Roentgenographic Measurement of Lumbar Intervertebral Disc Height

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The influences of differences in both intervertebral motion segment orientations and in reader judgments on measurements of the apparent intervertebral disc heights in lateral roentgenographs of the lumbar spine were examined. Forty-nine roentgenographs were obtained of nine discs that were tilted laterally up to ± 10 degrees, and rotated longitudinally up to ± 20 degrees. Three orthopaedic surgeons and three radiologists measured disc heights from five of these roentgenographs, all using the same measurement method. The differences in apparent height that resulted from the orientation changes and differences in judgments among the six readers were considerable, usually of the order of one half of the nominal disc height. The results show that, while roentgenographic measurements can be used to estimate disc height, accurate measurements cannot readily be made from routine roentgenographs, and the interpretation should always be cautious. [Key words: lumbar spine, intervertebral disc height, roentgenography, measurement]

INTERVERTEBRAL disc height is frequently estimated qualitatively and sometimes evaluated quantitatively from roentgenographs of the lumbar spine. Data on disc height are used to evaluate degenerative changes in the disc, and also sometimes to evaluate the effect of traction and other treatment methods, to study intervertebral disc motion, and in various research applications.

Pope et al[4] found that when different measurement methods were used even in the same roentgenographs to evaluate disc height, different results were produced. They also found that differences in film-specimen-focus distances led to different results. There is reason to suspect that even when a single measurement method is used and film-specimen-focus distances are kept constant, the accuracy of roentgenographic measurements of height might still be questionable. Benson, Schultz, and DeWald,[2] for example, found that roentgenographic measurements of vertebral longitudinal axis rotation can be quite inaccurate, and depend markedly on vertebral orientation with respect to the central x-ray beam. The curves in the lumbar spine differ from patient to patient. They also differ with different positionings of a given patient. Therefore, if roentgenographically apparent disc height depends on vertebral orientation to any significant degree, considerable caution will be needed in the interpretation of the apparent height measurements made from clinical roentgenographs. The purposes of the present study were to investigate the influence of vertebral orientation on the measurement of roentgenographically apparent disc height, and to see how much apparent disc height measurements are influenced by the judgment of the roentgenograph reader.

MATERIALS AND METHODS

Three fresh cadaver lumbar spine segments were removed *en bloc* at routine autopsies from male subjects aged 33, 35, and 68 years. The subjects had had no history of injuries to the spine, and died from pathologies not known to influence bone or connective tissue. A to-

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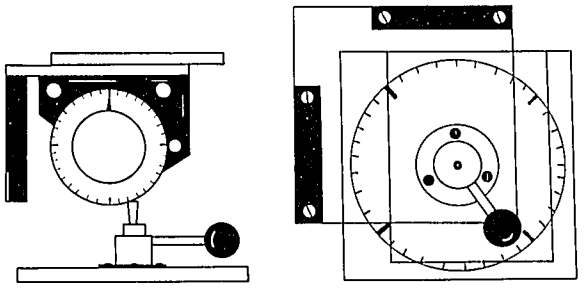

Fig 1. Device used for tilting and rotating the specimens.

tal of nine intervertebral discs from these segments were studied. The youngest spine segment included intact L2, L3, and L4 discs; the intermediate segment, L2 and L3 discs; and the oldest segment L1 through L4 discs.

The specimens were stored in a freezer, and prepared and tested at room temperature with 100% relative humidity. After the present series of tests, these spines were used for the mechanical property tests reported by Andersson and Schultz.[1] At the completion of those tests four of the nine discs were sectioned. Macroscopic degeneration grades were determined for the four discs, including two from the oldest spine. These were found to vary between 1 and 3, according to the method used by Nachemson.[3] Grade 1 indicates no visible degeneration in a sectioned disc. Grade 3 indicates visible degeneration in both nucleus and annulus. None of the nine discs was degenerated enough for its degeneration to be evident from the roentgenograph.

The spine segments were mounted on the platform of a device designed to provide measured amounts of platform tilting from the horizontal, and of vertical axis rotation (Figure 1). Mounting was such that the mean longitudinal axis of the segment was initially vertical. Lateral radiographs were taken of the segments with a 100-cm film-focus distance, and an 18-cm distance from the midsagittal plane of the segment to the film, corresponding to conditions of routine clinical roentgenography. The roentgen beam was centered on the middle of the segment.

Serial lateral roentgenograms were made of each of the three segments, using the platform adjustment devices to orient the segments with different amounts of lateral tilt and longitudinal axis rotation. Lateral tilt toward the roentgen tube was assigned a positive sign, and lateral tilt toward the film a negative sign. Similarly, longitudinal axis rotation of the anterior aspects of the specimens toward the roentgen tube was assigned a positive sign, and rotation toward the film a negative sign (Figure 2).

