IDIOPATHIC SCOLIOSIS IN THREE DIMENSIONS

A RADIOGRAPHIC AND MORPHOMETRIC ANALYSIS

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Eleven articulated scoliotic spines were examined radiographically and morphometrically. Measurement of the curve on anteroposterior radiographs of the specimens gave a mean Cobb angle of 70°, though true anteroposterior radiographs of the deformity revealed a mean Cobb angle of 99° (41% greater). Lateral radiographs gave the erroneous impression that there was a mean kyphosis of 41° while true lateral projections revealed a mean apical lordosis of 14°.

Morphometric measurements confirmed the presence of a lordosis at bony level, the apical vertebral bodies being significantly taller anteriorly ($P < 0.02$). There were significant correlations ($P < 0.01$) between the true size of the lateral scoliosis, the amount of axial rotation and the size of the apical lordosis. This study illustrates the three-dimensional nature of the deformity in scoliosis and its property of changing in character and magnitude according to the plane of radiographic projection.

Although idiopathic scoliosis is defined as a lateral curvature of the spine with no associated neuromuscular condition or congenital spinal anomaly, the deformity is more complex and does not exist in one plane only. A lordosis rotates to one side, producing scoliosis as a secondary phenomenon; there is, therefore, deformity in all three planes (Adams 1865; Dickson *et al.* 1984).

Despite the triplanar nature of scoliosis, conventional attempts to quantify the deformity are based upon measurements made on radiographs taken in one plane only. The method described by Cobb (1948) is generally preferred to that of Ferguson (1930) and measures, on an anteroposterior radiograph of the patient, the angle subtended by lines drawn parallel to the upper and lower end vertebrae. In an effort to measure the amount of rotation at the apex of the curve, Cobb measured the distance that the apical spinous process was displaced towards the concavity; this was modified by Nash and Moe (1969) with reference to the pedicles.

Our knowledge of the natural history of the idiopathic scoliotic deformity and its response to treatment are based upon these uniplanar measurements. However, as the lordosis rotates to the side it becomes more posteriorly directed, so that measurements on an anteroposterior radiograph do not reveal the full extent of the scoliosis. Only in one particular plane is the deformity truly seen, *en face*, and this has been referred to as the "plan d'élection" (du Peloux *et al.* 1965).

Three-dimensional analysis of spinal shape in scoliosis demonstrates the important relationship between the size of the scoliosis, the size of the lordosis and the amount of axial rotation, and indicates that the spinal deformity cannot be adequately quantified in one plane only.

MATERIAL AND METHODS

Eleven articulated spines with idiopathic scoliosis were studied; they were borrowed from the museum of the Royal College of Surgeons of Edinburgh.

Radiographic analysis. Each spinal column was mounted vertically on a specially constructed and calibrated turntable. Radiographs of each specimen were taken at 10° intervals of rotation through the complete range of 180°. From each radiograph the size of the deformity was measured using Whittle's adaptation of Cobb's method (Whittle and Evans 1979). Sequential changes in spinal shape were plotted graphically and the size of the deformity on true anteroposterior and lateral projections was correlated with axial rotation.

Morphometric analysis. The length of each entire articulated spinal column was measured both anteriorly, along a line joining the midpoints of the vertebral bodies, and posteriorly, along the line of the spinous processes, with a flexible rule and vernier calipers. In seven of the specimens measurements were also made of the anterior and posterior height of the individual vertebral bodies in the structural curve. The statistical significance of these measurements was determined using Student's *t*-test and by calculation of the correlation coefficient.

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RESULTS

Radiographic analysis. Figure 1 shows the change in Cobb angle of the deformity with rotation in Specimen 1; similar graphs were obtained for all the spines. The initial point on the graph represents an anteroposterior projection of the specimen; the apparent Cobb angle of the curvature increases with rotation until a maximum is reached in the position which represents a true anteroposterior view of the deformity. Thereafter, with continued rotation, the apparent size of the deformity diminishes until it becomes minimal at a point 90° further in rotation from the true anteroposterior view. This represents a true lateral projection of the apex of the deformity and if measurements of the curve at this point are restricted to the truly lateral apical vertebrae then a mean lordosis of 14° is observed. With further rotation the apparent Cobb angle of the deformity increases again until it reaches its original value when the specimen has been rotated through 180°.

