Short report

Vibratory perception thresholds at the clavicle in patients with spinal cord injury

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SUMMARY Vibratory perception thresholds were measured by an electromagnetic device applied over the clavicles of 64 patients with spinal cord injuries. Patients with neurological levels of C5 and below had low threshold values ($0.63 \pm 0.23 \mu\text{m}$ of vibration amplitude; mean $\pm$ SD) which were used as reference values. The patients with a neurological level of C1/2 had very high vibratory thresholds bilaterally (above $11.0 \mu\text{m}$). Patients with C2/3–3/4 neurological levels also had significantly elevated thresholds ($2.56 \pm 2.01 \mu\text{m}$), while those with C4–C4/5 levels did not differ significantly from the reference group. The results agree with earlier observations that the C4 segment innervates the clavicle and imply that patients with a lesion at or above C4 may have elevated clavicular vibratory thresholds. It is concluded that vibrometry, a non-invasive technique, is applicable in patients with spinal cord injury and disease, and can be useful for assessment of sensory level and particularly for follow-up of such patients.

Quantitative assessment of somatosensory deficits, as well as motor dysfunction, is important for diagnostic purposes and particularly for follow-up studies in neurological disorders. Vibratory perception is frequently impaired in patients with polyneuropathy and spinal cord lesions and testing vibratory sensibility is a routine diagnostic procedure. Quantitation by measuring perception threshold is useful in longitudinal studies^{1–3} and for screening of subclinical lesions.⁴ The most widely used instrument is the biothesiometer which gives the threshold in terms of applied voltage to the electromagnetic vibrator. The device is easy to use but has several sources of variation which prompted Goldberg and Lindblom⁴ to develop a more standardised and physiological technique with measurement of the actual movement amplitude of the vibrator when applied to the tissue. Their study included normative values with age regressions of vibratory thresholds for distal sites.

In spinal cord injury patients, it is also relevant to measure vibratory thresholds on proximal sites and in truncal dermatomes. However, the value of vibrometry on the trunk is hampered by the stimulus spread, especially with resonance in the thorax. We found that by applying the vibrator to the clavicle it was possible to produce a localised perception of vibration at low stimulus strengths. According to the literature,^{5–7} the segmental innervation of the clavicle is mainly from the C4 segment. We therefore measured vibratory thresholds at the clavicles in a series of 64 patients with spinal cord injury paying special attention to those with lesions at and around the C4 level. Our expectation was that the clavicular vibratory thresholds of patients with spinal cord injury at C5 level and below would be uniformly low and the aim of measurements in these patients was to explore the general applicability of the vibrometry technique and to obtain control values for those with lesions above C5 level.

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Material and methods

Sixty-four patients (51 males and 13 females) with spinal cord injury were tested. Their average age was 31 years

(range: 11–59 years). The average time after injury was 4 years (range: 2 months–16 years). The level of the injury and the degree of dysfunction were assessed by a detailed neurological examination with muscle tests and a screening sensory examination with quantitative measurements of thermal sensibility.⁸ The segmental levels of preserved motor and sensory functions were classified using the guidelines of the American Spinal Injury Association adopted from Austin.⁹ The level of the injury was defined as the last intact neurological segment. This was assessed separately for right and left sides. Where partial function (at least fair plus muscle grade and almost normal sensory perception) was present in the adjacent lower segment, this segment was also listed. For example, neurological level might be denoted as C2/3 or C3/4. The clavicular vibratory threshold was measured with a Vibrometer (Somedic AB, Stockholm), which was designed on the basis of the method of Goldberg and Lindblom.⁴ The measurements were obtained in a sound proof temperature controlled (20 to 22°C) room with the patient supine to provide optimal relaxation and concentration on the test procedure. The probe of the vibrator has a flat area of 1.13 cm² and slightly rounded edge to prevent irrelevant incisive tissue deformation. It was placed over the skin perpendicularly to the superior surface of the clavicle 8–10 cm from its sternal end. The application pressure of the vibrator was maintained at 450 g $\pm$ 20% by monitoring the pressure indicator at the instrument panel. The intensity of the vibratory stimulus (120 Hz sine wave) was controlled manually. The peak to peak amplitude of the probe movement was measured continuously by an accelerometer and displayed in micrometers. The vibratory threshold was determined according to the method of limits.¹⁰ Three successive measurements of threshold were averaged for each clavicle. Since several patients had asymmetrical lesions with different neurological levels, the threshold on each side was taken as a separate observation. This enabled a cranio-caudal ranking of the vibratory threshold values according to successively lower levels of the lesion. Student's unpaired *t* test was used for statistical analysis.

