A Study of Vertebral Rotation

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The roentgenographic determination of vertebral rotation is an important part of scoliosis evaluation. Cobb stressed its usefulness, particularly in cases being considered for fusion. In 1948, he described a standard technique for measurement of rotation based on the position of the tip of the spinous process in relation to the underlying vertebral body (Fig. 1). Values ranged from 0 to 4+, but no effort was

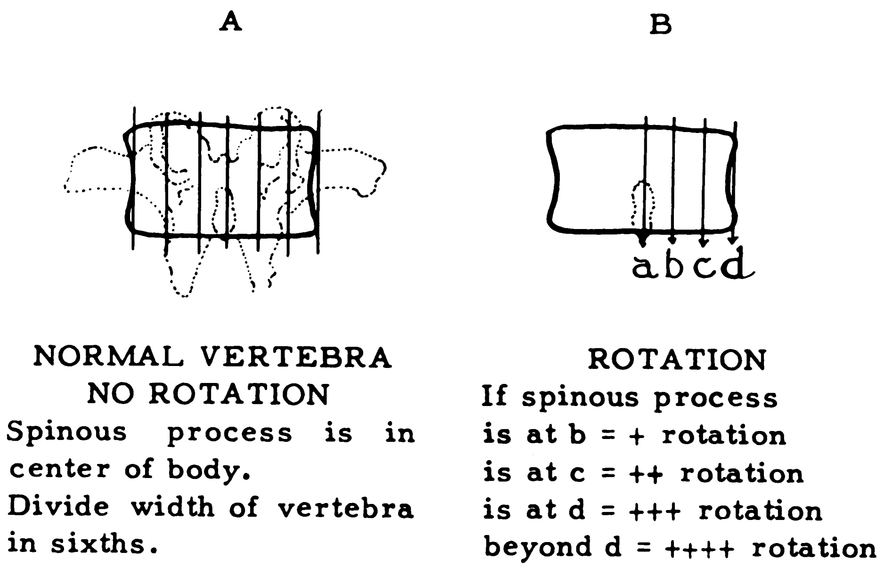

FIG. 1

Cobb's method of determining vertebral rotation. (Reprinted from Outline for the Study of Scoliosis by J. R. Cobb. *In* The American Academy of Orthopaedic Surgeons Instructional Course Lectures, Vol. 5, p. 267. Ann Arbor, J. W. Edwards, 1948).

made to correlate these grades with either the degree of rotation or the clinical deformity. Although many other authors have stressed the importance of rotational evaluation, few have either discussed or expanded this approach. In 1958, Moe stated that the spinous processes were often difficult to visualize and suggested using the pedicle shadows instead. Once again, no particular system was proposed.

The present study was undertaken to examine and compare the relative merits of rotational evaluation based on either spinous process or pedicle-shadow displacement. A standard method of determining rotation based on pedicle displacement was designed similar to that used by Cobb, and the two systems were then compared. At the same time, the approximate range of degrees represented by each gradation of rotation for each method was determined. Finally, as a result of these two studies, a simplified method of determining rotation was then devised that would combine the pedicle displacement seen with the approximate degrees of rotation represented by that displacement.

