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MEASUREMENT OF THE DEFORMITY IN SCOLIOSIS

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Two major difficulties encountered in assessing the results of treatment for idiopathic scoliosis are, firstly, the impossibility of knowing the future spontaneous course when active measures are taken, and, secondly, the uncertainly incurred in the measurement of the deformity. The former difficulty implies that some regression of the deformity must occur before it is possible to ascertain the effect of the treatment, or else one half of the patients must remain untreated so as to provide a control group—an unattractive alternative.

If the regression is only of moderate degree more accurate methods for measuring the deformity are required than are at present available.

THE DEFORMITY IN SCOLIOSIS

The magnitude of the deformity in scoliosis is almost invariably assessed on the basis of the primary curve in a frontal view. The measurement of this curve on the film is usually performed by either *Cobb's* (1) or *Ferguson's* (4) method.

In the former the difference between the angle of the upper and lower surface of the upper and lower vertebrae, respectively, is measured (Figure 1), whereas *Ferguson* determines the angle between the midpoints of 3 vertebrae, in which the upper- and lowermost are defined by what is taken to be the primary curve, and the third vertebra is one midway between them—or if there are two, it will be one of them (Figure 2). Another method has been evolved by *Tideström* (8) in which the angular deviation of each vertebra is determined, thus providing a general representation of the magnitude and extent of the scoliosis (Figure 3). The three methods are basically equivalent since they

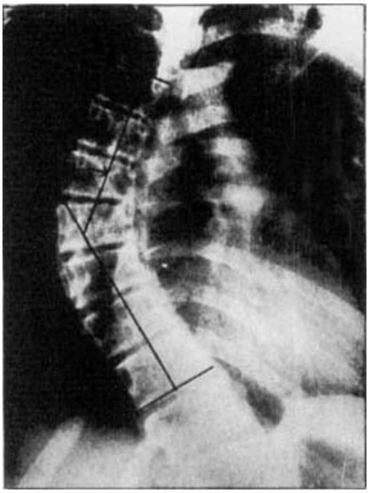


Figure 1. Conventional frontal view of idiopathic scoliosis. Measurement of the angles by Cobb's method. Scoliosis angle 54°.

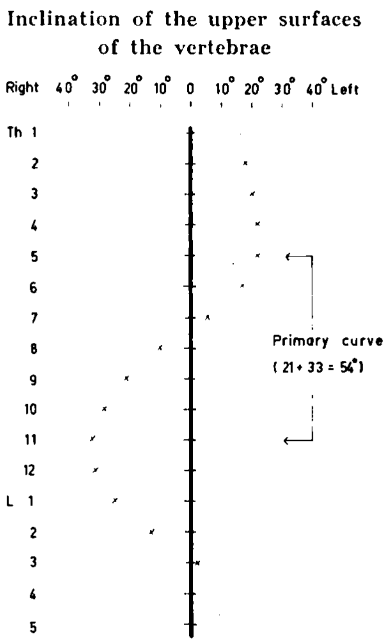
all provide a measure of the magnitude of the scoliosis. Ferguson's method gives a value for the angle that is dependant on both the deformity and the length of the spine within the curvature; but this is not necessarily a disadvantage and the method is concerned rather with the deformity as it is seen with the eye, whereas Cobb's technique can give large values for a short but sharply angled scoliosis that need not be so obvious on clinical examination.

In the present study Ferguson's method was used. In making comparisons from one occasion to another it is necessary, of course, to use the same vertebrae for determining the angle. As it can be difficult, particularly in mild cases, to determine accurately which vertebrae shall be regarded as the beginning and end of the primary curvature it is an advantage to choose the three so as to have the same number on each side of the middle one, and preferably to take the upper- and lowermost ones as far up and down as possible within what is regarded as the primary curvature. As scoliosis progresses a vertebra that lies at the border of the primary curvature will often be drawn completely within it.

The term "scoliosis angle" will be used to denote the sum of the deviations of the two arms of the angle from the vertical (angle TML, Figure 9). Each vertebra is defined by its centre, which is taken as the intersection of two diagonals from the corners of the vertebra (Figure 2).

