THE DEFORMITY OF IDIOPATHIC SCOLIOSIS
MADE VISIBLE BY COMPUTER GRAPHICS

F. R. HOWELL, R. A. DICKSON

From St. James’s University Hospital, Leeds

We present a method of visualising spinal deformities in three dimensions using conventional radiographs and computer graphics. The shape of the spinal column can be determined from the anteroposterior and lateral radiographs and displayed in any projection.

In patients with adolescent idiopathic scoliosis, the fundamental lesion, an abnormal lordosis, can be demonstrated without the need for additional views. The method is applicable to other spinal deformities and may help to elucidate their three-dimensional shape.

Radiography of spinal deformity displays its three-dimensional structure in two dimensions, depending on the planes of projection. These are usually anteroposterior and lateral in reference to the patient, but the three-dimensional structure can be inferred from measurements of vertebral rotation (Nash and Moe 1969; Mehta 1973; Aaro and Dahlborn 1981). By combining the information from two radiographic views of the same deformity, a three-dimensional image can be reconstructed with the aid of a computer (Suh 1974; Brown et al. 1976; De Smet et al. 1980; Hindmarsh, Larsson and Mattsson 1980; Raso, Gillespie and McNiece 1980). This image can then be manipulated geometrically to be displayed in two dimensions, varying the apparent viewpoint of the observer.

The conventional views of idiopathic scoliosis depict the deformity obliquely because of its axial rotation. The size of the deformity as measured by the Cobb angle (Cobb 1948) is thus an underestimate of its true size which will be seen when the deformity is viewed ‘en face’ (du Peloux et al. 1965; Deacon, Flood and Dickson 1984). Similarly, the lateral radiograph does not project the true lateral view of the apex of the curve.

The computer system allows multiple views of the deformity to be reproduced from the information obtained from two standard radiographs, and avoids the need for multiple exposures. The results confirm that a consistent inappropriate lordosis is the underlying deformity in late-onset idiopathic scoliosis (Somerville 1952; Roaf 1966; Dickson et al. 1984).

MATERIALS AND METHODS

The Leeds MRC epidemiological survey of the natural history of idiopathic scoliosis has identified a group of 962 schoolchildren aged eight to 13 years with a degree of truncal asymmetry on forward bend testing, from a population of 15,793 children. This cohort is being followed longitudinally, both clinically and radiographically. Postero-anterior and lateral radiographs are taken each year, using the low-dose technique and standardised positioning of Ardran et al. (1980), and these form the basis for this study.

The computer method requires identification of the same anatomical points on both views of the spine (Suh 1974). The points chosen are the bases of the pedicles, and the mid points of the upper and lower end plates (Figs 1 and 2); these have been shown to be the most consistent (Brown et al. 1976; De Smet et al. 1982). The points are marked on the radiograph, and, by means of a sonic digitising device, their co-ordinates are entered into a microcomputer for processing and storage. The data for each point from each pair of radiographs are merged to provide three Cartesian co-ordinates, for four points per vertebra, for all the vertebrae which can be visualised. A three-dimensional model of the spine is thus recorded.

The projection of this model on to a plane produces a two-dimensional image, which may then be rotated in any desired direction by a mathematical transformation.
This can produce images relating to the postero-anterior and lateral radiographic projections, or to any other chosen viewpoint.

The transformation itself is by a simple algebraic formula, which for rotation of a point \( x, y, z \) by an angle \( A \) around the vertical \( y \)-axis, will relate the horizontal projection in the new vertical plane, \( x_t \), to the old, \( x \), and to the third co-ordinate, \( z \), as follows:

\[
x_t = x \cdot \cos A - z \cdot \sin A
\]

The microcomputer is programmed to perform this using the basic language. The limiting factor in the technique as we describe it is the identification of the chosen anatomical points. The errors involved have been quantified (Hindmarsh et al. 1980). Magnification and other problems have been overcome by other means.

**Validation.** The anteroposterior and lateral views of mounted museum specimens from cases of idiopathic scoliosis were processed as above and a computer representation created. The same specimens were then radiographed at 10° intervals of rotation around a vertical axis. The computer diagram at any given rotation and the radiograph taken at that same rotation can be compared, and the similarity is quite obvious (Figs 3 and 4). This confirms that the two standard views contain all the necessary information to visualise the spine at any chosen degree of rotation.

