ULTRASOUND MEASUREMENT OF VERTEBRAL ROTATION IN IDIOPATHIC SCOLIOSIS

SHIGEO SUZUKI, TAKAO YAMAMURO, JITSUHIKO SHIKATA, KATSUJI SHIMIZU, HIROKAZU IIDA

From Kyoto University Medical School, Japan

Ultrasound can be used to outline the spinous processes and the laminae, and thus to measure axial rotation. Using our own technique, we measured vertebral rotation in 47 patients with idiopathic scoliosis. There was a strong linear relationship between the Cobb angle and the rotation of the apical vertebra in untreated patients, but this relationship was lost in patients who had had brace treatment.

Vertebral rotation can easily be measured by ultrasound. This is a harmless and fairly rapid investigation which can be used at routine follow-up examination of patients with idiopathic scoliosis.

Ultrasound helps diagnosis in various fields of medicine, and can provide information about soft tissues without the use of a contrast medium. Bone reflects most ultrasound at the surface of the cortex, giving a clear image and providing valuable information on its shape. In the spine it is possible to assess rotatory position of the lamina. Rotation of the spinal column around its longitudinal axis is important in scoliosis, because it causes rib cage deformity and affects cardiopulmonary function. It is therefore essential to assess rotation as well as lateral curvature. The complicated nature of the three-dimensional deformity, however, makes this difficult.

Cobb (1948) estimated axial rotation from the position of the tip of the spinous process in relation to the underlying vertebral body. Nash and Moe (1969) used the movement of the image of the pedicles, and since then a number of methods have been developed which use complicated mathematical calculations based on pedicle offset (Brown et al. 1976; Matteri, Pope and Frymoyer 1976; Coetsier, Vercauteren and Moerman 1977; Hindmarsh, Larsson and Mattsson 1980; De Smet et al. 1980; Hierholzer and Lüxmann 1982; Drerup 1985;

Stokes, Bigalow and Moreland 1986). Rotation can be measured directly from a CT scan (Aaro and Dahlborn 1981; Aaro, Burström and Dahlborn 1981).

These methods, however, have problems. Calculations based on pedicle displacement are theoretical, and measurement by CT scan involves more irradiation and should not be used for routine diagnosis. Ultrasonography, however, can display directly the rotatory position of the laminae and the transverse processes while involving no irradiation, so that examinations can be done as often as necessary. We have used ultrasound to measure vertebral rotation in patients with adolescent idiopathic scoliosis.

PATIENTS AND METHODS

Ultrasound technique. For the ultrasonic examinations we used a Shimazu SDL-300 machine on 5.0 MHz, based on a linear electronic scanning method. The patient is laid prone on a firm couch, with the shoulder girdle and the pelvis parallel to each other and the ground. The spinous processes are marked and lines are drawn parallel to the inclination of the vertebrae as seen on an anteroposterior radiograph of the spine (Fig. 1). The transducer with an attached inclinometer is placed on the spinous process in this line (Fig. 2). The transverse processes and the laminae are displayed on the screen and the transducer is then inclined until the image of the laminae becomes horizontal on the screen (Fig. 3). The inclination of the transducer is then the rotation of the lamina. In each case this was determined from T2 spinous process to the sacrum.

Three patients also had CT scans for other clinical reasons; in them the rotation of the apical vertebra was measured by both methods.

S. Suzuki, MD, Assistant Professor
T. Yamamuro, MD, Professor and Chairman
J. Shikata, MD, Assistant Professor
K. Shimizu, MD, Assistant Professor
H. Iida, MD, Assistant Professor
Department of Orthopaedics, Faculty of Medicine, Kyoto University, 54 Kawara-cho, Shogoin Sakyo-ku, Kyoto, 606 Japan.