So far only the measurement of the angle on the film has been con-

Figure 2. As in Figure 1, but the angles measured by Ferguson's method. Scoliosis angles then 36°.



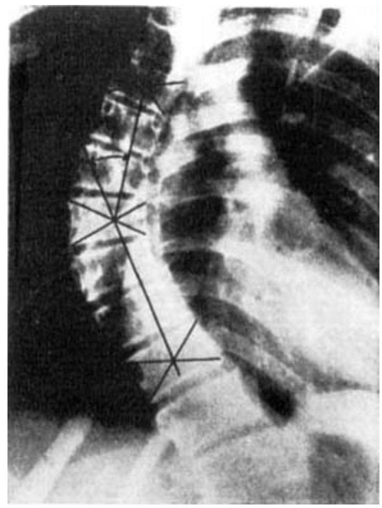


Figure 3. As in Figure 1. Registration of scoliosis angles by Tideström's method. The same scoliosis as in Figures 1 and 2.

sidered, but it is well known that small differences in setting the X-ray tube and in rotating the patient give different projections, and hence different angles. Such changes in angle comply with the principles of solid geometry, which however are fairly difficult to apply in practical work. It has been found by *Bergquist & Sevastikoglou* (7) that small changes in the direction of projection can result in changes in the scoliosis angle of up to 11 per cent.

The main sorce of error in determining the scoliosis angle is the lack of reproducibility of the projections from one occasion to another. The reason for this lies in the difficulty of defining the frontal plane and determining it clinically in cases of scoliosis, especially severe ones,

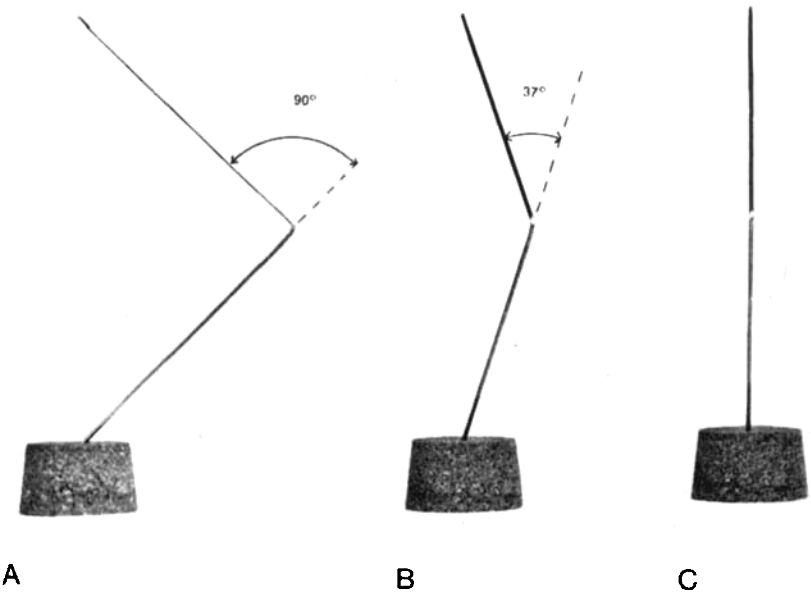


Figure 4. A steel wire bent through 90° (A). The scoliosis angle diminished as the wire is rotated (B). When it has been rotated through 90° (C) it is seen as a straight line.

owing to the marked deformation of the abdomen. Because of the rotation that accompanies the scoliosis the maximum curvature does not lie in the frontal plane. The angle reproduced in the frontal film will therefore be too small by an amount that will depend on the discrepancy between the frontal plane and the plane containing the maximum angle.

As, in the development of scoliosis, the plane containing the maximum angle changes because of the rotation, the error in the determination of the frontal plane will be supplemented by that incurred by the change in the plane of the maximum angle. After an operation to reduce this rotation it will be difficult, if the difference is only moderate, to ascertain by conventional methods whether or not the scoliosis angle has increased.

The determination of the *maximum scoliosis angle* and the deviation of its plane from the frontal plane is superior to conventional procedures for obtaining an impression of the deformations, and if the methods of determination are reproducible it should be possible to make a comparison from one occasion to another.

