Intraoperative electroneurography in the assessment of the level of operation for cervical spondylotic myelopathy in the elderly

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We treated 31 patients aged 65 years or more with cervical spondylotic myelopathy by microsurgical decompression and fusion at a single most appropriate level, in spite of MRI evidence of compression at several levels. Spinal cord potentials evoked at operation localised the level responsible for the principal lesion at C3-4 in 18 patients, C4-5 in 11 and at C5-6 in two. Despite the frequent coexistence of other age-related conditions, impairing ability to walk, the average Nurick grade improved from 3.5 before operation to 2.2 at a mean follow-up of 48 months. There was also good recovery of finger dexterity and sensitivity.

Operation at a single optimal level, as opposed to several, has the advantage of minimising complications, of particular importance in this age group.

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MRI may demonstrate clinically silent compression of the spinal cord in elderly patients.^{1,2} If the exact level responsible for the main functional change in cervical spondylotic myelopathy (CSM) can be established, anterior surgical intervention can be restricted to fewer levels than has previously been the case.³⁻¹² We have recorded the ascending spinal cord evoked potentials (SCEPs) at multiple levels after epidural stimulation to determine focal abnormalities of conduction¹³⁻¹⁸ during anterior surgery, before decompression, to exclude compression of the cord which was clinically silent. Surgical intervention could then be

directed to the appropriate level. We have previously described the favourable early results of this technique in 16 patients aged between 58 and 81 years.¹⁶ We now report a series of 31 elderly patients aged 65 years and over with a longer follow-up.

Patients and Methods

Between August 1991 and December 1996 we operated on 31 patients aged 65 years or more for moderate to severe spastic paresis of the limbs because of CSM. The patients were from a larger group of 52 who had undergone either anterior (40) or posterior (12) operations for CSM. The choice of surgical approach depended on the type of pathology, not on its extent. The posterior approach was used when posterior compression of the cord predominated on MRI. Of the 40 patients treated by anterior surgery, we excluded nine, five who had a single-level operation based solely on MRI showing an apparent herniation of the disc with cord compression, and two who had a single-level operation, with the help of SCEPs, but died from subarachnoid hemorrhage and renal cancer, respectively, within two years of the operation. A further two patients had a two-level operation for single or two-level abnormal SCEPs. The remaining 31 patients, who were found to have a conduction abnormality at a single level in the presence of multilevel compression, had anterior surgery confined to this particular site, and were followed for a minimum period of two years (Table I). There were 13 men and 18 women with a mean age of 75 years (65 to 86).

All but one had paresis of the lower limbs sufficient to impair their ability to walk. All had lost fine movement of the fingers in using tableware, doing up buttons and writing and all except three showed sensory impairment for light touch, pinprick, or vibration in the upper limb and, in all but four, in the lower limb. Sensory symptoms were present in every patient. A total of 21 had bladder symptoms. Ten had urinary retention and/or frequency, ten had a sense of retention and/or occasional incontinence, and one had retention and incontinence. Symptoms had been present for 12 months or less in 23 patients and for more than 12 months in the remainder. In those with a longer history, surgical decompression followed a major functional deterioration. To standardise the results, we used the grading of

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Table I. Details of the 31 patients with multilevel cervical myelopathy