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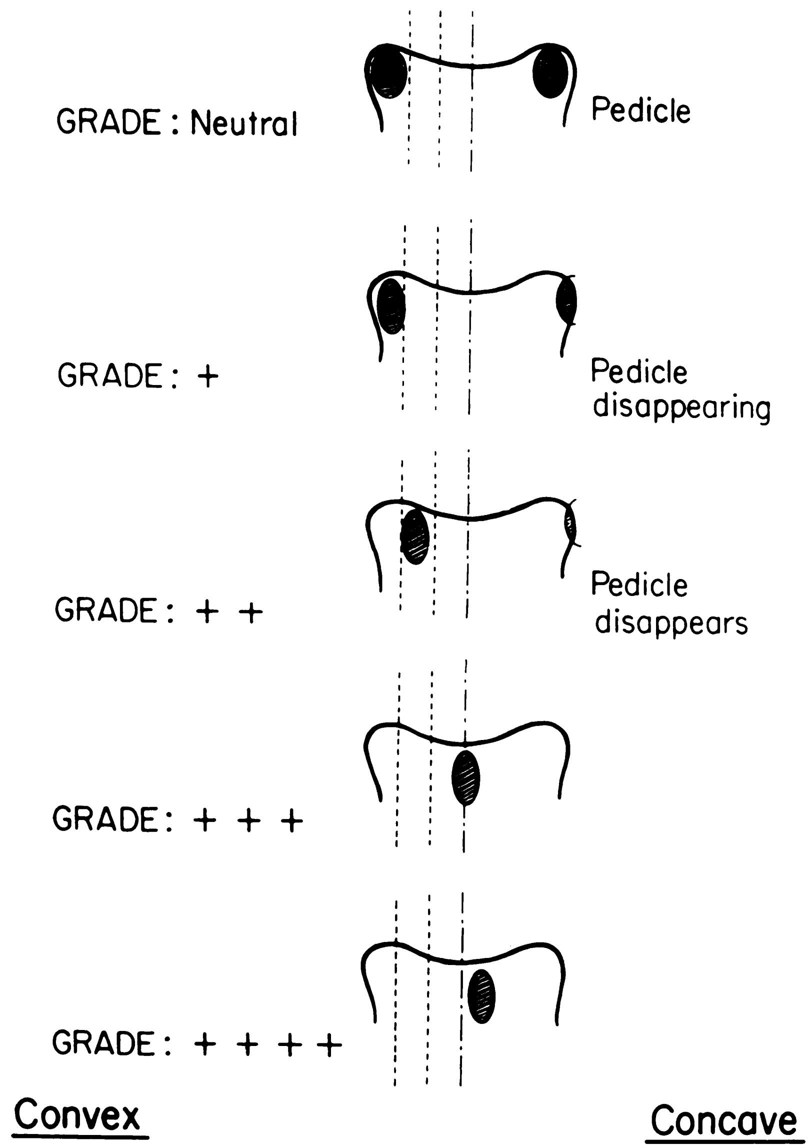

FIG. 2

Pedicle method of determining vertebral rotation.

	Pedicle	
	Convex	Concave
Grade: Neutral	No asymmetry.	No asymmetry.
Grade: +	Migrates within first segment. Early distortion.	May start disappearing. Early distortion.
Grade: ++	Migrates to second segment.	Gradually disappears.
Grade: +++	Migrates to middle segment.	Not visible.
Grade: ++++	Migrates past mid-line to concave side of vertebral body.	Not visible.

TABLE I
ROENTGENOGRAPHIC ESTIMATION OF ROTATION

Location	Technique	+ (Degrees)	++ (Degrees)	+++ (Degrees)	++++ (Degrees)
Upper thoracic (T2 to T5)	Pedicle	5 to 15	20 to 35	40	>50
	Cobb	5	10	15 to 20	>25
Thoracic (T7 to T10)	Pedicle	5 to 10	15 to 30	35 to 40	>50
	Cobb	5	10 to 15	20 to 25	>30
Lumbar (L2 to L4)	Pedicle	5 to 15	20 to 35	40 to 50	>60
	Cobb	5 to 10	15 to 20	25 to 35	>40

Method

A desiccated, normal, young adult spine was used for this study. Three and four complete vertebral segments taken from the upper thoracic, mid-thoracic, and lumbar areas were used representing the second to fourth thoracic vertebrae, the seventh to tenth thoracic vertebrae, and the second to fourth lumbar vertebrae, respectively. The tip of the spinous process and both pedicles of alternate vertebrae were marked with circumferential wires to aid in correlating the bone anatomy with the outlines seen on roentgenograms. Roentgenograms were then made of each segment in 5-degree increments of rotation from 0 to 40 degrees and then 10-degree increments thereafter to 90 degrees. The line of the posterior longitudinal ligament was taken as the center of rotation, as suggested by Roaf and others [2,7].

For initial comparison, each vertebral segment was graded at each 5 or 10-degree increment of rotation using both the position of the spinous processes (Cobb method) and the position of the pedicles. The position of the pedicles was rated in a fashion similar to Cobb's spinous process method in that the vertebral body was divided into six segments, and grades from 0 to 4+ were assigned depending on the location of the pedicle within these segments (Fig. 1). Since the concave pedicle outline disappears early in rotation, the convex pedicle, easily visible through a wide range or rotation, was used as the standard.

Specific rotation was assigned as follows (Fig. 2): 0 rotation had no asymmetry of either the position or shape of either pedicle; 1+ had medial migration of the convex pedicle limited to the most convex segment selected, and there was slight flattening of the oval of both pedicles with the concave border of the concave pedicle starting to disappear; 2+ rotation had further migration of the convex pedicle into the second convex vertebral segment while the concave pedicle gradually became indistinct; 3+ rotation was obtained when the convex pedicle reached the mid-line and was completely contained by the third segment; 4+ rotation occurred as the convex pedicle passed through the mid-line into the fourth segment on the concave side of the body.

