick) to assess whether the subject can feel pricking pain sensation	48,73,93
<b>Touch</b>			
Gentle stroking or touching with finger, feather or cotton wool	Light touch sensation (static or moving)	Gently stroke or touch an area of skin and let the subject indicate whether (s)he feels this or not	3,74
Ballpen test	Touch sensation / skin indentation	Touch the skin lightly with the tip of a ballpen and let the subject indicate whether (s)he feels this or not	4,9,26,96
Monofilament testing	Touch sensation / skin indentation	Touch the skin with a nylon monofilament and let the subject indicate whether (s)he feels this or not	4,11,20,69,93
<b>Two-point discrimination</b>			
Static two-point discrimination	Discrimination of two simultaneous, separate tactile stimuli; innervation density	Touch the skin with a calliper, bent paperclip or Discriminator and determine the minimum inter-prong distance the subject can detect as separate stimuli	23,33,68,74
Moving two-point discrimination	Discrimination of two moving simultaneous, separate tactile stimuli; innervation density	Move a calliper, bent paperclip or Discriminator over the skin and determine the minimum inter-prong distance the subject can detect as separate stimuli	31,41,74,89
<b>Thermal sensation</b>			
Warm and cold test tubes	Thermal sensation; Discrimination between hot and cold	Touch the skin alternately with the warm and cold test tubes and ask if the person can tell which one is warm and which is cold	3,73,74
Ether or alcohol test	Cold sensation	Dip a cotton wool swab in ether and alcohol and touch the skin of the person to be tested alternatively with a dry swab and the ether (alcohol) swab and ask whether the person can tell which one feels cold	
<b>Motor function</b>			
Voluntary muscle test (manual muscle strength test)	Muscle strength as a proxy for motor fibre function	Ask the subject to perform a specified movement and grade the muscle strength against resistance given by the tester	20,42,96
Dynamometry / pinch grip testing	(pinch) grip strength	Ask the subject to squeeze or pinch the instrument with as much force as they can and read off the results on the meter	80,82

**Pin prick test**

The pinprick has been widely used, particularly in India. In its basic form it is a non-graded 'yes/no' test, but modifications using spring-loaded devices or sliding weights have been proposed.<sup>48,73</sup> Given that loss of pain sensation is one of the key problems in leprosy,<sup>19,39</sup> and that histopathological evidence indicates that small (unmyelinated) fibres are among the first to get affected,<sup>7,81</sup> the validity of testing pain sensation seems beyond question. The test also seems relevant, as long as the affected person understands that their problems may be related to loss of pain sensation. We compared the reliability of a pinprick test performed with a wooden toothpick with that of monofilament testing and moving two-point discrimination.<sup>92</sup> The pin prick test performed less well than the two touch sensibility tests. Although careful testing with a wooden toothpick could be defended, the use of reusable pins should be discouraged, because of the risk of transmission of HIV and Hepatitis B infection.

**Ballpen test**

The ballpen test is perhaps the most widely used sensory test in the field of leprosy.<sup>8,15,26</sup> Its strengths lie in its simplicity and in the almost universal availability of the instrument.<sup>97</sup> The validity of the test has not been formally evaluated against a reference test, but theoretically, it should have good validity as a test of touch sensation. Given that a light touch with a ballpen will generate touch pressure in the range of 4 g upwards,<sup>12</sup> the ballpen test is not a valid test of normal sensibility, at least not on the hand (see normal thresholds under monofilament testing below).<sup>51</sup> The ballpen test is likely to be more valid as a test of protective sensation, although prospective evidence for this is lacking.<sup>17,76</sup>

Ballpen testing is often believed to be easy. However, applying a ballpen tip with consistent light pressure is far from easy. The tip of the ballpen should be applied to the skin with just enough force to see the skin move. If the skin blanches, too much pressure is being applied.

Reliability has been studied in Ethiopia, Nepal and Bangladesh and has been found to be moderate to good.<sup>4,57</sup> Responsiveness to change has not been studied separately, but several studies have reported use of the ballpen test in monitoring sensory function during MDT and also during steroid treatment of reactions and NFI.<sup>8,15,27</sup> From these reports it appears that the test is capable of detecting deterioration in sensory function and subsequent improvement during steroid therapy. However, as a non-graded test it is likely to respond only to major changes.

