VIBRATORY RESPONSE IN IDIOPATHIC SCOLIOSIS

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Recent clinical studies have suggested that a neurological lesion may be a cause of adolescent idiopathic scoliosis and animal experiments have implicated the posterior column pathway. We have tried to determine if differences in neurological response could be detected and measured clinically, and have compared the threshold of detection of vibratory sensation in 20 girls with adolescent idiopathic scoliosis with that in 20 clinically normal age-matched controls.

A highly significant reduction of the threshold of detection of vibration was seen in the scoliotic group compared to the controls (p < 0.001). Curve magnitude did not correlate with this threshold for either the upper (r = 0.172) or lower extremity (r = 0.126). Significant asymmetry between right- and left-sided thresholds to vibration was demonstrated in the scoliotic group. Our study supports the concept that an aberration in the function of the posterior column pathway of the cord may be of primary importance in the aetiology of idiopathic scoliosis. A clinically practical test to measure this function is presented.

Evidence of a neurological cause for idiopathic scoliosis continues to accumulate. Clinical studies have demonstrated differences in neurological responses when scoliotic children are compared to normal controls (Yekutiel, Robin and Yarom 1981; Barrack et al. 1984; Yamada et al. 1984). A lesion in the posterior column pathway has been implicated as a major factor in scoliosis. In animal studies, scoliosis has been induced by damaging this pathway at the dorsal root as well as in the thoracic cord itself (Liszka 1961; MacEwen 1973; Pincott and Taffs 1982; Pincott, Davies and Taffs 1984; Yamada et al. 1984), and a recent clinical study has demonstrated a difference in proprioception in patients with scoliosis (Barrack et al. 1984). Since vibration is generally agreed to be the most sensitive indicator of posterior column function (Jahss 1982, p. 1205), vibration threshold responses were tested. Patients with adolescent idiopathic scoliosis caused by a posterior column lesion would be expected to respond to vibratory stimuli differently from age-matched controls.

It is difficult to evaluate whether observed differences in clinical testing are the cause or the result of a scoliotic deformity. Afferent input from the arms enters the central nervous system at cervical cord level and, theoretically, would not be affected by spinal curvature at thoracic level. For this reason, vibratory sensation was tested in both upper and lower limbs to discover whether the level of disruption was proximal to the entry of the afferent pathways from the upper limb.

The study included measurement and evaluation of the responses to vibratory stimulation of patients with progressive adolescent idiopathic scoliosis and comparison of their threshold levels and right-to-left symmetry with those of age-matched normal control subjects with no clinical evidence of scoliosis.

METHODS AND MATERIAL

Test group. The test group consisted of 20 girls with adolescent idiopathic scoliosis. All had a primary scoliotic curve of greater than 20° by the Cobb method, in which at least a 5° progression of the primary curve had been shown radiographically. The 20 patients had a total of 31 curves that were under treatment. The major deformities included 11 right thoracic/left lumbar double curves, seven right thoracolumbar, and two right thoracic curves. The mean Cobb angle was 30°, with a range from 20° to 44° and all were under treatment. The mean age of the group was 14 years 5 months (range from 12 years 1 month to 16 years 1 month).

Control group. The control group was 20 normal girls recruited from outside the hospital and free from any known disease. They were all examined by the first author and showed no clinical evidence of scoliosis, and neither did their siblings. The mean age of the control group was 14 years 6 months (range from 12 years 5 months to 16 years 1 month).
**Test procedure.** The threshold to vibratory sensation was quantified in each subject, using a Bio-Thesiometer (Biomedical Instrument Company, Newbury, Ohio). This electronic instrument vibrates at a constant frequency of 120 hertz, and the amplitude of the vibratory element increases in proportion to the square of the applied voltage. The 1.2 cm round vibrator button was placed on a bony prominence, allowing the weight of the vibrator to apply a standard force. From zero, the voltage was slowly increased until the subject perceived vibration; then the voltage was recorded. The calibration table provided by the manufacturer then allowed the voltage readings to be converted to vibratory amplitude. All testing was done by one examiner and the results were recorded by another to minimise bias.

Tests were made with the subject in a relaxed recumbent position in a quiet room. Trial tests on the upper extremity were used to familiarise the subjects with the sensation and the procedure. Four sites were tested bilaterally: the ulnar styloid, the medial malleolus, the medial aspect of the first metatarsophalangeal joint, and the tip of the great toe. Each site was tested four times, alternating from right to left, and an average of the four results for each site was used for the statistical analysis.