Results

Table I, summarizing the results obtained, shows there was a significant difference between the spinous process and the pedicle methods. Specifically, the grades of rotation obtained in the Cobb technique occurred at 10 to 20 degrees less vertebral rotation than they did using the pedicle technique. For example, 4+ rotation by the Cobb technique started at 25 degrees in the upper thoracic, 30 degrees in the mid-thoracic, and 40 degrees in the lumbar areas, whereas, the pedicle method values for

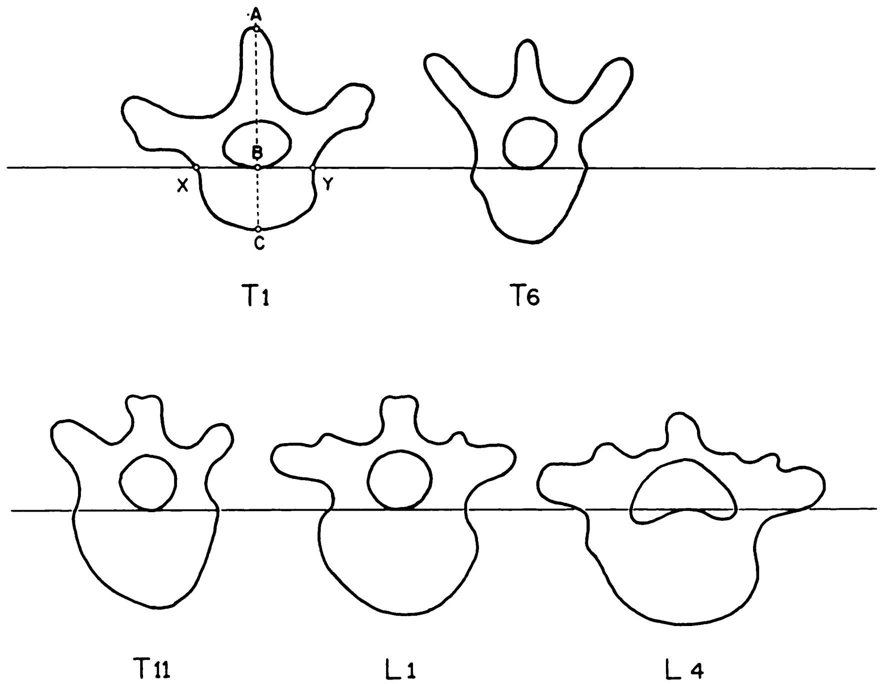

FIG. 3

The cross-sectional tracings of these vertebrae show a progressive loss of posterior height and increase of anterior depth. The vertebral body width gradually increases with progression from upper thoracic to lower lumbar areas.

the same rotation were 50, 50, and 60 degrees, respectively. These differences were noted across the board. In addition, Table I shows that, when the spinous process technique was used, the amount of rotation represented by each grade gradually increased from the upper thoracic to the lumbar areas; the pedicle method gave values that tended to remain constant throughout.

Finally, Figure 3 demonstrates the normal sequential variation in vertebral cross-sectional anatomy progressing from the upper thoracic to lumbar area. In the upper thoracic and mid-thoracic areas, the posterior elements dominate because of the length of the spinous processes. This is true when the depth of the posterior element is compared to either the depth or the width of the anterior element. In the lower thoracic and lumbar areas, the relationship of the posterior to anterior elements approaches equality and may even reverse slightly. This reversal is particularly noted in the comparison of the posterior depth to the anterior width. Therefore, it can be seen that, for each degree of rotation in the upper area of the spine, there will be relatively greater lateral displacement of the posterior elements than of the anterior elements. Furthermore, as the vertebral body becomes thicker and wider, greater degrees of rotation are required to cause an equal amount of lateral displacement of the posterior element relative to the anterior elements. This is graphically represented in Figure 4.

Discussion

Evaluation of vertebral rotation is not precise even when done on a normal spine under ideal conditions. The problem becomes more complicated when applied to the scoliotic spine because of the well known anatomical variations that occur in the vertebrae secondary to the deforming forces of the scoliosis [2,5,7] (Fig. 5). In addition, the actual center of rotation may be changing in the scoliotic spine, and it