**Static two-point discrimination**

The (static) two-point discrimination (2PD) test has been widely used to evaluate sensibility, mainly of the hand. It is a test of innervation density of the skin.<sup>32</sup> Its main field of use has been neural compression syndromes and traumatic nerve lesions.<sup>41,68,87</sup> Only one study has reported the use of static 2PD in people affected by leprosy.<sup>23</sup> The validity of the test is good in relation to hand function.<sup>33,35</sup> However, with regard to sensory function in patients with compression of the median nerve in the carpal tunnel, static 2PD was considerably slower to respond to change than monofilament and vibration perception testing.<sup>41,87</sup> Reliability has been reported to be good.<sup>34</sup>

**Moving two-point discrimination**

Like static 2PD, moving two-point discrimination (M2PD) is a test of innervation density, which is a valid parameter to measure nerve function in leprosy. It is an example of a test

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that is not very relevant to the person tested and, indeed, we have found it difficult at times to explain what we were asking the person to indicate. This was particularly true for measurements on the sole of the foot.<sup>51</sup> The validity of M2PD in terms of correlation with functional sensation of the hand has been extensively documented.<sup>33,35,71,89</sup> The same is true for reliability, which is good, despite the fact that the application force of the test instrument is not controlled.<sup>34,72,92</sup> Reference values are available from different populations.<sup>30,36,51,58</sup>

### Monofilament testing

The principle of sensibility testing with graded filaments (or horsehairs as were originally used) was invented by von Frey, towards the end of the 19th century. Semmes and Weinstein introduced the idea of using standardised nylon monofilaments, instead of hairs.<sup>98</sup> The method was first used in leprosy by Naafs<sup>69</sup> and later by Judith Bell-Krotoski at the National Hansen's Disease Centre in Carville, Louisiana.<sup>10-12</sup> The appropriate stimulus in this type of sensibility testing is skin indentation and that monofilament testing is a valid way of approximating this.<sup>50</sup> With regard to functional

sensation of the hand, a useful correlation has been demonstrated.<sup>89</sup> We showed that people who were unable to feel a 2-g filament on the hand, also had difficulties with functional sensation, such as texture discrimination and dot detection. However, other investigators found that monofilament testing did not correlate well with a timed object recognition test,<sup>33</sup> or the sensibility involved in Braille reading.<sup>71</sup>

Reliability has been tested in different settings and generally has been found to be very good.<sup>4,14,16,57,92</sup> Responsiveness to change has been shown in experimentally induced compression of the median nerve,<sup>41,59</sup> and in patients with carpal tunnel syndrome.<sup>87</sup> Normal thresholds for monofilament testing have been established for populations in North America as ~70 mg on the hand and ~300 mg on the foot.<sup>13,43,99</sup> In Nepal and India, these thresholds are around 200 mg for the hand and 2 g for the foot (see Table 2).<sup>5,51,60</sup> Thresholds for protective sensation are generally accepted to be in the range of 2 g for the hand<sup>54</sup> and 10 g on the sole of the foot.<sup>17,44</sup>

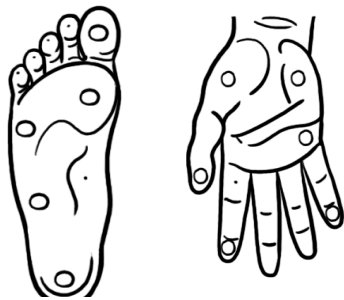
Often 10 or even more sites are tested on each hand and foot. This is time consuming and may compromise test reliability, particular-

**TABLE 2** Summary of normal sensory monofilament thresholds (95th centiles) by age group for some commonly tested sites on hands and foot (data obtained in Nepal;  $n = 600$ ).

Site	< 20 yrs		20-50 yrs		> 50 yrs		Overall	
	Force	Colour	Force	Colour	Force	Colour	Force	Colour
Little finger	120 mg	(Blue)*	200 mg	Blue	200 mg	Blue	200 mg	Blue
Hypothenar	120 mg	(Blue)*	200 mg	Blue	200 mg	Blue	200 mg	Blue
Thumb	120 mg	(Blue)*	200 mg	Blue	200 mg	Blue	200 mg	Blue
Big toe	500 mg	(Purple)*	2 g	Purple	6 g	(Orange)*	2 g	Purple
MTP1	500 mg	(Purple)*	2 g	Purple	6 g	(Orange)*	2 g	Purple
MTP5	500 mg	(Purple)*	2 g	Purple	6 g	(Orange)*	2 g	Purple
Heel	2 g	Purple	10 g	Orange	29 g	(Pink)*	10 g	Orange

\* The filament in parenthesis, though not corresponding with the actual threshold, is the one that should be used for the given test site and age. MTP1(5) = first (fifth) metatarsophalangeal joint.

ly when clinics are busy. Statistical analysis has shown that the number of test sites may be reduced, while preserving 95% of the sensitivity for detecting NFI obtained with testing ten sites. We currently recommend 6 sites on the hand (3 ulnar and 3 median) and 4 on the foot. The recommended test sites are shown in Figure 2-1.



**FIGURE 2-1:** Sensory test sites on hands and feet.

The disadvantages of monofilament testing are the limited availability of the standardised filaments, the lack of standardisation of filaments,<sup>65</sup> their fragility and the fact that careful testing methods and training are required,<sup>56</sup> particularly also in the *interpretation* of the results. In addition, the results – monofilament thresholds – are not very relevant to a person's daily life.