**RESULTS**

The data were analysed in two ways: first for sensitivity, that is the threshold to detection of vibration, and secondly for symmetry between right and left sides. **Threshold of vibration detection.** Striking differences were found between the scoliotic group and the control group in the ability to detect vibration. At all four test sites, the scoliotics were more sensitive, showing significantly lower thresholds (p < 0.001). The results gave a near Gaussian distribution, allowing the use of standard parametric statistical t-tests in the analysis of the differences between the two groups. The means, standard deviations, and t-values are recorded in Table I. Results for each limb were treated individually, giving 40 results for each site tested in each group. These are presented graphically in Figures 1 to 4.

Histograms showing the vibration thresholds at each of the four test sites for the scoliotic group and the normal age-matched control group. Threshold amplitude (in μm) is plotted against the number of occurrences. There are 40 data points for each group, representing both left and right limbs for 20 subjects. Scoliotic patients were significantly more sensitive to vibration (p < 0.001) than the normal controls at all four test sites.
The threshold to vibration did not correlate with the magnitude of the scoliotic curve for either the upper or lower limb or for either the most sensitive or the least sensitive side. Correlation coefficients for these comparisons are given in Table II.

**Symmetry.** The absolute values of the differences between the right and left sides were calculated and the results for the scoliotic group were compared with those for the control group, using the non-parametric Mann–Whitney rank sum test. Significant asymmetry at two of the four test sites was found in the scoliotic group as compared to the control group. These highly significant differences were found at the ulnar styloid (p = 0.011) and at the first metatarsophalangeal joint (p = 0.007). Differences were also found for the tip of the great toe, but these were not statistically significant and there was no difference between the two groups in tests at the medial malleolus. The means, variances and p-values for these comparisons are reported in Table III. These side-to-side differences between right and left also did not correlate with curve magnitude for any of the sites (ulna r = 0.0871, great toe r = 0.0277. MTP joint r = 0.0637, medial malleolus r = 0.02164).

**DISCUSSION**

Maintenance of a stable upright posture depends upon neurological input from visual, vestibular and proprioceptive pathways. Malfunction in one or more of these systems has been suggested as a cause of idiopathic scoliosis, and significant differences in these systems have been found between normal controls and scoliotic children (Hoogmartens and Basmajian 1976; Sahliand, Örtengren and Nacheinson 1978; Sahlstrand and Petruson 1979; Trontelj, Pecak and Dimitrijević 1979; Sahliand 1980; Sahlstrand and Lindström 1980; Yekutiel et al. 1981; Mixon and Steel 1982; Yamada et al. 1984).

Although it has been postulated that there may be defects in postural equilibrium, spinal muscle tone and reflexes, or in proprioception, the exact level and the pathway involved by any specific lesion has yet to be established. Our study was designed specifically to test posterior column function from both the upper and lower limbs to determine whether the lesion is proximal to the thoracic cord.

Proprioceptive sensation is conducted along the posterior column pathway, but it is not the most sensitive indicator of posterior column function since it may remain normal during many pathological processes (Jahss 1982, p. 1205). In contrast, vibratory perception is often the first modality affected in posterior column lesions. Vibratory sensation had not previously been studied in idiopathic scoliosis, and was therefore chosen for this study. Threshold tests are the most sensitive indicators of subtly progressive lesions with intact cortical connections (Gelberman et al. 1983; Szabo, Gelberman and Dimick 1984), so vibratory thresholds were measured.

Our results demonstrate that the vibratory threshold was significantly lower in scoliotic patients than in normal control subjects at all the sites we tested in both upper and lower limbs. This suggests the presence of a defect in the posterior column pathway at a level proximal to the thoracic cord, either in the cervical cord or the brain stem.

We also found significant asymmetry of vibratory response in the scoliotic test group as compared with the symmetry in normal controls. The direction of asymmetry did not correlate with that of the curvature, as has been reported for vestibular defects (Sahlstrand 1980; Sahlstrand and Lindström 1980). Asymmetry was found

