

Department of Orthopaedic Surgery (Head: T. Hiertonn, M.D.),
and the Department of Diagnostic Radiology (Former Head: F. Knutsson, M.D.),
University Hospital, Uppsala, Sweden.

EVALUATION OF THE RELIABILITY OF RADIOLOGICAL METHODS FOR REGISTRATION OF SCOLIOSIS

J. A. SEVASTIKOGLU & E. BERGQUIST

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Every orthopaedic surgeon dealing with scoliotic children faces the problem of estimating increases of the spinal curvatures in his patients. Accurate records, including photographs of the patient, measurements of the total body height and the length of the trunk, do not permit evaluation of minor progress of the spinal deformity, which might be of importance for either prognostic or therapeutic reasons. In such cases the radiologist is called to give the desired information by numerical measurements of the spinal curves on X-rays.

There are two main methods commonly used for measurement of the scoliotic angulation of the spine on X-ray films. The first method, described by Ferguson (1945) and called by Lusskin (1962) "the middle of curve" method, is based on measurements of the angle formed by two lines, one drawn through the geometrical centres of the apical vertebra and the top vertebra of the curve and one through the centres of the apical vertebra and the lowest vertebra of the curve. The second method, described first by Lippman (1935) and popularized later by Cobb (1948), has been called "the end of curve" method by Lusskin. This method is based on measurement of the angle formed by the intersection of the perpendiculars of one line drawn through the superior surface of the top vertebra and one drawn through the inferior surface of the lowest vertebra of the scoliotic curve. Measurements performed by either of these methods from time to time are considered to give reliable information regarding the development of the spinal deformity. In many cases, however, it is doubtful whether minor changes recorded by measurements on the X-ray films of consecutive examinations of the same patient are significant and the

question arises consequently as to the margins of error of these methods. It is commonly said that minor differences of comparative numerical evaluations on X-ray films can be due to errors of the projection, depending, among other things, on changes of the position of the X-rayed object or on centring variations of the tube between two examinations. In such cases the reliability of these estimations is unknown.

The present study has been undertaken by the authors in order to evaluate the reliability of the commonly used radiological methods for registration of scoliosis.

MATERIAL AND METHOD

The head, the spine, and the pelvis of a scoliotic skeleton were assembled and fixed by help of a plexiglass rod passed through the spinal canal and strips of scotch tape. In this way good stability of the spine was achieved and the specimen was then immobilized on a plexiglass plate by strips of scotch tape. The specimen could be moved and rotated at will without interfering with the scoliotic angulation itself. The convexity of the scoliosis was to the right. The spine was X-rayed several times by moving the tube or rotating the specimen in various directions and to various degrees for each exposure as is demonstrated in Table 1. After loosening the spine from the plexiglass plate, it was re-immobilized in the same way as above and new exposures were taken with the same variations of rotation of the specimen and movements of the tube. The distance between the tube and the film was always 150 cm.

The scoliotic angulation was measured on each X-ray film by help of a goniometer and according to both Ferguson's and Cobb's method. Measurements were made by each author separately and the mean value of the two estimations $\frac{(A+B)}{2}$ was used.

The combination of the centring of the tube and the degree of rotation during the various exposures of the two specimens as well as the results of the measurements are demonstrated in the following table.

RESULTS AND DISCUSSION

The measurements performed under the described conditions indicate that regardless of the method used for the numerical evaluation of a scoliotic angulation on X-ray films, minor deviations of the values occur by rotation of the spine or by movements of the tube, although the scoliotic deformity remains unchanged. Thus, as is shown in Table 1, the absolute differences in measurements between the control and the examined exposures had a mean value $1.15 \pm 0.98^\circ$ for the Ferguson and $2.06 \pm 1.09^\circ$ for the Cobb method in the first specimen and