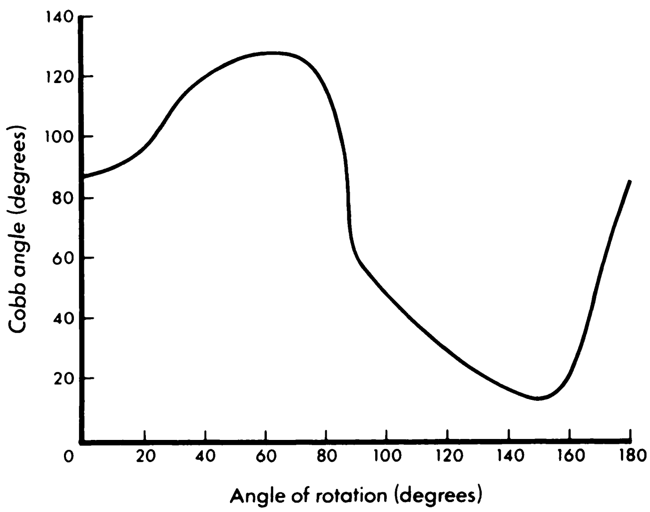

Fig. 1
Change in the measured Cobb angle with rotation (Specimen 1).

Figures 2 to 5 show sample radiographs obtained at four points during the rotational cycle: an anteroposterior view of the specimen, an anteroposterior view of the deformity, a lateral view of the specimen, and a lateral view of the deformity. The anteroposterior and lateral views of the specimen itself are entirely misleading; they do not reflect the true magnitude of the deformity and merely represent two oblique views. The anteroposterior view of the specimen underestimates the deformity while the lateral view creates the erroneous impression of the presence of a kyphosis. Inspection of the lateral view of the apex confirms that there is no kyphosis; on the contrary there is a lordosis.

Table I summarises the radiographic data obtained on the 11 specimens. It can be seen that in all except the mildest curve (Specimen 3) the anteroposterior Cobb angle of the specimen underestimated the true anteroposterior magnitude of the deformity considerably. Furthermore, the lateral projection of the spine in all but one case (the smallest scoliosis with no rotational component) produced the spurious impression of a kyphosis while a true lateral projection of the apex of the curve revealed the important lordosis.

There was a significant correlation ($P<0.01$) between the true extent of the deformity in the 11 specimens