Results

Vibratory threshold values were divided into three groups on the basis of the relation of the neurological level of injury to the C4 spinal segment. Three patients with C1/C2 neurological levels had extremely high thresholds bilaterally and were excluded from statistical analysis. In one patient the vibratory threshold was 19 μ m bilaterally, and in the other two the thresholds were above the maximal amplitude produced by the instrument (30 μ m and 48 μ m, respectively, depending upon individual differences in tissue damping). A fourth patient with a C1/2 neurological level on one side had a vibratory threshold value of 11 μ m on that side. The neurological level on the other side was lower, C2/3, and the value therefore included in the respective group.

The measurements in the group of patients with a neurological level of C5 and below showed homoge-

nous low vibratory threshold values which tended to be below 1 μ m. Forty-six of these measurements were from patients with lower cervical injuries and 8 from patients with thoracic injuries. The average vibratory threshold was 0.63 μ m (SD 0.23) with a range 0.27–1.20 μ m (Table 1). All other values were compared with this group.

Vibratory perception thresholds in patients with spinal cord injury (in μ m)

Neurological level	C2/3–C3/4	C4–C4/5	C5 and below
$\bar{X}$	2.56	0.67	0.63
SD	2.01	0.33	0.23
Range	1.00–8.00	0.27–1.50	0.27–1.20
N	13	32	54

The C2/3–C3/4 group had high vibratory threshold values with a mean of 2.56 μ m (table 1). This was significantly higher than in the control group ($p < 0.01$). The C4–C4/5 group was borderline with respect to the segmental innervation level of the test site. As appears from the table, the vibratory threshold values were slightly higher than those of the control group but the difference was not significant ($p > 0.05$). The variability was greater. The difference between this group and C2/3–C3/4 group was significant ($p < 0.01$).

No significant correlation was found between age and vibratory threshold in the C4–C4/5 and “C5 and below” groups. The non-uniform distribution of males and females in the population precluded statistical analyses of vibratory perception thresholds with respect to patient sex.

Discussion

In the present study our purpose was to test the usefulness of vibrometry in patients with spinal cord injury, especially those with high cervical lesions. There were no unexpected technical or psychological difficulties in the application of vibrometry in these patients. The low variability of the clavicular vibratory threshold in the control group is probably related to the fact that the clavicle has a flat superior surface in its lateral third and is relatively uniform with respect to the thickness of the overlying skin and subcutaneous tissue even in subjects of different body weight and type. This is an important factor in achieving reliable measurements of vibratory threshold since the damping effect of various tissues contributes greatly to the variability of the measured threshold amplitudes.⁴ Thus, in view of its innervation and anatomy, the clavicle is an appropriate site for the assessment of vibratory sensibility in patients

with spinal cord injury at mid and high cervical levels.

The finding that the clavicular vibratory threshold was increased only when the lesion was above C4 is in agreement with the report that the clavicle is innervated primarily from this segment through the subclavian nerve.⁵ Data regarding the skeletal innervation come from a single study of deep referred pain and from other clinical observations.⁵⁻⁷ The greater variability of vibratory threshold in the borderline C4-C4/5 group compared to the controls may be explained by minor anatomical variations in segmental innervation and/or minor differences in the exact upper border of the cord lesion.

This technique may be useful in the assessment of the sensory level of spinal cord injury patients, and also indicates the anatomical site of the lesion in patients with clinically complete lesions. In cases of incomplete lesion the patients sensory level may not correspond exactly to the actual lesion, but the vibratory threshold may document their present sensory level and be useful for follow-up of their clinical condition. In addition, the clavicle may be a suitable reference site for vibratory threshold measurement in peripheral neuropathies, especially when the thresholds at all distal sites are already abnormal. The only significant problem which may arise when the clavicular threshold is increased is that the sensation may spread contralaterally or diffusely in the thorax, so one has to check with a patient whether the recorded vibratory threshold refers to a localised vibratory sensation in the clavicular region. In a study of normal subjects, (unpublished), it was found that the spread of sensation usually occurred at the relatively high amplitudes (10-15 μ m).

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