Table 1. Material

Exposure no.	Rotation of the spine	Centring of the X-ray tube	Speci-		
			F		
			$\frac{A+B}{2}$	d°	% d
Control	Neutral	On the spinal process of the apical vertebra	53°	—	—
1	5° at right	On the spinal process of the apical vertebra	54°	+1.0	1.88
2	10° at right	On the spinal process of the apical vertebra	56.5°	+3.5	6.60
3	10° at left	On the spinal process of the apical vertebra	48°	—5.0	9.43
4	5° at left	On the spinal process of the apical vertebra	52.5°	—0.5	0.94
5	Neutral	5 cm below the sp. proc. of the ap. vert.	52.5°	—0.5	0.94
6	Neutral	5 cm above the sp. proc. of the ap. vert.	50.5°	—2.5	4.71
7	Neutral	5 cm at right of the sp. proc. of the ap. vert.	55.0°	+2.0	3.77
8	Neutral	5 cm at left of the sp. proc. of the ap. vert.	51.0°	—2.0	3.77
9	10° at right	5 cm below the sp. proc. of the ap. vert.	52.5°	—0.5	0.94
10	10° at right	5 cm above the sp. proc. of the ap. vert.	50.5°	—2.5	4.71
11	10° at right	5 cm at right of the sp. proc. of the ap. vert.	50.0°	—3.0	5.66
12	10° at right	5 cm at left of the sp. proc. of the ap. vert.	51.0°	—2.0	3.77
13	—10° at left	5 cm at left of the sp. proc. of the ap. vert.	58.0°	+5.0	9.43
14	10° at left	5 cm at right of the sp. proc. of the ap. vert.	60.0°	+7.0	13.20
15	10° at left	5 cm below the sp. proc. of the ap. vert.	59.5°	+6.5	12.62
16	10° at left	5 cm above the sp. proc. of the ap. vert.	60.5°	+7.5	14.15
$\bar{d}$			—	1.15	6.04
$s\bar{y}$			—	± 0.98	± 1.11

$\frac{A+B}{2}$ = Mean value of the individual measurements of the two authors.

F = Measurement by Ferguson's method.

C = Measurement by Cobb's method.

$0.60 \pm 0.21^\circ$ and $0.98 \pm 0.31^\circ$ respectively for the second. The percentage differences were $6.04 \pm 1.11^\circ$ and $6.40 \pm 1.05^\circ$ in the first specimen and $1.28 \pm 0.43^\circ$ and $1.82 \pm 0.59^\circ$ in the second specimen.

The differences between the measurements performed by each of the authors (A-B) ranged between -5° and $+3^\circ$ for the Ferguson method and between -11° and $+9^\circ$ for the Cobb. The mean difference between all measurements performed by each author, i.e. the error of the measurements, was for the Ferguson method $1.82 \pm 0.21^\circ$ and for the Cobb method $3.12 \pm 0.48^\circ$.

Cobb's method gave consistently higher values than Ferguson's method in all exposures; the difference ranged between 4° and 16° , mean value $7.84 \pm 0.51^\circ$, i.e. $8.47 \pm 0.73^\circ$ in the first and $7.20 \pm 0.70^\circ$ in the second specimen.

and results.