Despite these difficulties, the monofilament is increasingly used, also in the monitoring of diabetic neuropathy.<sup>34,45,71</sup> Some programmes use a two-filament screening test, usually 2-g for the hand and 10-g for the foot, others use a graded 5, 6 or even 20-filament test. The full advantage of the monofilaments can only be appreciated when a graded test is used.<sup>55</sup> This allows monitoring of touch thresholds over time using visually easy-to-interpret colour coding of results, matching the colours of the filaments (personal experience of the author).

Monofilament testing is often considered difficult, especially when compared to ballpen

testing. In my experience, the reverse is true. While filament testing requires careful training, the buckling qualities of the nylon ensure a repeatable touch stimulus for a given filament. In contrast, the pressure exerted by the ballpen is dependent on the force applied by the tester. Ballpen testing can provide reliable results, but (maintaining) a good technique is not easy. Other issues in monofilament testing are that thresholds may vary 1) with the moistness of the skin,<sup>64</sup> 2) with (non-)use footwear,<sup>86</sup> and 3) with age, with filament thresholds increasing with age.<sup>5</sup> With subjects above 60 years of age, higher normal reference values should be used.

#### Temperature discrimination test

Temperature sensation is a potentially important test because it is mediated by small myelinated and unmyelinated fibres, which are affected early in leprosy (see above).<sup>81</sup> Testing for temperature discrimination using hot and cold test tubes or cotton swabs dipped in ether or alcohol has been used for a long time. However these tests are crude, cumbersome (test tube testing) and are not always easy to perform under field conditions. WHO introduced a handheld thermal testing probe, which was battery powered and had one hot tip and one at ambient temperature. Some investigators found it very useful,<sup>85</sup> others found that even healthy volunteers could often not distinguish both ends of the probe.<sup>79</sup> The latter could be due to high environmental temperatures. In recent years, automated computerised systems have become available, with which quantitative assessment of warm and cold perception thresholds is possible.<sup>6,39</sup> However, these systems are not practical under field conditions. They may be very useful in certain research settings. The validity and relevance of temperature discrimination testing in leprosy is high, as wounds due to impairment of thermal sensation are very common.

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### Voluntary muscle test

The voluntary muscle test (VMT) or manual muscle strength test (MMST) has been in use for a long time.<sup>1</sup> Goodwin first recommended voluntary muscle testing for use in leprosy.<sup>42</sup> As several muscle groups in face, hands and feet are commonly affected in leprosy, the VMT would seem a valid and relevant test. Brandsma recommended a modified MRC scale for grading the test when assessing people affected by leprosy.<sup>20</sup> In the modified scoring system, because only small muscles are evaluated, the effect of gravity is not taken into account (see Table 3). Although formal validity evaluation has not been done in the field of leprosy, many studies bear witness to the validity of the VMT as a proxy measure to monitor motor nerve function.<sup>9,27,52,91</sup> Reliability of the 0-5 MRC scale has been well established.<sup>21,22,40,53</sup> However, extending the scale by adding in-between categories (e.g. 4+, 3+, etc) was not found to be helpful, as such grading was not reproducible.<sup>22</sup> No reports on formal reliability testing of the abbreviated 3-point (strong, weak, paralysed) and 4-point scales (strong, resistance reduced, movement

reduced, paralysed) have been published. Responsiveness to change has been operationally confirmed through the use of the test in many studies. The test is technically one of the more difficult ones to perform, as the tester uses 'intrinsic normal values', based on the tester's experience of what is normal muscle strength. Since normal muscle strength varies with sex and age, this requires considerable practice. A strength of this type of testing is the fact that no testing instruments are required. The simplified version of the VMT, called the Quick Muscle Test (QMT) is often used in the field (Table 4).<sup>15</sup>

**TABLE 4** Muscles and movements tested in the Quick Muscle Test (QMT). Each movement is graded as 'Strong', 'Weak' or 'Paralysed'.

Nerve	Muscle (group)	Movement
Facial	Orbicularis oculi	Tight eye closure
Ulnar	Hypothenar muscles	Little finger out
Median	Thenar muscles	Thumb up (with palm horizontal)
Radial	Wrist extensors	Wrist up (forearm pronated)
Lateral popliteal	Foot dorsiflexors	Foot up

**TABLE 3** Modified MRC grading for voluntary muscle testing.

	Grade	Criteria
Hands & Feet	5	Full range of movement of the joint on which the muscle or muscle group is acting. Normal resistance can be given.
	4	Full range of movement but less than normal resistance
	3	Full range of movement but no resistance
	2	Reduced range of movement with no resistance
	1	Perceptible contraction of muscle(s) not resulting in joint movement
	0	Complete paralysis
Eyes	5	Normal forced eye closure
	4	Full closure against reduced resistance
	3	Full closure without resistance
	2	Partial closure (lid gap persisting)
	1	Muscle flicker (no closure)
	0	Complete paralysis