Case	Gender	Age at operation (yr)	MRI (cord indentation and/or deformed cord)				Level of conduction abnormalities (level of operation)	Duration of follow-up (mths)	Functional outcome				Other condition impairing the ability to walk
			C3-4	C4-5	C5-6	C6-7			Nurick grade		JOA grade		
									Preop	Postop	Preop	Postop	
1	M	79	+	+	+		C3-4	57	5	2	4	1	OA* of knee
2	M	73	+	+	+	+	C3-4	84	4	1	3	1	
3	F	73	+	+	+	+	C3-4	87	4	2	4	1	
4	F	76	+	+	+		C4-5	24	4	2	4	1	
5	F	65	+	+	+	+	C3-4	79	5	3	4	2	
6	F	79	+	+	+	+	C4-5	77	3	2	4	1	OA of knee
7	F	69	+	+	+	+	C3-4	24	2	2	3	1	
8	F	75	+	+	+	+	C3-4	79	3	2	4	2	
9	F	70		+	+		C5-6	71	2	1	2	1	
10	M	79	+	+	+		C3-4	62	4	2	3	2	
11	M	81	+	+	+		C3-4	63	4	2	3	2	Lumbar stenosis, OA of hip
12	M	68	+	+	+	+	C3-4	63	3	2	4	1	Lumbar stenosis
13	F	70	+	+	+		C4-5	48	1	1	2	1	OA of hip
14	F	79	+	+	+	+	C3-4	56	4	3	5	3	
15	M	71		+	+	+	C4-5	45	5	3	5	2	
16	F	68	+	+	+		C3-4	65	2	2	3	1	
17	M	86		+	+	+	C4-5	48	5	2	4	2	
18	F	81	+	+	+	+	C3-4	48	4	4	3	2	Dementia
19	F	84	+	+	+		C4-5	47	4	4	3	4	
20	M	70	+	+	+	+	C4-5	36	2	1	2	1	
21	F	73		+	+	+	C4-5	41	4	2	4	2	
22	M	69	+	+	+	+	C4-5	33	5	2	3	1	
23	F	81	+	+			C4-5	32	5	3	3	1	OA of knee
24	F	85	+	+	+	+	C3-4	33	2	2	3	1	OA of knee
25	M	67	+	+	+		C5-6	24	2	2	3	1	
26	F	79	+		+		C3-4	26	2	1	3	1	
27	F	69	+	+	+		C3-4	24	4	2	4	2	
28	M	83	+	+	+		C3-4	26	2	2	2	1	
29	M	83	+	+	+	+	C3-4	28	4	2	4	1	
30	F	73	+		+		C3-4	27	2	2	3	2	
31	M	76	+	+	+	+	C4-5	24	5	4	4	3	

* osteoarthritis

Nurick¹⁹ for disability in the lower limb (Table II) and that of the Japanese Orthopaedic Association (JOA)²⁰ for the upper limb (Table III).

All patients had surface-coil MRI of the cervical spinal cord before operation, with one of three superconducting systems (0.5 T MRT-50 and 1.5 T MRT-200, Toshiba Corporation, Tokyo, Japan; 1.5 T Signa, GE Corporation, Milwaukee, Wisconsin). Measurements of the cord were made at each intervertebral level from C2-3 to C6-7, including the anteroposterior (AP) diameter, by a vernier calliper to the nearest 0.1 mm on midsagittal T1-weighted images and the cross-sectional area on axial T1-weighted images using a digitiser (Mitablet-II KD 4030; A Graphtec Corporation, Yokohama, Japan). The values were converted to the actual diameter and area using appropriate magnification factors.

Evoked potential studies and operative technique. Under general anaesthesia, a pair of stimulating electrodes (UKG-100-2PM; Unique Medical Corporation, Tokyo, Japan),

Table II. Functional grading of the lower limb adapted from Nurick¹⁹

Grade	
1	Able to walk normally despite signs of spinal cord compromise
2	Some difficulty in walking, although able to walk unaided
3	Requires a cane or crutches to walk
4	Requires a walker or someone else's help to walk
5	Chairbound or bedridden

Table III. Functional grading of the upper limb adapted from the JOA²

Grade	
1	No impairment of finger dexterity for everyday life
2	Writing is clumsy but functional; cuff buttons can be fastened
3	Writing is possible but not functional; only large buttons can be fastened
4	Can manage to feed oneself, but no other function
5	Unable to feed oneself