Fifteen roentgenographs were taken of each of the oldest and youngest spines: in all combinations of −10, 0, and +10 degrees of lateral tilt, and −20, −10, 0, +10, and +20 degrees of axial rotation. Nineteen roentgenographs were taken of the intermediate-age specimen: 15 in all combinations of −5, 0, and +5 degrees of tilt, and −10, −5, 0, +5, and +10 degrees of rotation, and four with 10-degree tilts or 20-degree rotations.

Multiple copies incorporating two discs were made of five of the roentgenographs of the intermediate-age specimen. These five films showed the specimen with different amounts of lateral tilt, but all were taken with zero longitudinal axis rotation. The copies were presented in random order to three orthopedic surgeons and to three radiologists for read-out. All knew the general purpose of the study, but none knew under what conditions, nor of what specimens the roentgenographs had been taken. They were asked to mark the four "corners" of the vertebral bodies on the roentgenograms for the purpose of quantitatively determining anterior and posterior disc heights. The distances between the marks were then measured by an independent technician to the nearest 0.5 mm using a machinist's scale. These measurements yield the anterior and posterior disc heights. The remaining roentgen films were marked in the same way by one of the authors, and measured by the technician. Disc height was calculated as the mean of the anterior and the posterior heights. No corrections for roentgenographic magnifications were made.

RESULTS

Interorientation Differences

The nominal disc heights (the mean of all height measurements of a given disc) of the nine specimens, measured by the single reader, and uncorrected for magnification, ranged from 7.5 to 14.3 mm. The differences between the largest and the smallest apparent mean heights over the 15 or 19 orientations studied ranged from 1.2 to 8.6 mm, or from 16 to 69% of the nominal disc height (Table 1). For all but two of the nine discs, the difference exceeded 40% of the nominal disc heights. Lateral tilting of the specimen usually changed the apparent height more than longitudinal axis rotation (Figures 3 and 4 show sample results), but either orientation change could be responsible for significant changes in apparent mean disc heights. There were no other clear-cut patterns to the relationship be-

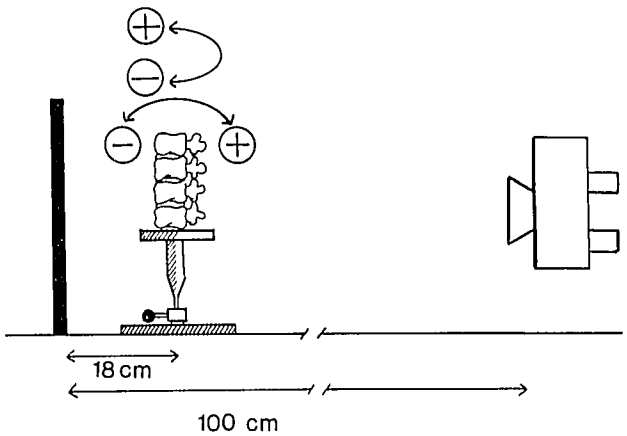

Fig 2. Sign conventions for longitudinal axis rotation and lateral tilt. The longitudinal axis rotation is considered positive when the anterior edge of the vertebral body rotates toward the x-ray source. The lateral tilt is considered positive when the superior portions of the segment tilt toward the x-ray source.

Table 1. Differences in Apparent Disc Height Measurements (mm) Among Orientations*

	Nominal mean height	Largest apparent mean height	Corresponding orientation,† (degrees)	Smallest apparent mean height	Corresponding orientation,† (degrees)	Difference	Difference (percent of nominal height)
33-year-old male							
L2	13.2	16.0	(0, 20)	10.2	(10, 0)	5.8	44
L3	12.8	14.9	(0, 0)	9.2	(10, 0) (10,−10)	5.7	45
L4	12.5	15.6	(−10, 20)	7.0	(10, 0)	8.6	69
35-year-old male							
L2	14.3	16.2	(0, 20)	11.9	(10, 0)	4.3	30
L3	13.8	16.5	(5, 10)	10.0	(10, 0)	6.5	47
68-year-old male							
L1	7.5	8.2	(0, 10)	7.0	(10, 20) (10,−10)	1.2	16
L2	9.6	11.8	(0, 20)	7.0	(−10, 0)	4.8	50
L3	11.2	13.8	(10, 10)	6.6	(−10, 0)	7.2	64
L4	12.4	15.4	(10, 0)	9.8	(−10, 0)	5.6	45

* All nine discs, radiographed with lateral tilts up to 10 degrees and longitudinal axis rotations up to 20 degrees. Readouts by a single reader.
† Lateral tilt, longitudinal rotation.

tween orientation changes and apparent height differences.