Correspondence should be sent to Dr S. Suzuki at Department of Orthopaedics, Shiga Medical Center for Children, 120–6 Moriyama-cho, Moriyama, Shiga 524, Japan.
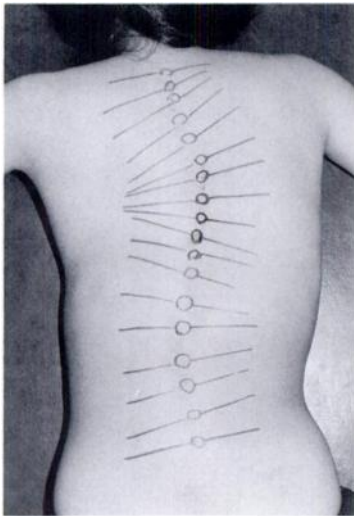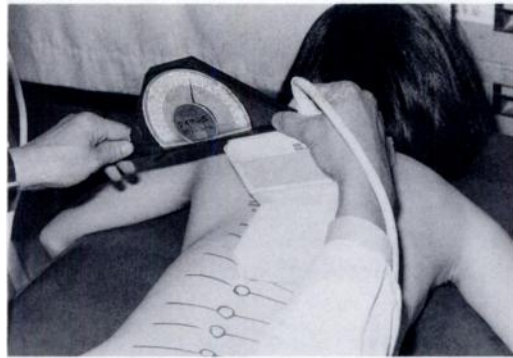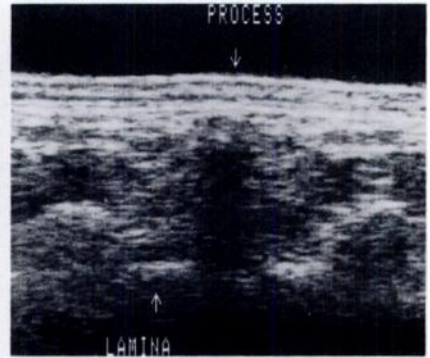
Fig. 2

Fig. 3

Figure 1 – The spinous processes and the vertebral tilt have been marked. Figure 2 – The transducer and inclinometer in use. Figure 3 – Ultrasonogram showing both laminae at one level.
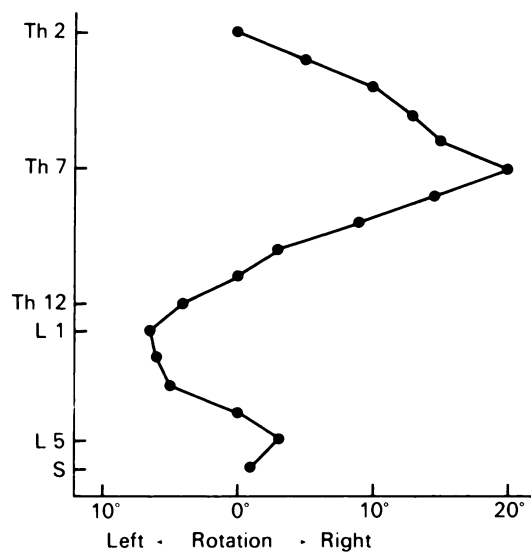
Fig. 1

Fig. 4

Rotation at each vertebral level in a 14-year-old girl with a 60° right thoracic and a 44° left thoracolumbar curve due to idiopathic scoliosis. No treatment had been given.

Patients. Of the patients, 25 (aged nine to 21 years), had received no prior treatment. Nine had a single thoracic curve, seven a lumbar curve and nine had a double curve, giving 18 thoracic curves, and 16 lumbar curves to be measured. The other 17 patients, aged 10 to 20 years, had had brace treatment for more than six months (16 with an underarm brace and one a Milwaukee brace). Of these, nine had a single thoracic curve, one a single lumbar and seven a double curve, giving 16 thoracic curves, and eight lumbar curves.

