Surface stereophotogrammetry of thoracic kyphosis

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The thoracic kyphosis angles of 16 normal individuals, 10 patients with Scheuermann's disease and 11 with adolescent idiopathic scoliosis were measured both radiographically and from Integrated Shape Imaging System (ISIS) scans obtained by surface stereophotogrammetry. There was a high correlation between the two measures.

The method of kyphosis measurement from ISIS scans was then used for 30 patients with adolescent idiopathic scoliosis who underwent corrective surgery. A significant reduction in thoracic kyphosis was observed postoperatively. In another group of 28 patients managed conservatively by bracing, some hypokyphosis developed after treatment. However, we found no association between hypokyphosis and curve progression.

Smith and Dickson (1987) suggest that in scoliosis the primary abnormality is lordosis, leading to rotational instability and increasing lateral curvature. Measurements of the sagittal curvature may therefore have clinical significance by indicating instability.

Interest in surface topographic measurements has led to the development of an automated stereophotogrammetric technique, ISIS – Integrated Shape Imaging System (Turner-Smith et al. 1982, 1988, Turner-Smith 1988), which computes and analyses the shape of the back in three dimensions. Thus, sagittal profiles form an integral part of the analysis, and a measure of kyphosis/lordosis is immediately available (Figure 1).

Our study was divided into three parts. The first part was concerned with the verification of the method of measuring sagittal angles from ISIS scans. In the second and third parts, ISIS scans were used to assess the effects of both surgical (posterior Harrington instrumentation) and conservative (Boston brace) treatment on the thoracic sagittal profiles in patients with adolescent idiopathic scoliosis.

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Materials and methods

Patients

The methodologic part of this study included 16 normal individuals, 10 patients with Scheuermann's disease, and 11 patients with adolescent idiopathic scoliosis. The mean age was 15 (8–20) years. There were 19 females and 18 males.

The second group of 30 patients (mean age 15 [12–20] years; 26 females, 4 males) had undergone Harrington instrumentation surgery for adolescent idiopathic scoliosis. All of them had had ISIS scans immediately before and 1 year after surgery.

The third group of 28 patients (mean age 13 [10–16] years; 15 females, 13 males) underwent treatment with the Boston brace for adolescent idiopathic scoliosis. The follow-up for these patients was 22 (6–43) months, and only 4 patients had less than 1 year's follow-up.

Data analysis

Group 1 – Verification of the method. Each of the 37 individuals had a lateral radiograph with a corresponding ISIS scan. The angles in the thoracic region were measured from the lateral radiographs by the Cobb (1948) method. From the standard ISIS scans produced in the scoliosis clinic (Turner-Smith et al. 1988), the ISIS angles of kyphosis were measured as shown in Figure 1. The former ISIS measures of ky-

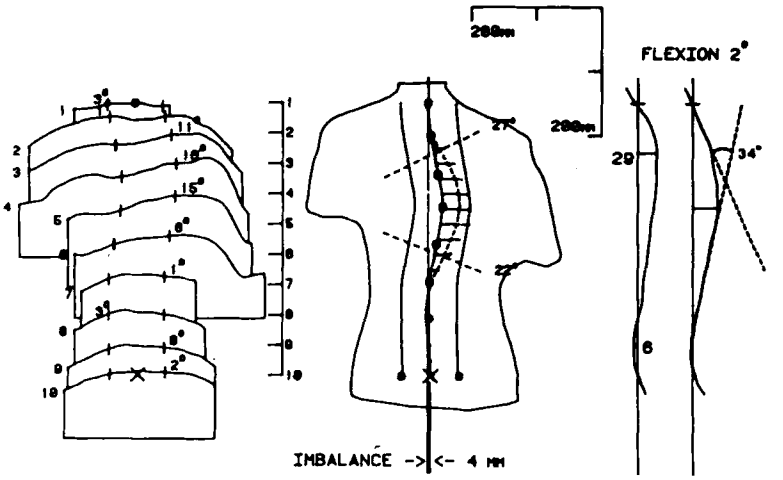

Figure 1. Measurement of kyphosis angle by ISIS scan.

phosis and lordosis were the maximum and minimum distances from a flat-back reference plane in the thoracic and lumbar spines, respectively. In this study, an additional algorithm was incorporated into the ISIS analysis to compute the gradients of the steepest tangents to the upper and lower parts of the thoracic and lumbar curves. Kyphosis and lordosis angles were measured as the angles between these steepest tangents. In the middle of the back, the slope was calculated at the point of inflexion of the sagittal curve, whereas in the upper thoracic and lower lumbar regions, an algorithm was used to determine where the slope should be calculated, and also to avoid edge effects. To test the accuracy of the method, similar measurements were performed manually by 4 independent observers who gauged the steepest tangents by eye. Analysis of variance (ANOVA) was carried out on the results of both automated and manual measurements and the radiographic angles.

Groups 2 and 3. In Groups 2 and 3, ISIS scans alone were taken. The pretreatment and posttreatment values of the kyphosis were analyzed for both groups separately using a paired *t*-test to assess the significance of the difference in mean values produced by the surgery or the brace. In Group 3 the lateral asymmetry (Turner-Smith et al. 1988) – the surface analogue of the Cobb angle – was also used to assess whether any progression of the scoliotic curve occurred (Weisz et al. 1988), and whether this could then be related to a decrease in kyphosis angle.