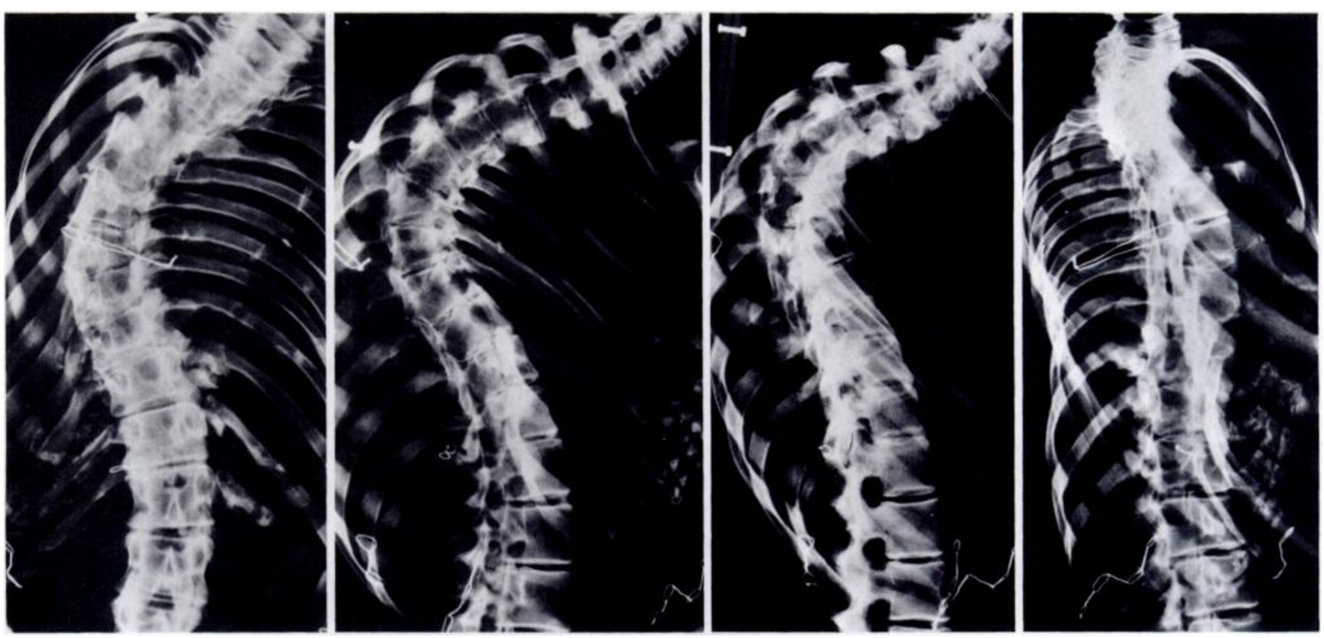

Fig. 2 Fig. 3 Fig. 4 Fig. 5

Radiographs obtained at four points during the rotational cycle of an articulated scoliotic spine (Specimen 1). Figure 2—An anteroposterior view of the specimen with an apparent Cobb angle of 87°. Figure 3—Anteroposterior view of the scoliosis with a true Cobb angle of 128°. Figure 4—Lateral view of the specimen with an apparent kyphosis of 61°. Figure 5—Lateral view of the scoliosis with a true apical *lordosis* of 14°.

Table I. Radiographic measurements (in degrees) of the 11 specimens

	Specimens											
	1	2	3	4	5	6	7	8	9	10	11	Mean
Cobb angle in AP view of specimen	87	21	18	43	41	53	104	122	75	103	105	70
Maximum Cobb angle in true AP view of deformity	128	40	18	64	55	58	125	184	114	135	174	99
Rotation (0 to max.)	65	50	0	50	50	25	35	70	65	60	90	50
Lateral profile of specimen	K61	K15	L3	K37	K23	K15	K16	K90	K31	K75	K94	K41
Lateral profile of curve apex	L14	L10	L3	L9	L8	0	L18	L19	L25	L22	L32	L14

K, kyphosis
L, lordosis

and the amount of axial rotation at the apex, showing that, as the lordosis rotates further and further to the side, it produces a bigger and bigger anteroposterior deformity. Furthermore, there was a significant correlation ($P < 0.01$) between the true size of the deformity and the amount of lordosis; the bigger the lordosis the bigger the secondary deformity it produced.

Morphometric analysis. All the spinal columns were longer anteriorly than posteriorly, that is, the mean anterior length (46.1 cm) was significantly greater than the mean posterior length (40.7 cm; $P < 0.01$). Table II shows the anterior and posterior heights of the vertebrae in the structural curve of each of the seven specimens measured; it shows that while the vertebrae above and below the region of the curve apex retain their normal kyphotic configuration, posterior height being greater than anterior, a reversal occurs at the curve apex where the specimens were truly lordotic at bony level, the anterior vertebral height being greater than the posterior ($P < 0.02$).

DISCUSSION

Although there is considerable merit in trying to quantify a complex three-dimensional deformity as simply as possible (Ferguson 1930; Cobb 1948; Nash and Moe 1969), it is abundantly clear from these results that conventional methods of measuring the deformity in idiopathic scoliosis depend entirely on the radiographic projection.