Fig. 1

Case 12. Left, sagittal and axial T1-weighted MRI (TR 600 ms; TE 20 ms) in a 68-year-old man with cervical spondylotic myelopathy. Compression of the cord at C3-4 is exceeded both in AP diameter and in cross-sectional area by that at C5-6. Right, SCEPs recorded unipolarly from the intervertebral discs between C6-7 and C2-3 after epidural stimulation at L2. An abrupt reduction in size of the negative wave at C3-4 followed by a monophasic positive wave at C2-3 indicates a conduction block at C3-4. There is normal conduction between C6-7 and C4-5 in the presence of compression. A single-level operation at C3-4 resulted in an improvement from Nurick grade 3 to grade 2 and from JOA grade 4 to grade 1.

with two platinum tips at the end of an 18-gauge polyethylene tube was introduced percutaneously into the dorsal epidural space at the lumbar or lower thoracic level using a Tuohy needle.^{21,22}

Through a vertical incision, just anterior to the sternocleidomastoid, the anterior aspect of the vertebral bodies was exposed. A lateral radiograph of the spine was used to guide a series (G1) of recording needle electrodes (Dantec 13R23; Dantec Medical, Skovlunde, Denmark) which were inserted through the intervertebral discs in the midline, and advanced posteriorly enough to cover the diameter of the disc calculated from measurement on the preoperative lateral radiograph.^{16,18} Another series (G2) of needle electrodes (Dantec 13R21) inserted into the longus colli muscles at the same level as G1 served as the reference. An eight-channel averager (Dantec Evomatic 8000) allowed simultaneous recording of the potentials from all sets of electrodes after epidural electrical stimulation of 0.1 ms in duration and 20 to 40 mA in intensity, delivered at a rate of 3 to 20/s. Each test set comprised an average of 100 to 200 summated potentials with a frequency response of 20 Hz to 5 kHz (3 dB down). Measurements of the potentials included latencies from the stimulus artifact to the initial

positive peaks, and amplitudes from the baseline to the initial positive and the major negative peaks.

The results of the measurements of SCEPs thus obtained determined the subsequent surgical intervention, leading to a discectomy at a single appropriate level. This was followed by partial removal of the adjacent vertebrae above and below with a high-speed carbide-tipped burr, creating a vertical trench 10 to 15 mm long and at least 15 mm wide through the centre of each vertebra. The trench was then deepened using a diamond-tipped burr under an operating microscope until the posterior vertebral cortex and osteophytes had been completely removed. Usually, although not always, the decompression was completed by incising the posterior longitudinal ligament in the shape of a cross, which allowed the dura to bulge into the decompressed area. Finally, a piece of tricortical iliac bone was tapped into the intervertebral space, which had been extended using a spreader or the Casper retractor. Patients were allowed to sit up wearing a Philadelphia-type collar or a soft collar on the second or third postoperative day.

We used the Wilcoxon rank-sum test to analyse the data, considering two-tailed tests to be significant when $p < 0.05$.

Fig. 2

Case 27. Left, sagittal and axial T1-weighted MRI (TR 500 ms; TE 19 ms) in a 69-year-old woman with cervical spondylotic myelopathy. Compression of the cord at C3-4 is greatest in terms of AP diameter, and equivalent to or even exceeded by that at C4-5 and C5-6 in terms of cross-sectional area. Right, SCEPs recorded unipolarly from the intervertebral disc of C6-7 to that of C2-3 after epidural stimulation at L2. An abrupt reduction in size of the negative wave with a concomitant augmentation of the initial positive wave at C3-4 indicates a conduction block at C3-4. There is normal conduction unaffected by cord compression at C5-6 or C4-5. A single-level operation at C3-4 resulted in an improvement from grade 4 to grade 2 both in the Nurick and JOA classifications.