men I				Specimen II							
C			C-F	F			C			C-F	
$\frac{A+B}{2}$	d°	% d		$\frac{A+B}{2}$	d°	% d	$\frac{A+B}{2}$	d°	% d		
60.5°	—	—	6.5°	59.5°	—	—	67.5°	—	—	8.0°	
61.0°	+0.5	0.82	7.0°	58.5°	—1.0	1.68	66.5°	—1.0	1.48	8.0°	
61.5°	+1.0	1.65	5.0°	58.5°	—1.0	1.68	66.5°	—1.0	1.48	8.0°	
54.5°	—6.0	9.91	6.5°	59.75°	+0.25	0.42	66.25°	—1.25	1.85	7.5°	
59.5°	—1.0	1.65	7.0°	60.00°	+0.5	0.84	68.5°	+1.0	1.48	8.5°	
61.5°	+1.0	1.65	9.0°	58.5°	—1.0	1.68	66.0°	—1.5	2.22	7.5°	
66.5°	+6.0	9.91	16.0°	59.5°	0.0	0.00	67.0°	+0.5	0.74	7.5°	
63.0°	+2.5	4.13	8.0°	59.0°	—0.5	0.84	66.5°	—1.0	1.48	7.5°	
66.5°	+6.0	9.91	15.5°	58.0°	—1.5	2.52	66.5°	—1.0	1.48	8.5°	
62.5°	+2.5	4.13	10.5°	57.0°	—2.5	4.20	65.0°	—2.5	3.70	8.0°	
58.0°	—2.5	4.13	7.5°	58.5°	—1.0	1.68	65.5°	—2.0	2.96	7.0°	
58.5°	—2.0	3.30	8.5°	58.0°	—1.5	2.52	67.0°	—0.5	0.74	9.0°	
56.5°	—3.5	5.78	5.5°	59.5°	0.0	0.00	65.5°	—2.0	2.96	6.0°	
66.0°	+5.5	9.09	8.0	59.5°	0.0	0.00	63.5°	—4.0	5.92	4.0°	
67.5°	+7.0	11.59	7.5	58.5°	—1.0	1.68	67.5°	0.0	0.00	9.0°	
67.5°	+7.0	11.57	8.0	59.5°	0.0	0.00	67.75°	+0.25	0.37	8.25°	
68.5°	+8.0	13.22	8.0	60.0	+0.5	0.84	67.75°	+0.25	0.37	8.25°	
—	2.06	6.40	8.47	—	0.60	1.28	—	0.98	1.82	7.20	
—	±1.09	±1.05	±0.73	—	±0.21	±0.43	—	±0.31	±0.59	±0.70	

d° = Difference in degrees from neutral.

% d = Percentage difference from neutral.

$\bar{x}$ = Mean difference.

s $\bar{y}$ = Standard deviation of the mean.

Generally speaking the registered differences of the performed measurements were somewhat higher for the first than for the second specimen. The absolute and the percentage differences between the control and the 16 exposures in each specimen were almost of the same degree of magnitude for both methods of measurement.

The reported results indicate further that rotation of the spine alone, by 5° to 10° in either direction without movement of the tube (exposures 1–4) and movement of the tube by 5 cm in either direction without rotation of the spine (exposures 5–8) as well as combined rotation of the spine and movement of the tube (exposures 9–12 and 13–16) results in differences in the measurements of the scoliotic deformity, which, however, hardly surpass the margins of error of

the measurements, at least when the values obtained from both specimens are considered together.

George & Rippstein (1961) performed measurements of the spinal deformity by Ferguson's and Cobb's methods on the X-ray films of 25 scoliotic patients with a total of 27 curves before and after correction of the scoliosis. The mean difference between measurements performed by Cobb's and Ferguson's method was 13.29° before correction. The authors found further that Cobb's method showed a consistently higher percentage of correction than Ferguson's method did. The mean percentage difference between the two methods was 16 per cent. The authors maintained that the margin of error in the Ferguson method is minimum and that by this method exaggeration of the curve before correction and exaggeration of the amount of correction after treatment are completely excluded.

Lusskin (1962), by comparing Ferguson's and Cobb's method on 11 scoliotic patients, found a mean difference of 14.6° between the results obtained by each of the methods.

The results of the present study are in agreement with the earlier observations as to the larger values obtained by measuring scoliotic curves on X-ray films by Cobb's than by Ferguson's method. However, appreciable differences, neither in absolute nor in percentage values, do not exist between measurements performed by the two methods.

SUMMARY

An evaluation of the results obtained by consecutive measurements on X-ray films of an unchanged scoliotic deformity of the spine by Ferguson's and Cobb's methods has been done.

It was found that minor rotations of the spine as well as movements of the X-ray tube or a combination of both do not influence the results of reading in an appreciable degree whether Ferguson's or Cobb's method is used. The margins of error of the numerical measurements of the scoliotic curve on X-ray films are, however, relatively small, i.e. $1.82 \pm 0.21^\circ$ for Ferguson's and $3.12 \pm 0.48^\circ$ for Cobb's method.

Measurements performed by Cobb's method gave consistently higher values than those performed by Ferguson's method: the differences ranging between 4° and 16° , mean values $7.84 \pm 0.51^\circ$. There were, however, no appreciable differences between measurements performed by the two methods.

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