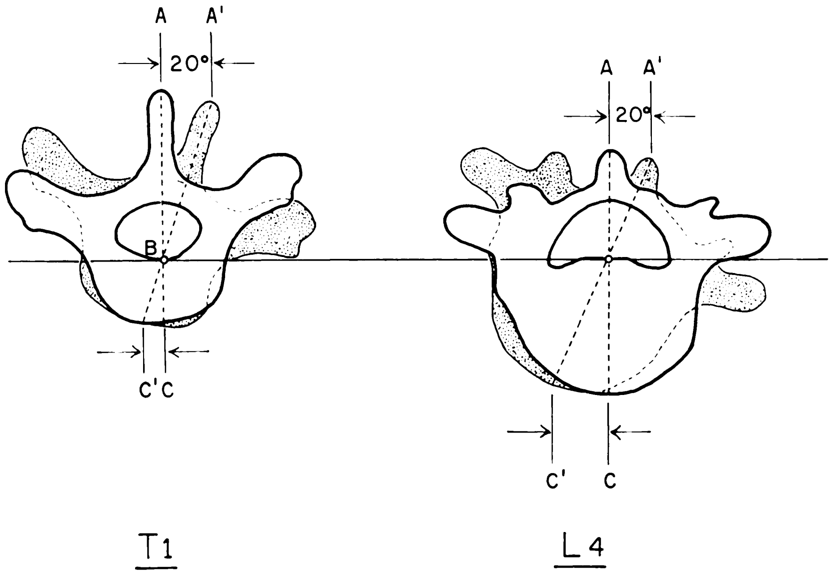

FIG. 4

Comparative lateral displacement of anterior (C'-C) and posterior (A'-A) vertebral segments caused by 20 degrees of rotation is shown. The discrepancy in spinous-process displacement caused by changes in configuration can be easily seen. This accounts for the variation in degrees of rotation as determined by the Cobb method. Pedicle displacement, however, compares favorably.

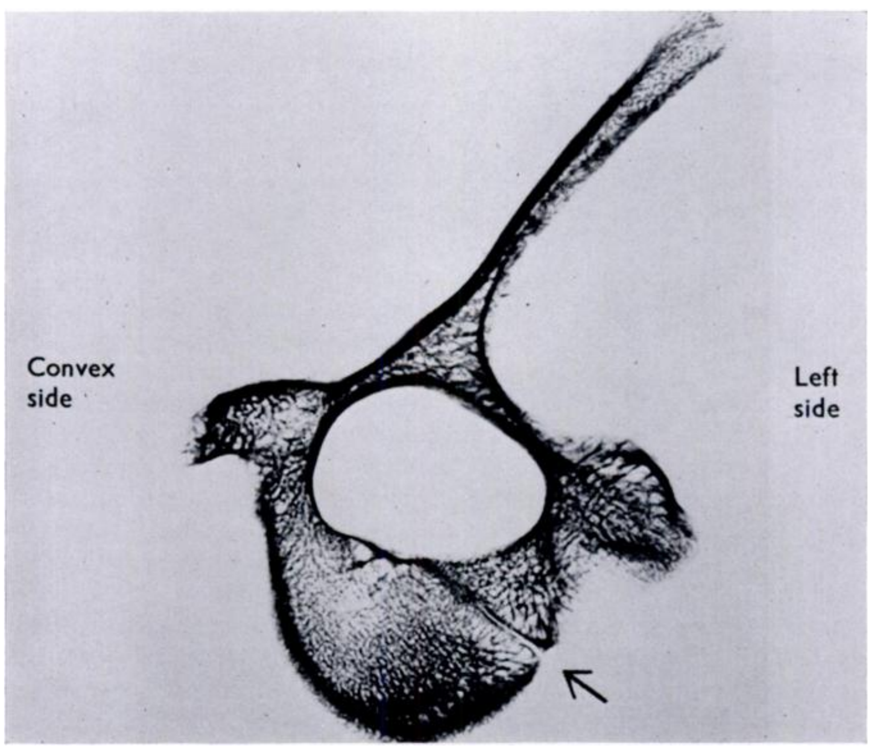

FIG. 5

This roentgenogram taken from the experimental work of Michelsson shows the typical vertebral distortion caused by the forces of scoliosis. Note the marked displacement of the spinous process and the relative constancy of the pedicles. (Reprinted from The Development of Spinal Deformity in Experimental Scoliosis by Jarl-Erik Michelsson. Acta Orthop. Scandinavica, Supplementum 81, p. 62, 1965.)

is difficult to look at a spine and say how much change is rotation and how much is deformity.

When one compares the spinous process and pedicle method of evaluating rotation, these considerations, as well as the differences noted in the two techniques on normal spines, favor the use of the pedicle technique. There is no question that the pedicle outline, particularly on the convex side, is more readily seen throughout a greater range of rotation. In addition, it has the dividend of being present for postoperative evaluation of rotational correction. The Cobb method is also subject to a normal variation in the spinous-process configuration so that similar degrees of rotation do not give similar grades of rotation on roentgenograms. The problem is compounded by the distortional forces of scoliosis, which tend to exaggerate the concave migration of the tip of the spinous process.

