Evaluation of the dermatomal somatosensory evoked potential in the diagnosis of lumbo-sacral root compression

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SUMMARY The dermatomal somatosensory evoked potential from the lumbo-sacral dermatomes was recorded from 21 patients with radiographically and surgically (20) proven lumbo-sacral root compression due to prolapsed intervertebral disc or canal stenosis. The potential was abnormal in 19 of the 20 surgically proven cases. The dermatomal somatosensory evoked potential is as accurate as myelography for diagnosis but has the advantage of being non-invasive and repeatable. It provides useful additional diagnostic and pathophysiological information about lumbo-sacral root compression.

Diagnosis of lumbo-sacral root compression would be aided by a reliable test of conduction through the sensory nerve root, as compressed nerves have reduced conduction velocities. Electromyographic investigation of root disorders relies on the F response which tests only the motor root, the H reflex which depends on both motor and sensory roots, and the use of concentric needle myography to detect denervation in muscles, which also evaluates only the motor root. These methods have a low diagnostic yield¹ although considerable success has been claimed in selected patients.² Patients present most commonly with only sensory symptoms and signs yet there is no objective way of testing sensory roots.

A method for stimulating individual dermatomes and recording the somatosensory evoked potential from the scalp has been described.³ Preliminary results indicate that a delayed or absent dermatomal somatosensory evoked potential may be diagnostically useful.⁴ One criticism of the technique is that stimulation of the skin must excite nerve fibres traversing two or three roots owing to the overlap of segmental innervation. To overcome this we stimulated the "signature" areas of the dermatomes where

sensory loss first occurs and is most dense.^{5,6} It was assumed that overlap at these sites would be minimal and preliminary results of direct recording support this.⁷

This paper describes the application of the technique to patients with clinically definite root lesions confirmed radiologically and surgically. The cause of compression was either prolapsed intervertebral disc or degenerative spondylotic spine disease causing canal stenosis. The study was designed as an evaluation of the sensitivity and accuracy of the dermatomal somatosensory evoked potential (DSEP) in proven cases as a basis for testing in cases where the diagnosis is in doubt. The findings show the technique to be as sensitive as myelography and to allow repeatable assessment of sensory root function.

Methods

Twenty one patients with back pain and sciatica were admitted under the care of neurosurgeons at this centre. Their clinical details are given in table 1. The diagnosis was made from the clinical and myelographic examination and confirmed or modified by the operative findings. Surgeons were asked to identify at surgery which roots were compressed without prior knowledge of the dermatomal somatosensory evoked potential findings. The dermatomal somatosensory evoked potential was recorded prior to surgery but the results were not used to make the diagnosis or to determine the management.

The method for recording the dermatomal somatosensory evoked potential and the criteria for abnormality of the L5 and S1 dermatomes have been published.³ The findings were extended to other lumbar dermatomes to define abnormal-

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Table 1 Clinical signs, myelography, DSEP and operative findings