Results

MRI and evoked potential studies. MRI showed multi-level compression in all 31 patients. Mid-sagittal T1-weighted images revealed indentation of the cord at 72 intervertebral levels, 23 each at C3-4 and C4-5, 22 at C5-6 and four at C6-7. The axial images revealed a deformed cord at 101 levels, 26 at C3-4, 28 at C4-5, 30 at C5-6 and 17 at C6-7. Cord indentation and/or deformity were seen at two levels in four patients, at three levels in 13 patients and at four levels in 14 patients. By contrast, evoked potential studies revealed a single site of a conduction block in 29 and a delay in two, of which 18 occurred at C3-4, 11 at C4-5 and two at C5-6 (Table I). The mean amplitude of the negative component was significantly ($p < 0.0001$) reduced to $33 \pm 19\%$ (0 to 75) compared with the immediate caudal level in 29 patients with conduction block (Figs 1 and 2). This diminution of the negative peak was accompanied by a significant ($p = 0.0017$) increase in the amplitude of the initial positive peak to $145 \pm 82\%$ (39 to 450). In the remaining two cases, there was no abrupt reduction in amplitude. In these subjects conduction delay was inferred by a disproportionate increase in latency from C5-6 to C4-5 (0.76 and 1.20 ms, respectively) compared with the adja-

cent caudal or rostral segments. With this method of intra-operative testing, we encountered no neurological complications, leaks of spinal fluid or infections.

A quantitative MRI assessment of compression of the cord in relation to the level of conduction abnormality, revealed that this particular level had a significantly smaller AP diameter (3.8 ± 1.0 mm; $p < 0.002$) and cross-sectional area (49.0 ± 9.8 mm², $p < 0.003$) than the remaining more caudal or rostral levels. The degree of compression, however, sufficient to cause conduction abnormalities, varied widely from one patient to another, and the AP diameter or cross-sectional areas were equally reduced or smaller at more caudal levels in eight patients (cases 6, 12, 14 to 16, 27, 29 and 30) and at more rostral levels in one patient (case 20).

Surgical outcome. As shown in Table I, the mean follow-up of the 31 patients was for 48 months (24 to 87). Six patients died from disorders not attributable to the myelopathy or the spinal surgery. At the latest review, all of the five chairbound and two bedridden patients (Nurick grade 5) were walking; three patients had improved to grade 2, three to grade 3, and one to grade 4. Of the 14 patients who had required walking aids or help in walking (grades 3 and 4) all but three became independently mobile (grade 1 or

2). The remaining three either improved from grade 4 to 3 (case 14) or remained in grade 4 (cases 18 and 19). One (case 18) initially improved from grade 4 to grade 2, but later her condition deteriorated to grade 4. In another (case 19) dementia precluded functional improvement both in the upper and lower limbs. Of the nine patients who had walked unaided, but with some difficulty (grade 2), three improved to grade 1 and six were still mildly affected (grade 2). Consequently, the average Nurick grade improved from 3.5 preoperatively to 2.2 at the latest follow-up. In 11 patients, neurological improvement in capacity to walk was neutralised by other conditions such as osteoarthritis of the knee (cases 3, 8, 16, 21, 23 and 27) or the hip (cases 10, 14 and 15), lumbar stenosis (cases 10 and 11), or senile dementia (case 19).

Functional recovery from loss of finger dexterity was more consistent. Based on the functional grading of the JOA (Table III), all but one patient improved to a better grade of finger use for everyday tasks, 28 patients out of 31 reaching either normality or the mildly affected grade (Table I). All but two showed improvement in sensory impairment in the upper limb and all but three in the lower limb; 18 patients had no objective loss of sensation. Loss of bladder control was also reversed in 17 patients out of 21, the recovery being complete in 12 and incomplete in five.

No deterioration was seen in the early postoperative period. In one patient (case 18) there was a regression a year later after initially good improvement. The functional deterioration had been insidious and was not attributable to any other condition. A further MR scan did not show new or an increased compression.⁵

Despite the frequent incidence of osteoporosis in this age group, there was no instance of extrusion of the graft, collapse, or resorption. One patient (case 11), having had a single procedure at the C3-4 level, showed radiological evidence of nonunion at the latest follow-up, but remained free from symptoms.