It should be borne in mind that in the determination of the maximum

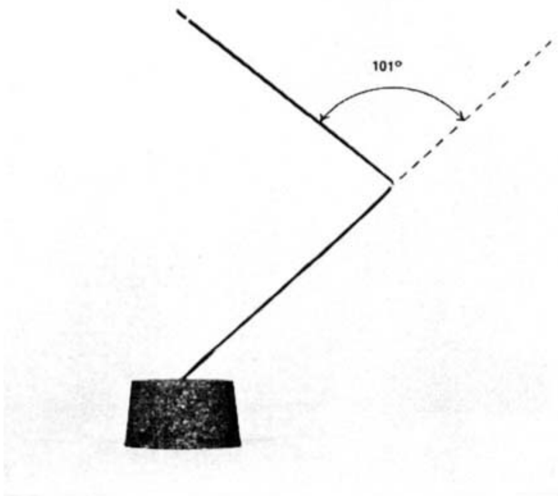


Figure 5. As in Figure 4, but the wire is inclined forwards so that the "scoliosis angle" is increased.

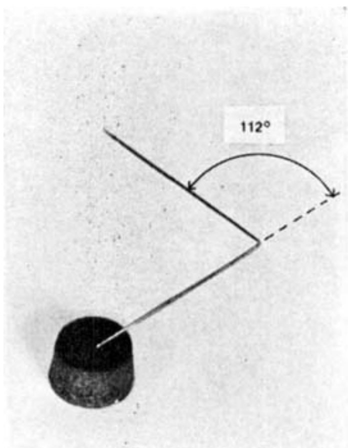


Figure 6. As in Figure 4. The wire is neither inclined nor rotated but the camera is placed above the level of the vertex of the angle; the scoliosis angle is then increased.

angle one is measuring a combination of pure scoliosis and kyphosis (or lordosis). This, however, is probably not a disadvatage.

On the basis of a mechanical theory of the origin of scoliosis *Lindahl* has resected transverse processes, and later on such processes and the posterior part of the ribs on the concave side of the scoliosis (5, 6). The result of this was chiefly to reduce the rotation of the thorax, rather than the scoliosis angle. This angle was then measured by Ferguson's method and the usual radiologic technique.

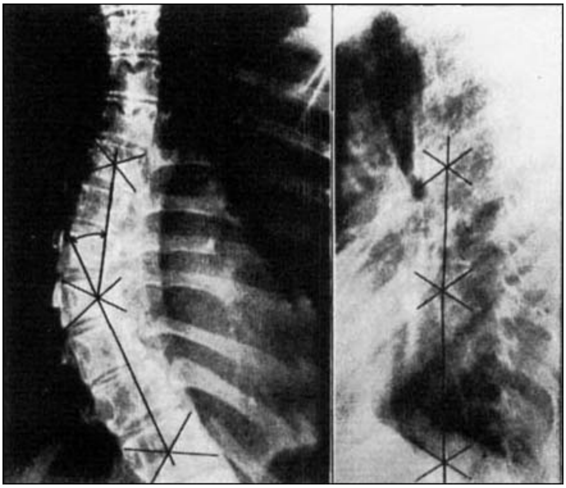


Figure 7. Idiopathic scoliosis as represented by "the direct method". Right.—The scoliosis is seen as a straight line. Left.—Plane perpendicular to that of the right figure, the scoliosis angle then being projected to give its maximum value (33°).

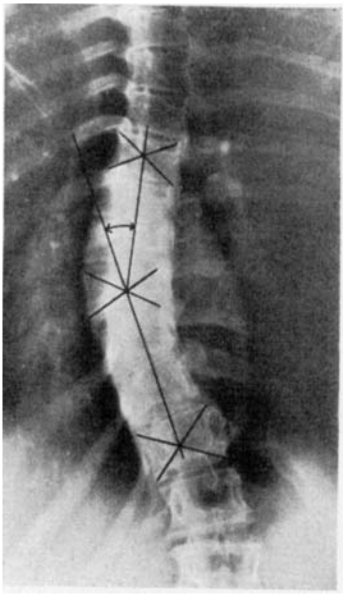
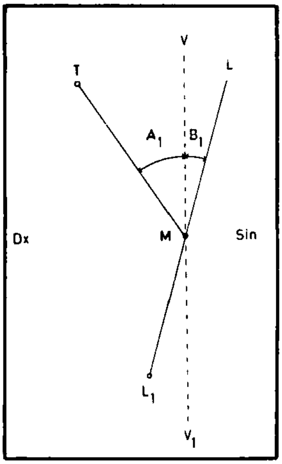