Clinical findings											
Case	Age (yr) & sex	Sciatica Side & duration	Clinical findings		Tendon reflex knee, ankle		SLR & stretch test		Myelography	DSEP	Operative findings
			Motor	Sensory	Rt	Lt	Rt	Lt			
1	35 F	Lt 5 yr	N	Lt S1	++	++	25	5	L5/S1 PID	Lt L5 delay	Central L5/S1 PID compressing Lt L5
2	69 M	Lt 2 m	Lt L5, S1	Lt L5-S2	++	++	90	90	Large central L4/5 PID	Rt L5, S1 absent	L4/5 PID bilat L5 & S1 root compression
3	22 M	Lt 2 yr	N	N	++	++	80	30+	Left lateral L4/5 PID	Normal	L4/5 PID compressing L5 root on Lt
4	69 F	Lt 1 m	Lt L2-L5	Lt L4, 5, S1	++	++	80	50+	Large central L3/4 PID	Delay Lt L4	Conservative management
5	33 M	Lt 6 m	Lt L5	Lt L5	++	++	90	90	Large central L4/5	Absent Lt L5	Central L4/5 PID and postero-lateral L5/S1
6	50 M	Rt > Lt 3 yr	Lt L5, S1	Lt L4, 5, S1	+	++	90	90	L4/5 PID complete block CT-L4/5 PID	Rt L5, S1 Delayed	Rt L5 root compressed
7	46 M	Rt 3 m	Rt L5, S1	Rt S1	++	++	10+	90	Rt lateral L5/S1 PID	Rt & Lt L5 delay	Large L4/5 PID compressing L5 bilat and Rt S1
8	42 F	Rt 1.5 yr	N	N	++	++	40	80	Central L2/3 PID CT confirmed	Rt S1 delay	L5/S1 PID compressing the Rt L5 & S1 the latter more severely affected
9	45 M	Rt 1 yr	Rt L5	N	++	++	90	90	Central L4/5 PID	Bilat L4 delay > on the Rt. L3 normal	L2/3 central PID affecting L3 L4 nerve roots on the right
10	41 F	Rt & Lt 4 yr	Bilat L5	Bilat S2-S4	++	++	10+	10+	Rt lateral L5/S1 PID CT central L5/S1 PID	Rt L5, S1 absent	L4/5 PID compressing Rt L5
11	34 M	Rt 1 yr	N	Rt L5, S1	++	++	40+	90	Central L5/S1 PID	Lt L5 delay	L5/S1 lateral PID compressing Rt S1
12	58 M	Lt > Rt 1 yr	N	Lt L4-S1	++	++	90	90	Central L3/4 & L4/5	Rt L5 absent	Large L5/S1 PID compressing Rt L5 root
13	64 F	Rt 2 yr	N	N	++	++	75	90	L2/3, L3/4 impressions L4/5 spondylolithesis	Bilat L5 delay	Central L3/4 PID L4/5 canal stenosis involving the L5 roots bilaterally
14	62 F	Lt 9 m	Lt L5	N	++	++	90	+60	Lt lateral L4/5 PID	Lt S1 delay	Lumbar canal stenosis L4/5 & L5/S1 L4 & L5 roots involved bilaterally
15	46 F	Lt 4 m	Lt L5	Lt L5/S1 + perianal	++	+	70	35+	Lt lateral L4/5 PID	Lt L5 delay	L4/5 spondylitis compressing the Lt L5 root. No PID
16	44 M	Bilat Rt > Lt 4 yr	L2-S1	Rt L4	+++	+++	60+	60	Spinal stenosis complete L1/2 block	Lt L5 S1 absent	Canal stenosis
17	67 M	Lt 1 yr	Lt > Rt Lt L3-5	Bilat L5-S4	++	++	90	50+	Spondylotic change at L5, Lt L5, S1 roots obliterated	Rt L5 delay	Lt L5 compressed
18	51 M	Lt 6 m	Lt L3	L3, 4	++	0	90	75	Lt lateral L3/4 PID and small L4/5 PID	Lt L5 bilat	Canal stenosis
19	61 F	Lt > Rt 2 m	N	Lt L2-L4	++	++	40+	50+	L4/5 PID, facet hypertrophy complete obstruction	Lt L4 delay	Canal stenosis L3/4 mainly on the left compressing the Lt L3 & L4 N root. No PID
20	23 M	Lt 2 yr	Lt L5	Lt S1	++	++	30	+20	? Lt S1 root fills poorly. CT L5/S1 PID	Lt L3 absent	Canal stenosis L4/5, L5/S1 L4 & 5 root involved bilaterally
21	36 M	Rt 2 yr	N	N	++	++	80	70	Normal. CT lateral L5/S1 PID	Rt L5 delay	Lt L5 root compressed by fibrous tissue. No PID
					++	++				Normal	Rt L5 root thick and inflamed. No PID

Cases 2, 8, 10, 15 minor urinary symptoms (frequency, urgency). Case 12 urinary incontinence. 16 urinary retention and faecal incontinence.

Reflex: +++ brisk; ++ normal; + reduced; 0 absent.

N = normal. Stretch test + = Positive Lasague. DSEP = Dermatomal somatosensory evoked potential.