Discussion

Conduction block in the spinal cord probably plays the most important role in producing potentially treatable clinical weakness and sensory loss.²³⁻²⁶ In the presence of multilevel compression, the identification of such a block and its precise localisation should have a direct influence on the management of compression myelopathy. We have recorded the SCEPs from intervertebral discs after epidural stimulation during anterior surgery. We used this recording technique because anterior surgical exposure allows access for the placement of electrodes through the discs and general anaesthesia minimises the burden of epidural stimulation on the patient.

In the measurement of SCEPs, the combination of two opposite changes in waveform, namely an abrupt reduction in size of the negative peak and a concomitant augmentation of the initial positive peak, identified the site of a

conduction block.^{16-18,27,28} Whereas compression of the cord may appear without functional change, the presence of conduction abnormalities implies a sufficient degree of compression, usually at the level of the smallest AP diameter and cross-sectional area of the cord. In the patients with the same degree of compression at more than one level, MRI by itself was insufficient to localise the site primarily responsible for myelopathy (Figs 1 and 2). Our SCEP study has proved particularly valuable, identifying the precise site of the failure in conduction enabling differentiation of symptomatic compression of the cord from that which is clinically silent. In elderly patients, CSM tends to spare the C5-6 and the C6-7 levels where radiological changes develop with the greatest frequency and severity.^{29,30}

When surgical intervention was confined to a single level, most commonly C3-4 or C4-5, functional recovery was impressive even although other sites of compression were left untreated because they showed few abnormalities in conduction. The capacity to walk improved with the average increase in Nurick grade from 3.5 to 2.2. This is comparable to the improvement from 2.4 to 1.2 reported by Emery et al.⁶ They studied 108 patients with CSM, treated either by single-level (15%) or multilevel (85%) anterior operations, at a mean age of 58 years. They and Seifert et al.¹¹ also noted that the surgical outcome depended on the severity of neurological involvement before operation with better preoperative function associated with a better outcome. We have noted that in elderly people CSM particularly affects the ability to walk, which tends to deteriorate severely and return incompletely. This may be enhanced by other age-related coexisting conditions such as osteoarthritis in the lower limb, stenosis of the lumbar canal, or senile dementia. By contrast, loss of finger dexterity for everyday life and sensory deficits carried a more favourable prognosis.

Anterior decompression, followed by fusion at a single optimal level, when compared with more than one level using a strut graft,^{3,6,7,9-12} is less invasive and is sufficiently stable after operation to allow early mobilisation and rehabilitation with less rigid cervical orthoses. These advantages of a single-level operation have an important bearing on perioperative morbidity, especially in elderly and fragile patients. We encountered no major complication or permanent sequelae, and with this short fusion, osteoporosis did not affect the integrity of an iliac-crest graft or its integration.

In no instance did the myelopathy become worse as a result of the operation at which all structures responsible for compression were removed at one level. This may be partly attributable to the use of a microscope, which is essential for three-dimensional viewing in the depths of a wound which is shorter in length than the interpupillary distance.³¹

Excessive compensatory movement adjacent to a fused segment may lead to a recurrent myelopathy.^{4,32,33} The

possibility of recurrence resulting from compression which was asymptomatic at the time of surgery, is also a matter of concern. One of our patients had an initial improvement and later deterioration which is similar to that noted in previous reports,^{3,5-10} with a large proportion of these cases having a fusion at more than one level. It may be inferred that a physically less active daily life, together with a shorter life expectancy in the elderly, may lower the rate of regression. Furthermore, the late manifestation of myelopathy in elderly patients may reflect an inherited anatomical characteristic, such as a relatively wide canal.³⁴ This in turn may explain a less frequent rate of recurrence than may be expected.

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