Figure 8. As in Figure 7, but with the scoliosis depicted on a conventional frontal film. The scoliosis angle is then 27° (—22 per cent).

To obtain a more accurate estimate of the way, and the degree to which, the scoliosis is affected by these measures, a new radiologic technique has been evolved by which it is possible to measure the maximum scoliosis angle and the plane of this angle in relation to a vertical plane through the two iliac spines.



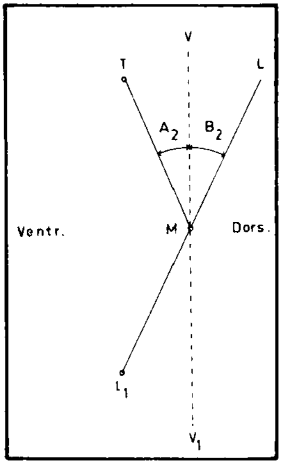


Figure 9. Diagram showing measurement of scoliosis angle by the mathematical method. Left.—Film in the same plane as the iliac spines. Right.—Film perpendicular to the former. To calculate the maximum angle the scoliosis angle TML is divided into the components A and B on each side of a vertical line (VV_1).

METHOD

Two alternative methods were evolved.

The Direct Method

The patient is examined erect by fluoroscopy (oblique lateral projection) and rotated so that the scoliosis disappears and the spine is projected straight and *vertical*. The maximum scoliosis angle is then obtained with projection at right angles to the former, and with the patient's position unchanged.

It is then also possible to measure directly the angle between this plane and a vertical plane containing the two spines. Accurate apparatus for measuring this angle is required.

The Mathematical Method

From the scoliosis angles measured on two perpendicular projections of the spine (arbitrary planes) it is possible by applying the principles of solid geometry to calculate (*i*) the maximum scoliosis angle and (*ii*) the angle between the plane containing the maximum angle and any of the planes of the projections. It is convenient to take one of the planes as that passing through the iliac spines. The solid geometry technique has been developed and applied to radiology by *Edholm* (2, 3). By means of a stereo instrument (designed by him and manufactured by Kifa, Stockholm) it is quite a simple matter to determine angles without the need to resort to the otherwise inevitable mathematical calculations.

An advantage of this method is that the influence of any inclination of the spine to the vertical, or any adjustment above or below the maximum curvature, is

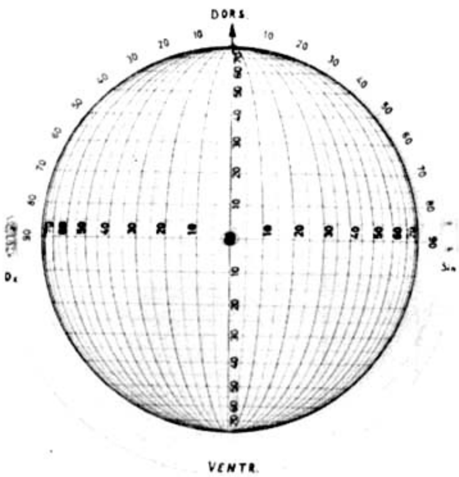


Figure 10. Edholm's stereo instrument. Dx, Sin, Ventral and Dorsal are marked.

automatically corrected for and there is no need to seek the position in which the scoliosis curve is projected as a straight line.

MEASURMENT OF ANGLES

A complete account of the theory underlying the measurement of angles in radiologic examinations is provided in *Edholm's* monograph (2); it will suffice here to outline the principles for the measurement of scoliosis angles. Figure 4 depicts a steel wire bent through a right angle. If the ends of the arms of the angle are held one vertically above the other, the scoliosis angle will be seen to *decrease* as the object is rotated about an axis passing through the two ends (B). The maximum angle (90°) is obtained when the film is perpendicular to the plane containing the arms of the angle (A). On rotation through 90° from this position (C) the wire is seen as a straight line (the scoliosis angle is zero).