Results

The results of the automated method for computing kyphosis and lordosis angles from ISIS scans did not differ from the manual measurements of ISIS outputs by 3 of the 4 observers. For these same three measurers, the interobserver differences were also below the level of significance. The fourth observer consistently obtained higher tangent angles than the other 3 observers and the automated method.

When the different sets of ISIS measurements were compared with the radiographic angles (Table 1, Figure 2), the correlation coefficient was consistently significant. For the 4 different observers the values ranged from 0.88 to 0.96; for the automated method the value was 0.89. The ANOVA tests showed no difference between the ISIS method and the radiographic measurements.

In the patients undergoing Harrington instrumentation, the mean kyphosis angle according to ISIS measurements was reduced from 26° (SD 13°) to 17° (SD 10°; $t = 4.2$, $P < 0.001$).

Brace treatment also caused a reduction in thoracic kyphosis, although it was less marked than in the surgical group. The mean kyphosis angle pretreatment was 30° (SD 9°), and that after bracing was 26° (SD 10°), $P < 0.01$. These patients were divided into 2 groups

Table 1. Kyphosis angle (°) from radiographic and ISIS measurements for the patients in Group 1. Mean *SD*

	n	Radiography		ISIS	
Normals	16	35	*4*	3	*5*
Scheuermann's	10	51	*9*	52	*7*
Scoliotics	11	27	*10*	25	*11*
Total	37	37	*12*	38	*13*

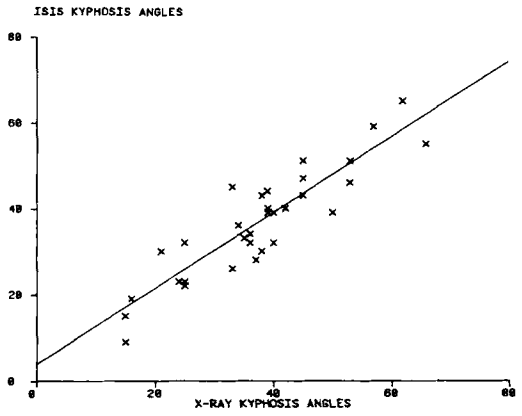

Figure 2. Scatter diagram and regression line for radiographic and automated ISIS measurements of kyphosis angles. ISIS = 0.88 x (radiograph) + 3.91.

according to whether their kyphosis decreased or not. The critical angle for a change in kyphosis was taken to be 4°, based on measurements of Willner and Johnson (1983). However, the 2 groups did not differ with respect to curve progression as measured by lateral asymmetry.

Discussion

Radiographic measurements of the kyphosis angle are notoriously unreliable (Beckman and Hall 1979). In addition, lateral radiographs of the spine are not truly sagittal views, because they do not take into account the vertebral rotation. Because of the need to reduce exposure to radiation, noninvasive methods have a particular application in both screening programs and follow-up examination. Those used to describe and quantify the sagittal curve include manually performed skin surface measurements, such as the pantograph (Willner 1981) and the kyphometer (Debrunner 1972), both of which are relatively time-consuming and do not produce a full analysis of back shape. Moiré topography has also been used (Suzuki et al. 1981), but the digitization of the photographs is very labor-consuming, and the results are not immediately available to the clinician.

The method of calculating kyphosis angles verified by our study has now been incorporated into the standard ISIS analysis, because a high correlation was found between the kyphosis angles measured radiographically and by ISIS. A similarly high correlation between the kyphosis angles measured from the lateral radiograph and the surface contour was also found by Dangerfield et al. (1987) and Willner (1981) for their respective techniques. However, their measurements were made in isolation, concentrating solely on the sagittal profile. ISIS presents the sagittal measurements as part of one investigation in which the whole surface of the back is analyzed in three dimensions.

The first part of the study demonstrates that the mean kyphosis angle of the patients with Scheuermann's disease was significantly greater than that of the normal subjects. Likewise, the mean kyphosis angle of the patients with scoliosis was significantly less than the normal subjects (Table 1). Surface-shape topography thus confirms the anatomic reports that scoliosis is associated with hypokyphosis (Roaf 1960, Deane and Duthie 1973, Somerville 1952).

In the group of patients who underwent conventional Harrington instrumentation, the lateral profile became significantly flatter. This effect is well recognized (Winter et al. 1986), and its detection here confirms the sensitivity of ISIS scanning to changes in the lateral profile.

Brace treatment for scoliosis attempts to prevent flexion of the thoracic spine, because it is in this position that the vertebrae are more liable to rotate. The other objective of bracing is to reduce the lumbar lordosis and thus extend the thoracic spine, in an attempt to prevent further vertebral rotation. It has been suggested that prolonged brace treatment may lead to a persistent hypokyphosis, which in itself may be associated with vertebral instability and curve progression (Dickson et al. 1984). When the patients whose kyphosis decreased after bracing were compared with the patients whose kyphosis remained stable or increased, it was found that in each group half had progression in lateral asymmetry. These results would seem to confirm that brace treatment is not always effective, and also to question the association of hypokyphosis with curve progression.

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