### Dynamometry and pinch grip testing

Dynamometry – measurement of grip and pinch strength – has not been used widely in leprosy. Soares & Riedel have reported its use with people affected by leprosy.<sup>82</sup> They described an inexpensive dynamometer, made of a blood pressure cuff. Other investigators have published normal values,<sup>94</sup> but these would need to be repeated in local populations. The discriminative ability of hand-held dynamometry is good for ulnar nerve lesions.<sup>80</sup> While attractive because of the quantitative results, normal values vary considerably with sex and age. The test is therefore most useful if the person can be used as his/her own control. Its value to discriminate between people with mild to moderate weakness (normal range of motion) should be evaluated, as this is the range in which the 0-5 MRC scale has little discriminative power. The test is relevant to people who complain of weakness of the hand.

### Which tests to choose?

Table 5 summarises the measurement properties of the most commonly used sensory and motor tests. In the field of hand surgery, (moving) two-point discrimination is also often used. However, this test is less suitable for use on the soles of the feet and therefore less useful in leprosy.<sup>92</sup>

For most field programmes, a combination of the ballpen test and the QMT is probably the most feasible option, particularly in integrated programmes. However, in referral centres and hospitals where patients are evaluated for surgery or are treated with corticosteroids for nerve function impairment, use of the graded monofilament test and the 6-point VMT is strongly preferable. To assess the need for and success of reconstructive surgery, an activities of daily living (ADL) assessment should be added to the nerve function assessment. Discussion of the latter is outside the scope of this chapter.

**TABLE 5** Qualities of tests commonly used in nerve function assessment.<sup>7-10</sup>

	Ballpen	SWM	VMT <sup>1</sup> (0-5 scale)	QMT <sup>2</sup>
Validity	/ +++ <sup>7,3</sup>	++++	++++	+++
Repeatability	+++ <sup>4</sup>	++++	+++	?
Sensitivity to early impairment	-	+++	++	++
Responsiveness to change	++	+++	++	++?
Normal values available	NA <sup>5</sup>	yes	NA	NA
Availability	++++	++	++++	++++
Ease of use	++ <sup>6</sup>	+++	+	+++

Comments: **1** Voluntary muscle test. **2** Quick muscle test. **3** Probably good for screening for protective sensation; poor for detecting normal sensibility. **4** Good, provided the testing technique is good and consistent. **5** Not applicable. **6** The correct technique to provide a light touch stimulus is not as easy as often thought.

In addition to choosing the most appropriate tests, one needs to decide on criteria for the diagnosis 'impairment'. The following are recommended for sensory and motor impairment.

### Sensory impairment

A patient is diagnosed as having sensory impairment if the monofilament threshold is increased by three or more levels (filaments) on any site, two levels on one site AND at least one level on another site, OR one level on three or more sites for one nerve.

### Motor impairment

A patient is diagnosed as having motor impairment if the VMT score for any muscle is less than four on the 0-5 (modified) MRC scale.

Similar criteria need to be formulated to define what constitutes a clinically significant change in impairment.

### RECOMMENDATIONS

1. In the context of reconstructive surgery, the graded monofilament test is currently the sensory test of choice, provided standardised filaments are available, staff can be adequately trained and filaments can be replaced when damaged or bent. If a rapid test is required, a two-filament screening test is recommended. On the Indian sub-continent, a 2-g and 10-g filament may be used for protective sensation screening the hand and foot respectively. To screen for impairment of normal sensibility, 200 mg and 2 g are more appropriate. Higher thresholds should be used for people above 50 and for barefoot walkers.
2. Voluntary muscle testing should complement sensory testing. The choice of a 3-, 4- or 6-point scale will depend on the level of skill and understanding of the staff, but for pre- and post-operative surgical assessment, the 6-point modified MRC scale is recommended.
3. Testing of autonomic function, temperature discrimination or pain sensation might detect early sensory impairment, but tests are not (yet) available to do this easily and reliably under field conditions.
4. Sensory testing should always be included in a nerve function assessment, as a) sensibility is more frequently affected than motor function, b) current sensory tests are probably more sensitive than motor tests and c) sensory loss may precede motor impairment.
5. Moving 2-point discrimination is an attractive alternative to monofilament testing, if a quantitative test is required. It can be done with simple and robust instruments, such as a paperclip, but is less suitable for senso-

ry testing of the foot.

6. If a non-graded screening test is sufficient and the use of filaments is not possible for whatever reason, the ballpen test offers a cheap and easily available alternative. Care should be given that staff is carefully trained in the correct technique and that this technique is maintained.

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