In Figure 5 the same wire is seen when no rotation is performed but the ends of the arms of the angle are inclined to the vertical. An inclination perpendicular to the direction of projection (to the sides) does not affect the size of the angle, but an inclination in the direction of the central ray (forwards or backwards) results in a gradual *increase* in the angle.

Figure 6 shows the effect of altering the direction of the central ray above or below the actual apex of the angle. The rotation is the same throughout and there is no inclination in the vertical plane. This produces an *increase* in the scoliosis angle in both directions.

When the direct method is used it is necessary to eliminate these errors through controlled changes in position of the patient and the X-ray tube, but with the mathematical method the error in setting is corrected automatically in calculation of the angle.

PRACTICAL PROCEDURE

We use a focus-to-film distance of 140 cm and the patient is required to hold his arms above his head with the elbows bent. Vertical cassettes with grids are used in both projections.

When the direct method is used only one accurate setting is required as a rule, any correction of the forward—backward inclination of the back being effected by fluoroscopy. In the projection that is perpendicular to the plane for which the scoliosis curve is reproduced as a straight line and *vertical,* the maximum or "true" scoliosis angle is then obtained directly (Figure 7). In a conventional frontal film (Figure 8) the scoliosis angle will in this case be 7° smaller, and it is difficult to reproduce this projection in repeated exposures. In the case of smaller changes of this "frontal scoliosis angle" one therefore never knows for certain whether the compared films are taken identically as regards rotation.

When the mathematical method is used the actual X-ray examination is simpler to perform. Only 2 perpendicular projections are obtained, one of which is taken parallel to the two iliac spines. The lower edge of both X-ray films shall be horizontal. The central ray should pass through the middle vertebra in the scoliosis curvature. The only difficulty is then to calculate the required angles.

Figure 9 shows a scoliosis angle drawn with two perpendicular projections. The image on the left is in the same plane as the two spines (almost a frontal film), and that on the right is perpendicular to the former (practically a lateral film). In both projections the line V–V_1 corressponds to the perpendicular through the middle vertebra (M).

To calculate the maximum scoliosis angle the scoliosis angles in the two projections must be divided into two, one on each side of the vertical, here designated A_1, A_2, B_1 and B_2. These are oriented in different

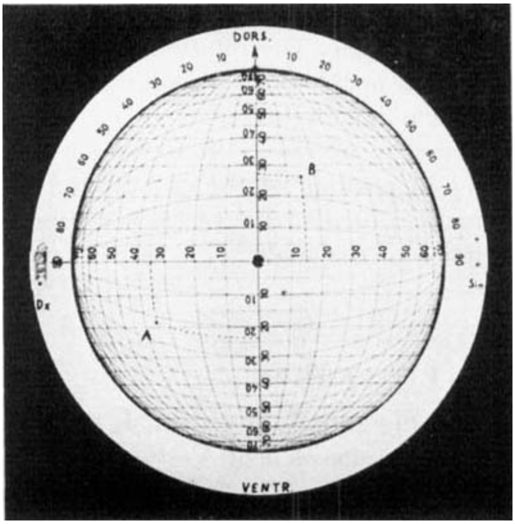


Figure 11. Edholm's stereo instrument. The coordinates for the maximum scoliosis angle have been entered with the guidance of the two values for A and B.

directions, A_1 to the right (Dx) and A_2 ventrally, and B_1 and B_2 to the left (Sin) and dorsally, respectively.

If the angles are measured on the films in question the following values are obtained:

Component angles	Scoliosis angle in the respective projections
A_1 = 35° dx A_2 = 23° ventral	58° in the frontal film
B_1 = 15° sin B_2 = 27° dorsal	42° in the lateral film

From these values the required angles can then be obtained with *Edholm's* stereo instrument.