RESULTS

The rotational position of each vertebra in one patient is shown in Figure 4. In every patient maximum rotation was at the apex of the scoliotic curve. The relationship between the Cobb angle and the maximum rotation for all untreated curves is shown in Figure 5. There was a strong linear relationship between the Cobb angle and vertebral rotation in both thoracic and lumbar curves ($p < 0.01$).
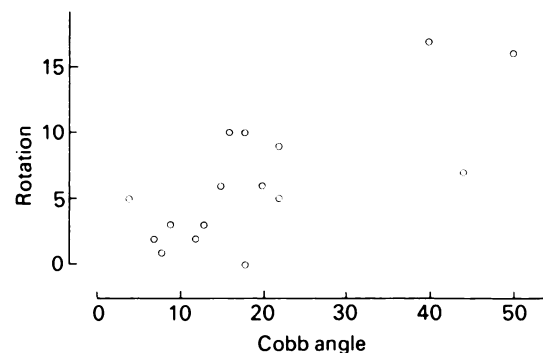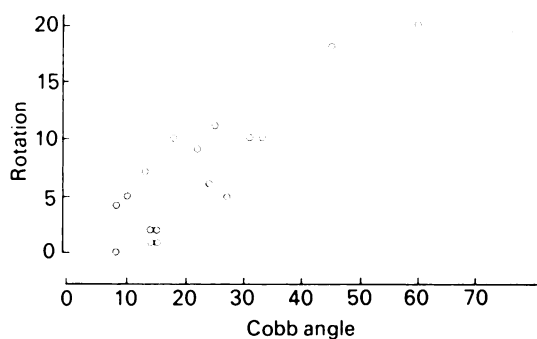

Fig. 5

The relationship between Cobb angle and spinal rotation in untreated cases of idiopathic scoliosis. Left – A thoracic curve (Coefficient of correlation, R = 0.8055). Right – A lumbar curve (R = 0.742).
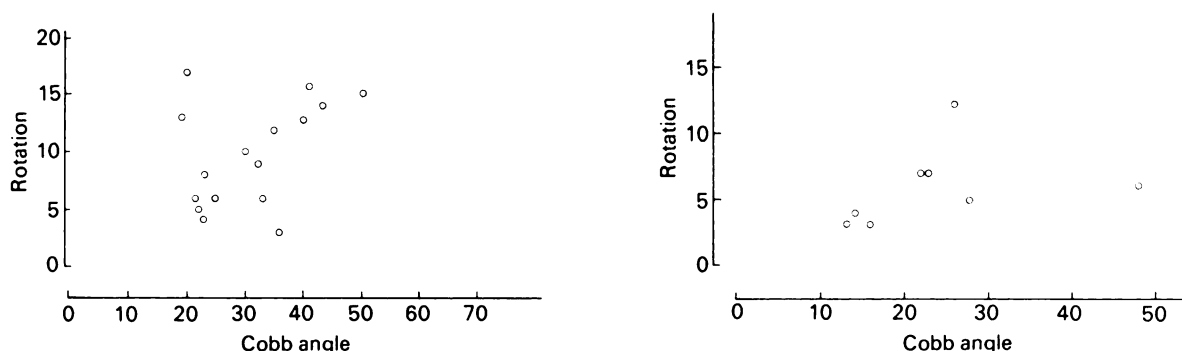
Fig. 6

The relationship between Cobb angle and spinal rotation in cases of idiopathic scoliosis after treatment by brace. Left – A thoracic curve (R = 0.370). Right – A lumbar curve (R = 0.352).

Figure 6 gives this relationship for patients who had had brace treatment. In these the linear relationship between Cobb angle and rotation was lost in both thoracic and lumbar curves, giving a lower coefficient of correlation than that for untreated cases.

The CT scan of the patient with results shown in Figure 4 shows the extent of deformity of the whole transverse section (Fig. 7). The amount of rotation varies in different parts of the vertebra and is greater in the laminae than in the vertebral body.

DISCUSSION

The measurement of vertebral rotation from the asymmetries of the pedicles originated in Cobb's and Nash and Moe's methods, and has been developed by many investigators. However, the calculation is based on data obtained from anatomically normal vertebrae; the vertebrae of the scoliotic spine, however, have anatomical variations (Benson, Schultz and Dewald 1976) as shown in Figure 7, and this may introduce errors. It is sometimes difficult to identify the index point for measuring and complicated calculation is required.