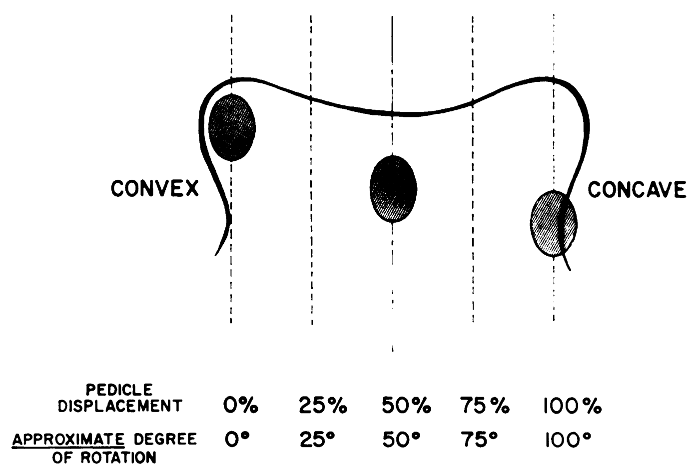

FIG. 6

This diagram summarizes a simplified technique of describing vertebral rotation and estimating the degrees of rotation present.

These problems hold true for the pedicle technique as well but to a lesser extent. The pedicles are closer to the center of rotation and tend to maintain a constant relationship to the vertebral body throughout the spine. This is important since both systems use the vertebral body as a standard of measurement. Although pedicle distortions occur in scoliosis, the relative magnitude and displacement are less than those in the more susceptible spinous processes.

It must also be noted that in the thoracic region the spinous process of one vertebra overlies the body of the next caudad vertebra. Since the amount of rotation in each of these vertebrae differs, the grade of rotation assigned by the spinous process method will represent a compromise of the two vertebral rotations. In the pedicle system, each vertebra is evaluated as a separate unit.

Our central purpose was to establish a reasonable approach to the evaluation of vertebral rotation in scoliosis. Thus, a system of grading was designed based on the more consistent pedicle position but using the model of the previously described Cobb method so that the two techniques could be compared. Once it was determined that the pedicle approach was preferable, a less complicated system of evaluation was devised to eliminate the need of memorizing a list of grades and criteria as well as the difficulty of choosing the correct grade for borderline positions.

Instead of assigning arbitrary grades, one reads the amount of displacement of the convex pedicle as it migrates from the convex to the concave borders of the vertebral body directly as a percentage of the entire width of the vertebral body (Fig. 6). Therefore, no distortion or displacement is 0 per cent while migration of the convex pedicle from the convex border to the mid-line of the vertebral body is 50 per cent displacement.

In addition, there proved to be a good numerical correlation between the percentage displacement and the degrees of rotation represented by that displacement. That meant that 25 per cent displacement was equivalent to approximately 25 degrees of rotation. Obviously, the accuracy of this correlation was only to the nearest 5 or 10 degrees of rotation, but a fair estimation could be made. On the basis of Table I, then, Grade 1 had 5 to 15 degrees of rotation and between 5 and 15 per cent displacement of the convex pedicle. The same general relationship held true across the board.

Thus, although rotation can be described according to a grading system similar to that used by Cobb, it can also be described more simply as the per cent displacement of the convex pedicle toward the concave border of the vertebral body. This figure can then be translated directly into a rough approximation of the degrees of rotation represented by that displacement.

Finally, no attempt has been made to correlate degrees of vertebral rotation with clinical deformity. Changes in rib configuration, which can occur independently of vertebral rotation, may either exaggerate or minimize the rotational deformity.

Summary

The problem of roentgenographic evaluation of vertebral rotation has been studied using upper thoracic, thoracic, and lumbar segments of a normal spine which were marked with wires and which then had roentgenograms made in known increments of rotation. The results showed a definite difference between a grading system based upon the position of the spinous process and a system based on the position of the pedicle located on the convex side of the curve. The pedicle technique proved to have definite merit in its ease of application over a wide range of rotation and its over-all consistency of values even when applied to the scoliotic spine.

As an additional part of the study, the approximate range of degrees of rotation represented by each grade of rotation was determined.

Finally, by combining the two parts of this study, we were able to propose a simplified method of describing vertebral rotation, which correlates the amount or percentage of convex pedicle displacement seen on roentgenograms with the approximate degrees of rotation present in that vertebra.

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