PID = prolapsed intervertebral disc.

ities as follows:

- (1) An absent DSEP.
- (2) A side to side difference of more than 3.5 ms for L4.
- (3) The latency of a dermatome should lie between the latencies of the dermatome above and the one below.
- (4) Side to side amplitude ratio exceeding 4/1.
- (5) Latencies of response other than L5 and S1 taken from reference 8.

Although a previous study showed no significant effect of age, allowance was made for this in patients over 45 years old whose absolute latency values were borderline. (See table

III in ref 3); latency is prolonged by approximately 0.86 ms per decade for L5 and 0.38 for S1.

Sensory threshold to stimulation of the skin by single pulses was determined by the method of limits and expressed in mA. Pulses of 2.5 × sensory threshold, which excite only cutaneous afferents, were used to evoke the potential. The stimulus was applied at the signature areas shown in fig 1. The posterior tibial nerve was also stimulated at the ankle as previously described.³ Recording was from scalp electrodes placed at Cz' (2 cm posterior to Cz on the 10-20 system) with the reference midway between Fpz and Fz. The averaged

waveform was a W shaped response and the latency to the first positive peak was measured. Responses were noted as delayed or absent and the findings were compared with the final diagnosis, (fig 2).

Results

Twenty one patients were studied; 13 were male and eight female. Their ages ranged from 22 to 69 years, mean 47.5 years and their symptoms had been present for 1 month to 5 years with a mean of 18.4 months.

The clinical details are shown in table 1; the final diagnosis was provided by the operative findings. Eleven had prolapsed intervertebral disc, including one whose condition improved and in whom surgery was deferred. Eight had spondylotic changes causing canal stenosis, this term is taken to include central canal, root canal and lateral recess stenosis.⁹ One of the eight patients had a prolapsed intervertebral disc also (case 12) but his problems related to the level of stenosis rather than to the disc. Of the two remaining patients, one had a L5 root compression by fibrous tissue but no disc or degenerative change. In the other, the root was described as thickened and inflamed but no disc or stenosis was seen.

Comparison of the dermatomal somatosensory

Fig 2 Dermal somatosensory evoked potential and tibial nerve SEP are shown from a 23 year old female (case 20) with a surgically proven left L5 root lesion. The response latency from the L5 dermatome was 50.4 ms on the right and 55.2 ms on the left. From the S1 dermatome the latencies were 51.6 ms on the right and 52.0 on the left. The side to side difference from L5 was 4.8 ms and the upper limit of normal is 3.5 ms.

Fig 1 The signature areas of the lumbo-sacral dermatomes are hatched. Dermal stimulating electrodes were applied at these sites.

evoked potential findings with the final diagnosis indicates the sensitivity of the test. In 19 of the 21 cases the dermatomal somatosensory evoked potential was abnormal indicating a high sensitivity of the test. It failed to reveal root dysfunction in case 3. This man had limited straight leg raising but no motor, sensory or reflex signs. Myelography showed a L4/5 prolapsed intervertebral disc which was confirmed at surgery to be compressing the left L5 root. In case 21 there were no clear objective clinical findings except slight limitation of straight leg raising, myelography was normal but a CT scan was interpreted as showing a lateral L5/S1 prolapsed intervertebral disc. At surgery no compression or disc was seen, root inflammation was reported but no cause was found. In this case the CT scan was, in retrospect, over-interpreted but the dermatomal somatosensory evoked potential had accurately predicted the absence of root compression.

In the other 19 cases the dermatomal somatosensory evoked potential showed an abnormality. In five of these cases no clinical sensory change had been detected despite careful testing. Comparison of the dermatomal somatosensory evoked potential abnormality with the final diagnosis revealed abnormality in the appropriate root or roots and on the expected side in 17/19 cases. Case 1 had a L5/S1 prolapsed intervertebral disc with clinical sensory changes in the left S1 dermatome, however both the dermatomal

somatosensory evoked potential and the operative finding showed a compressed L5 root, the DSEP predicted the operative finding rather than confirming the clinical changes. Case 10 had a right lateral L5/S1 prolapsed intervertebral disc compressing the S1 root but clinically there were bilateral L5 motor signs and bilateral S2-S4 sensory signs. The left L5 dermatome somatosensory evoked potential was abnormal but the operative finding was of a compressed right S1 root.