Table II. Anterior and posterior heights (in centimetres) of vertebrae in the structural curves

	Specimens													
	1		2		3		4		5		6		7	
Vertebra	A	P	A	P	A	P	A	P	A	P	A	P	A	P
T1			1.32	1.35										
T2			1.73	1.76	1.68	1.63								
T3			1.78	1.56	1.63	1.60								
T4			1.72	1.54	1.63	1.61							1.68	1.74
T5			1.60	1.61	1.64	1.50					1.82	1.85	1.82	1.84
T6			1.83	1.97	1.69	1.67			1.95	2.15	1.81	1.84	1.60	1.45
T7			1.64	1.92	1.70	1.70	1.77	1.82	1.88	2.19	1.59	1.88	1.85	1.25
T8	2.26	1.77	1.73	1.75	1.81	1.87	1.88	1.64	1.96	1.66	1.90	1.70	1.80	1.38
T9	2.25	1.45	1.95	1.97	1.82	1.87	2.04	1.52	2.23	1.81	1.91	1.54	2.15	1.49
T10	2.41	1.25	2.10	2.18			2.05	1.45	2.35	2.10	1.89	2.09	2.27	1.85
T11	2.45	1.45	2.22	2.32			2.20	2.06	2.05	2.26			2.36	2.46
T12	2.46	1.31					2.31	2.04					2.37	2.60
L1	3.24	2.25					2.36	2.45						
L2	3.28	2.59												

A, anterior; P, posterior
T, thoracic; L, lumbar

Indeed an anteroposterior projection of the patient is really only anteroposterior as regards the vertebrae above the scoliosis and those below, not for those in the structural curve itself (Fig. 2). It is the three-dimensional nature of the deformity which renders uniplanar measurements fallacious. This is exemplified by the fact that the true anteroposterior magnitude of the deformity was on average 41% greater than that obtained from the anteroposterior projection of the specimen; similarly the apparently kyphotic lateral profile varied by an average of 55° from the true lateral projection which showed the lordosis.

It is important to realise that curve size and rotation are significantly related. An anteroposterior view of the patient underestimates the true extent of the deformity, and this phenomenon becomes more marked with increasing curve size. As the secondary deformity rotates past the coronal plane so it is directed progressively more posteriorly; thus an anteroposterior view of the patient will demonstrate a reducing Cobb angle when in fact quite the reverse is happening to the deformity. This trend continues until a plane is reached where there is little or no deformity on an anteroposterior view of the patient while a view at 90° to this will demonstrate the full deformity *en face*. This explains why surgeons may be under the misapprehension that a serious deformity is improving when the opposite is in fact occurring.

True lateral projections of the apex of the curve demonstrate the presence of a lordosis; its fundamental role in progression of the deformity is supported by its close correlation with the size of the scoliosis and with the amount of axial rotation. Although overall morphometric measurements of the spinal columns demonstrate that anterior height is excessive, this is particularly significant at the apical segments of the structural curves where a lordosis exists at bony level. These measurements confirm that in idiopathic scoliosis the apical vertebral bodies are wedge-shaped in the opposite direction to that in Scheuermann's disease.

True measurement of the size of the deformity is an important consideration in investigations of the natural history and treatment of idiopathic scoliosis. This study demonstrates the three-dimensional nature of the deformity in scoliosis and its property of changing in character and magnitude according to the vertebral level under consideration, and the plane of radiographic projection. It is unique as it is not ethically possible to obtain multiple radiographs, taken in small serial increments of rotation, of the deformed spines of otherwise normal children. The specimens studied are admirably suitable for this purpose.

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REFERENCES

Adams W. *Lectures on the pathology and treatment of lateral and other forms of curvature of the spine*. London: John Churchill and Sons, 1865.

Cobb JR. Outline for the study of scoliosis. *Am Acad Orthop Surg Inst Course Lect* 1948;**5**:261–75.

Dickson RA, Lawton JO, Archer IA, Butt WP. The pathogenesis of idiopathic scoliosis: biplanar spinal asymmetry. *J Bone Joint Surg [Br]* 1984;**66–B**:8–15.

du Peloux J, Fauchet R, Faucon B, Stagnara P. Le plan d'élection pour l'examen radiologique des cypho-scolioses. *Rev Chir Orthop* 1965;**51**:517–24.

Ferguson AB. The study and treatment of scoliosis. *South Med J* 1930;**23**:116–120.

Nash CL Jr, Moe JH. A study of vertebral rotation. *J Bone Joint Surg [Am]* 1969;**51–A**:223–9.

Whittle MW, Evans M. Instrument for measuring the Cobb angle in scoliosis. *Lancet* 1979;**i**:414.