This instrument is shown in figure 10, and the 4 directions dx, sin, dorsal and ventral are drawn in on the instrument. In the following calculation the top transparent disk is provided for marking with a pencil and the middle disk is rotated 90° with respect to the bottom one.

Figure 11 shows how the angles are drawn in on the instrument as in a coordinate system. A_1 and B_1 are set off on the meridians of the middle disk and A_2 and B_2 along the meridians of the bottom one. The value of A_1, which has the direction "Dx", is set off in the direction "Dx" on the instrument, and A_2, which has the direction "Ventral", downwards. The intersection of the coordinates gives the point A. In the same

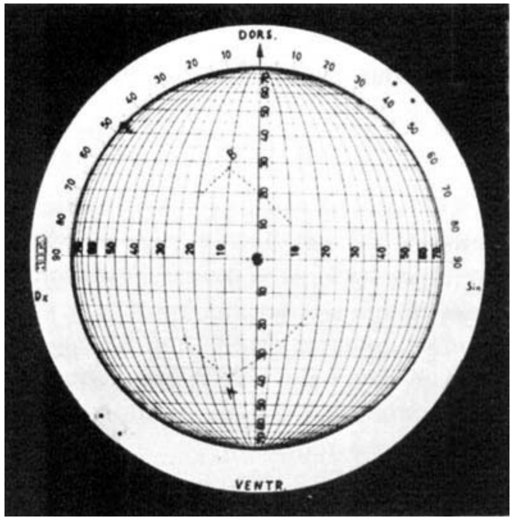


Figure 12. Edholm's stereo instrument. The points A and B on the top disk have been rotated so as to lie on the same "meridian" of the bottom scale. The maximum scoliosis angle can then be read off on the vertical scale in the bottom disk. The rotation of the plane containing the maximum scoliosis angle is indicated by the arrow.

way the point B is entered. To obtain the maximum angles A and B the top disk on which the points are marked is rotated so that the points lie on the same "meridian" of the bottom scale (Figure 12).

On the vertical bottom scale it is then possible to read off these maximum angles (here 28° and 38°). The maximum scoliosis angle is thus 66° (28° + 38°).To reach this position it is necessary to rotate the top disc 47° counter clockwise, and this angle (47°) corresponds to the plane of the maximum angle in relation to the "sagittal" plane (a plane perpendicular to that through the two iliac spines).

For a full account of the stereo instrument and the underlying mathematical theory the reader is referred to *Edholm's* paper. By means of the instructions given here it is possible to obtain the required angles without understanding the underlying theory.

In the cases in which the direct and mathematical methods were compared they showed close agreement, and it would seem that either of them provides more accurate, complete and reproducible information on the deformation in scoliosis than the conventional procedures.

SUMMARY

The authors have evolved two X-ray methods by means of which it is possible to determine in different ways the maximum scoliosis angle and the angle between a frontal plane through the iliac spines and the plane containing the maximum angle. This technique enables a high

level of reproducibility to be obtained in the determination of the angles on different occasions. This is difficult with the usual technique, where frontal films are not defined and therefore not reproducible.

RESUME

Les auteurs ont développé deux méthodes radiologiques au moyen desquelles il est possible de déterminer de différentes manières l'angle maximum de la scoliose et l'angle entre un plan frontal à travers les épines iliaques et le plan contenant l'angle maximum. Cette technique permet dans la détermination des angles à différentes occasions d'arriver à un degré élevé de reproduction, ce qui est difficile avec la technique ordinaire, les films frontaux n'étant pas définis et par conséquent impossibles à reproduire.

ZUSAMMENFASSUNG

Die Verfasser haben zwei Röntgenmethoden entwickelt mittels derer es möglich ist in verschiedener Weise den maximalen Skoliosewinkel und den Winkel zwischen einer Frontalebene und einer Ebene im maximalen Winkel zu bestimmen. Diese Technik ermöglicht es ein hohes Niveau von Reproduktionsfähigkeit bei der Bestimmung von Winkeln bei verschiedenen Gelegenheiten zu erhalten. Dies ist schwierig mit der gewöhnlichen Technik bei der Frontalfilme nicht genau bestimmt und daher nicht reproduzierbar sind.

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