Direct measurement of the axial rotation of the spine with a CT scan is inaccurate unless the section is at a right angle to the spinal column. This makes it impossible to obtain information on the whole spinal column in this way and, in addition, the hazards of exposure to radiation and the cost are too great for routine follow-up.

Ultrasound is harmless and can give a clear image of the outline of the laminae, allowing rotation to be measured directly from the inclination of the transducer. CT scans show that rotation differs in different parts of the vertebra, being greater in the laminae than in the vertebral body, so that laminal rotation is relevant to total spinal rotation. With ultrasound by our method, the rotation of the whole spinal column can be measured in a short time.

Fig. 7

CT scan at the level of the apical thoracic vertebra in the same patient as Figure 4.

It is very important that patients lie on a firm surface with both the shoulder girdle and the pelvis parallel to the ground. Although the anterior rib cage deformity is less than the rib hump (as shown in Figure 7) any asymmetry would influence the measurement. In a right thoracic curve, the left anterior rib cage is more prominent than the right. Uncorrected, this would cause the rotation of the laminae to be underestimated. A line connecting the shoulder joints must be parallel to the ground.

With ultrasound, as with the CT method, spinal lordosis or kyphosis may produce incorrect values of rotation. Lordosis or kyphosis was not severe in our cases and was not taken into consideration. If either of these deformities is severe, however, the couch must be tilted so that the longitudinal axis of each vertebra in turn is parallel to the ground.

From our study, it is still not clear whether rotation takes place before or after the lateral curve has started,

but we found that spinal rotation in untreated cases related to the Cobb angle, and that this linear correlation was lost in patients who had had brace treatment. This indicates that brace treatment changed the relationship between lateral curvature and rotation. There may be some cases in which the rotation deformity is rigid and brace correction of this is more difficult than of the lateral curvature, and others in which control of the rotation can be more effective than that of lateral curvature. In double curves, correction of the thoracic rotation may influence the degree of lumbar rotation.

REFERENCES

Aaro S, Dahlbom M. Estimation of vertebral rotation and the spinal and rib cage deformity in scoliosis by computer tomography. *Spine* 1981;6:460-7.

Aaro S, Burström R, Dahlbom M. The derotating effect of the Boston brace: a comparison between computer tomography and a conventional method. *Spine* 1981;6:477-82.

Benson DR, Schultz AB, Dewald RL. Roentogenographic evaluation of vertebral rotation. *J Bone Joint Surg [Am]* 1976;58-A:1125-9.

Brown RH, Burstein AH, Nash CL, et al. Spinal analysis using a three-dimensional radiographic technique. *J Biomech* 1976;9:355-65.

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

Coetsier M, Vercauteren M, Moerman P. A new radiographic method for measuring vertebral rotation in scoliosis. *Acta Orthop Belg* 1977;43:598-605.

De Smet AA, Tarlton MA, Cook LT, Fritz SL, Dwyer SJ III. A radiographic method for three-dimensional analysis of spinal configuration. *Radiology* 1980;137:343-8.

Drerup B. Improvements in measuring vertebral rotation from the projections of the pedicles. *J Biomech* 1985;18:360-78.

Hierholzer E, Lüxmann G. Three-dimensional shape analysis of the scoliotic spine using invariant shape parameters. *J Biomech* 1982;15:583-98.

Hindmarsh J, Larsson J, Mattsson O. Analysis of changes in the scoliotic spine using a three-dimensional radiographic technique. *J Biomech* 1980;13:279-90.

Matteri RE, Pope MH, Frymoyer JW. A biplane radiographic method of determining vertebral rotation in postmortem specimens. *Clin Orthop* 1976;116:95-8.

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

Stokes IAF, Bigalow LC, Moreland MS. Measurement of axial rotation of vertebrae in scoliosis. *Spine* 1986;1:213-8.