**RESULTS**

In the cohort of 962 children followed up for two years, 69 have an idiopathic type of curve, with a Cobb angle greater then 10° and rotation of the vertebral body towards the convexity of the curve. In all 69 cases there is an inappropriate lordosis at the apex of the curve. There may or may not be a frank lordosis visible on the lateral view, but when the computer model is rotated then an apical lordosis becomes obvious (see Fig. 5). This view corresponds to the Stagnara or ‘Leeds lateral’ projection (Dickson 1987).

A normal, straight spine does not show any such lordosis, but a rotated view does produce artefactual ‘curves’. These could be confused with minor idiopathic type curves on a plain radiograph if viewed obliquely (see Fig. 6)

If a progressive idiopathic curve is followed over a period of time, then the abnormal lordosis can be seen to increase on the oblique reconstruction in parallel with other measures of the deformity (see Fig. 7).

**DISCUSSION**

The deformity of idiopathic scoliosis is known to be a rotated lordoscoliosis, but single plane radiographs cannot adequately demonstrate its three-dimensional nature. Two orthogonal views do however contain all the information required to describe the deformity in any plane and the use of this can avoid the need for multiple radiographs and reduce the radiation dosage to a child during observation or treatment.

In our cohort, we found a fundamental lordosis in every case of progressive idiopathic scoliosis. In some of these, the initial curve was small (5° or less), and a diagnosis of ‘early’ idiopathic scoliosis was not practical because of the size of the curve in relation to positional and other variables. However, these early curves declare themselves by progression, and reconstruction of their early deformities shows that an underlying lordosis is present. When this lordosis is followed, it increases and starts to rotate as the deformity progresses (Fig. 7).

When there are greater degrees of vertebral rotation, the overall shape of the patient is spuriously kyphotic, as the vertebral bodies come to face backwards. We do not use this definition of kyphosis, which relates to the sagittal plane of the patient and not of the spine, because it has led to confusion in discussion of the pathogenesis of these curves in the past (De Smet et al. 1984; Stokes, Bigalow and Moreland 1987).

A normal straight spine, viewed obliquely, shows an apparent scoliosis which simulates a double structural thoracic and lumbar curve (Fig. 6). On a plain radio-

Fig. 1

The identification of the four points to be digitised on the anteroposterior and the lateral radiographs.
Fig. 3

Fig. 4

Radiographs of a museum specimen of a scoliotic spine taken at 0, 40, 90 and 130° of rotation, with computer reconstructions of the specimen at the same positions of rotation.
Reconstruction of a case with right thoracic idiopathic scoliosis: projections at 0, 35, and 90° of rotation, equivalent to anteroposterior, oblique and lateral views. An abnormal lordosis is visible in the oblique view.

Reconstruction of a normal straight spine in anteroposterior, 45° oblique and lateral projections.

Reconstructions of the curve shown in Figure 5 over three successive years, all viewed at the same obliquity, showing progression of the lordosis.

Top view of a left thoracic idiopathic scoliosis.

graph, the lumbar component is indistinguishable from true idiopathic scoliosis, and is apparently a rotated lordosis with rotation of the vertebral body to the convexity of the curve. The thoracic component, however, can be differentiated because rotation is in the opposite direction; the displacement of the vertebral body is to the concavity of the curve, showing it to be a rotated kyphosis, not a rotated lordosis. This phenomenon may explain, in part at least, the observation of a group of curves within a screened population, in which vertebral rotation is ‘non-standard’ (Armstrong et al. 1982). The concept of Eulerian buckling of a unstable flexible column as the cause of idiopathic scoliosis (Gordon 1978) would predict that these curves will not progress as the idiopathic type may well do.

We have used rotation about the vertical axis to show the lordotic deformity in idiopathic scoliosis, but it is as easy to reproduce a ‘top view’ of the spine (Fig. 8), and this has been claimed to monitor more accurately the progression of the deformity (De Smet et al. 1983). Again, the lordosis may be seen.

Scoliotic deformity is complex and does not lend
itself readily to quantification. The Cobb angle at least has the merit that it is widely used. The computer method we have described goes no further in quantifying the deformity, nor is it intended that it should. It does, however, make the qualitative nature of the deformity easily visible.

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REFERENCES