In six cases the dermatome somatosensory evoked potential abnormality was bilateral but only one patient complained of bilateral sciatica and none had bilateral clinical signs. However two had bilateral spondylotic change and three had central prolapsed intervertebral disc so it was possible that the roots were compressed bilaterally.

Both delayed and absent responses were seen; some cases showed both (fig 3). We thought that absent responses may be associated with a more severe clinical deficit but this was not the case. Absent responses were more frequently associated with acute lesions.

Symptoms had been present for a mean of 6.2 months ± 4.8 in the six cases with absent responses but for 23.2 months ± 19.2 in those with delayed responses. The difference is statistically significant, $p = 0.04$ (Mann-Whitney U test).

Sensory thresholds to electrical stimulation of the dermatomes were determined as part of the procedure. Comparison of the thresholds in mA with those obtained from normal subjects is given in table 2. In the painful leg the thresholds were slightly but significantly raised and there was a smaller but not statistically significant rise in the symptom free leg. A significant rise in threshold was also seen from the dermatome giving abnormal potentials regardless of whether the leg was symptom free or not. It was of interest that the threshold from the L5 dermatome was raised even in those patients with a normal dermatome somatosensory evoked potential again regardless of the presence of symptoms.

Study of table 1 shows that clinically noted sensory loss in the L5 dermatome was always accompanied by an abnormal dermatome somatosensory evoked

Fig 3 A set of DSEPs from case 18 is shown. Note the absence of response from the left L3 dermatome. The response from L4 was delayed by 2.5 ms compared with the right but the amplitude ratio was just within normal limits at 3.9/1.

Table 2 Sensory Thresholds of L5 and S1 dermatomes to electrical stimulation.

Dermatome	Normal	Patients			
		Painful leg	Other leg	DSEP abnormal	DSEP normal
L5	4.1 ± 1.1 (n = 76)	5.5 ± 2.9* (n = 17)	4.7 ± 2.8 (n = 17)	5.1 ± 2.7* (n = 19)	5.1 ± 2.9* (n = 17)
S1	4.2 ± 1.1 (n = 76)	4.9 ± 1.9* (n = 17)	4.6 ± 1.9 (n = 17)	5.3 ± 2.8* (n = 9)	4.5 ± 1.5 (n = 27)

Single stimuli 0.2 mS duration, amplitude in mA. * = significantly different from normal ($p < 0.05$, t test).

potential but the converse was not the case. Sensory abnormalities in the S1 dermatome however were unreliable as predictors of an abnormal dermatomal somatosensory evoked potential. A clinical study has also shown that L5 signs were a more reliable indication of L5 root involvement than S1 symptoms and signs were of predicting S1 root involvement.¹⁰ The dermatomal somatosensory evoked potentials therefore may be abnormal even though careful sensory testing reveals no abnormality.

SEPs from the posterior tibial nerve were abnormal in only seven patients, all of whom had multiple root involvement, which indicates that stimulation of a nerve trunk is not a sensitive diagnostic test.

Discussion

Sensitivity of dermatomal somatosensory evoked potential

The dermatomal somatosensory evoked potential successfully predicted root compression in 19/20 cases; case 21 has been omitted as the surgical findings were inconclusive. In case 3 the dermatomal somatosensory evoked potential gave a false negative result; the reasons for this are speculative but he was the youngest patient and had no objective clinical signs except limited straight leg raising. A small lateral disc was found at surgery. In case 2 the abnormal dermatomal somatosensory evoked potential was found from the asymptomatic leg but the surgeon noted bilateral L5 and S1 compression due to a central disc protrusion. The diagnostic accuracy of the dermatomal somatosensory evoked potential in this group of patients compares favourably with myelography which shows 5–10% false negatives.^{11–13}