<table>
<thead>
<tr>
<th>Test site</th>
<th>Normal Controls Mean</th>
<th>Normal Controls Variance</th>
<th>Scoliotics Mean</th>
<th>Scoliotics Variance</th>
<th>Significance of difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulnar styloid</td>
<td>0.38</td>
<td>0.01</td>
<td>0.27</td>
<td>0.07</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>First metatarsophalangeal joint</td>
<td>0.43</td>
<td>0.08</td>
<td>0.27</td>
<td>0.10</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Tip of great toe</td>
<td>0.48</td>
<td>0.09</td>
<td>0.33</td>
<td>0.01</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Medial malleolus</td>
<td>0.67</td>
<td>0.15</td>
<td>0.52</td>
<td>0.16</td>
<td>p &lt; 0.001</td>
</tr>
</tbody>
</table>

**Table II.** Correlation coefficients between the magnitude of the scoliotic curve and the threshold of detection of vibration

<table>
<thead>
<tr>
<th>Test site</th>
<th>Less sensitive side</th>
<th>More sensitive side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ulnar styloid</td>
<td>r = 0.2638</td>
<td>r = 0.2340</td>
</tr>
<tr>
<td>First metatarsophalangeal joint</td>
<td>r = 0.0084</td>
<td>r = 0.0469</td>
</tr>
<tr>
<td>Tip of great toe</td>
<td>r = 0.1036</td>
<td>r = 0.0944</td>
</tr>
<tr>
<td>Medial malleolus</td>
<td>r = 0.0120</td>
<td>r = 0.0676</td>
</tr>
</tbody>
</table>

**Table III.** Means and variances for the differences in threshold (in micrometers) between right and left sides in normal controls and in scoliotic patients

* Significant differences by the Mann Whitney rank sum test
in both upper and lower limbs, again supporting the concept that the lesion is proximal to the thoracic cord.

Increased sensitivity produced by a pathological process may seem to be paradoxical, but is not without precedent. Several authors have described heightened responses when testing neurological pathways in patients with idiopathic scoliosis (Hoogmartens and Basmajian 1976; Guyton 1976, pp. 640–708; Trontelj et al. 1979; Adler et al. 1983), but no explanation is currently available.

The exact localisation of a lesion is not possible by indirect clinical testing and will probably require anatomical dissection (Lloyd-Roberts et al. 1978). However, the identification of the nature of the primary aetiology may allow for the development of clinical tests to determine which patients have a defect which is associated with progressive deformity (Connolly and Michael 1984). It is possible that vibratory threshold studies can help to identify patients at risk of rapid progression.

In our study, the threshold results of the two groups define two populations, both of which have an approximately Gaussian distribution, but with some overlap. Since the start of this study, the curves in four patients have progressed despite treatment. Two of these patients have had operations, and the other two are candidates for this form of treatment. Retrospective review of the vibratory threshold data from these four patients showed that they had lower thresholds (were more sensitive) than the mean value for the scoliotic group as a whole. Of the 32 test sites in these four patients 30 were more sensitive than average for the scoliotic group, 19 differing from the mean by more than one standard deviation. Figure 5 illustrates this “sensitive group” (to the left of the scoliotic group) for one of the four sites tested. It is of interest that 25 of the 32 results were more than two standard deviations more sensitive than the mean for the control group. It appears from this that scoliotic patients with values in the normal range did not become worse during conservative treatment, while four patients with curves that did progress had thresholds which were among the most sensitive measured.

The development of a screening test which is related to the aetiology of the scoliotic deformity rather than to its description may be helpful in defining that subpopulation of scoliotic patients which will require active treatment.

CONCLUSIONS

The threshold of detection of vibratory sensation was tested in patients with adolescent idiopathic scoliosis and in clinically normal age-matched controls. The following conclusions were drawn:

1. The Bio-Thesiometer offers a straightforward and practical method for testing and quantifying vibration sense.
2. There were striking differences between the two groups in the threshold at all the test sites in both the

![Figure 5](image-url)
upper and the lower limbs. The scoliotic patients were more sensitive (had a lower threshold) than the normal controls.
3. Side-to-side differences were greater in the scoliotic patients than in the controls.
4. These conclusions support the concept that there may be a lesion in the posterior column pathway cranial to the lower cervical cord, because threshold differences were shown in the arm as well as the leg.
5. The vibratory threshold test may help the clinician to identify those patients who have a basic neurological deficit which is associated with progression of their idiopathic scoliosis.

The authors would like to thank all the subjects and their patients for their enthusiastic cooperation in this study. We would also like to thank Tracy Grindeland, Edmund Biden DPhil, Sherill Marciano, Richard Olshen PhD, Elizabeth Wright and Judy Leach PT, of the Motion Analysis Laboratory at the Children’s Hospital–San Diego for their assistance in this project.

REFERENCES