Other groups have used dermatomal somatosensory evoked potential for assessing lumbo-sacral radiculopathies^{14–18} with conflicting conclusions about the diagnostic yield. An early study found abnormalities in 92% of patients¹⁴ while others¹⁵ found abnormalities in only 5/19 patients. In the latter study the diagnostic criteria of root compression were so lenient that a low yield does not truly contradict our findings. Previous workers did not have the advantage of a carefully studied control series and

an appropriate stimulus strength for cutaneous nerve fibres in the skin was established only recently.³ In surgically proven cases of root compression, abnormalities were found in 33/34 patients when the big or little toes were stimulated bilaterally. Rather surprisingly the method depended on detecting an asymmetry of the responses from the two hemispheres.¹⁸ It is known that a SEP wave can be recorded over both hemispheres from the one leg but the waveform and latency are different on each side.¹⁹

The dermatomal technique has been applied in a similar manner to cervical radiculopathy.²⁰ Poor correlation was noted with the clinical findings, in that half the patients with a radiculopathy had a normal DSEP. Although the test may help in a few cases, its low yield is disappointing (Katifi and Sedgwick, unpublished observations). This could be a reflection of greater overlap of dermatomal innervation in the upper as compared with the lower limb. Clinical experience is that sensory signs in the legs are more reliable than motor but in the arms motor signs are considered more reliable.^{21 22}

Mixed and sensory nerves have been stimulated in an attempt to detect radiculopathies.^{15 23 24} We argue that, as each nerve trunk carries fibres which enter the spinal canal by several roots, a monoradiculopathy would be masked by a normal somatosensory evoked potential mediated by impulses in unaffected roots. This was the case in this series where the tibial nerve SEP was abnormal in only 7/21 cases. An interesting series of suspected or myelographically proven radiculopathies showed only 16/28 (57%) abnormalities on SEP following cutaneous nerve stimulation.²⁴ In view of this it is surprising that another study showed abnormalities of the peroneal nerve SEP in all patients with prolapsed discs.²³ SEP abnormalities from several nerves were found in a high proportion of patients with spinal stenosis; posterior tibial and peroneal nerves gave abnormal responses in 95 and 90% respectively while the sensory nerves, sural and saphenous, showed abnormalities in 60 and 12% of cases.²⁵ Spinal stenosis frequently involves several roots and abnormal SEPs from nerve trunks are more likely to be seen.

A valuable extension of SEP studies in spinal stenosis has been the demonstration of reversible deterior-

ration of the SEP from great and small toes after walking, flexion or extension of the spine in patients complaining of spinal claudication.²⁶

Types of abnormality

In the prolapsed intervertebral disc group of patients, five showed bilaterally abnormal dermatome somatosensory evoked potentials although only one had bilateral symptoms. The surgical findings in four of these patients confirmed central discs compressing roots bilaterally. In another seven patients, more than one root on one side were shown to be involved and there were discrepancies in the identification of the compressed root between the clinical and surgical findings. Previous studies have noted similar discrepancies.¹³ Abnormal tibial nerve SEPs were seen in only 4/12 patients and all four had involvement of more than one root.

Of the 10 patients with canal stenosis, eight showed involvement of more than one root but the tibial nerve SEP was abnormal in only 3/8 (38%). Multiple root involvement is to be expected due to the nature of the underlying pathology of canal stenosis.

Conclusions

The dermatome somatosensory evoked potential is a very accurate method of detecting abnormalities in root function and correlates strongly with demonstrable root compressions at surgery. Tibial nerve SEPs detect only a small proportion of patients. The group of patients likely to benefit most from this technique are:

- (1) Patients with clinical evidence of root lesion where confirmation of the diagnosis is sought without recourse to invasive procedure, for example patients to be managed conservatively.
- (2) Patients with clinical evidence of root lesions where myelography is equivocal or does not explain the symptoms and signs; in this group additional information about the functional status of the nerve roots is invaluable.
- (3) Cases where functional overlay predominates or psychogenic sensory loss is suspected.
- (4) In spinal stenosis where multiple lesions are usually demonstrable on myelography, knowledge of the roots most severely affected can be a helpful pre-operative guide to ensure adequate decompression.

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