Interinterpreter Differences

The nominal disc heights of the two discs evaluated by the three radiologists and the three orthopedic surgeons were 11.6 and 10.8 mm. The differences between the largest and the smallest apparent mean heights among the six readers and the five orientations were both 5.5 mm, or approximately 50% of the nominal height (Table 2). The differences in apparent height caused by differences in the five orientations, when judged by a single reader, ranged from 0.5 to 4 mm (Figure 5 shows sample results). For any single orientation, the height differences among the six readers ranged from 1.8 to 5 mm. In other words, for the situations studied, reader judgment and orientation differences seemed equally capable of making a roentgenographic disc height measurement ambiguous.

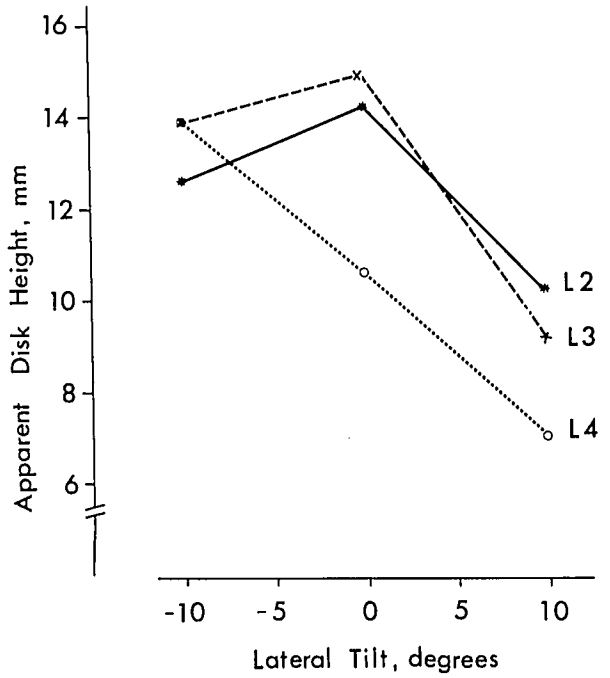

Fig 3. Illustration of the effect of lateral tilt on apparent disc height. Three discs from a 33-year-old male fresh cadaver, at 0 degrees rotation. Measurements by Reader 1.

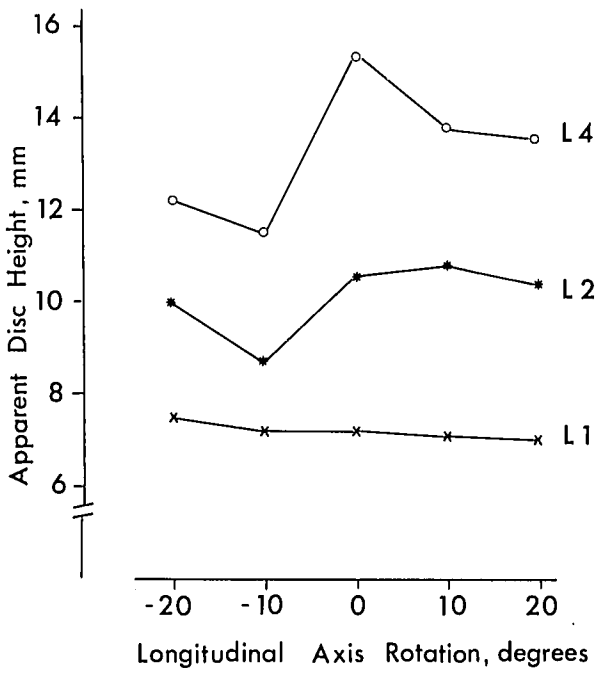

Fig 4. Illustration of the effect of longitudinal axis rotation on apparent disc height. Three discs from a 64-year-old male, at 10 degrees of lateral tilt. Measurements by Reader 1.

Table 2. Differences in Apparent Disc Height Measurements (mm) Among Six Readers*

	L2 disc	L3 disc
Nominal mean height	11.6	10.8
Largest apparent mean height	15.5	14
Corresponding orientation† (degrees)	(5, 0)	(−5, 0)
Smallest apparent mean height	10	8.5
Corresponding orientation† (degrees)	(10, 0)	(10, 0)
Difference	5.5	5.5
Difference (percent of nominal height)	47	51

*Two discs from the 35-year-old male spine, radiographed with 0° longitudinal axis rotation, and lateral tilts of −10°, −5°, 0°, 5°, or 10°.

† Lateral tilt, longitudinal rotation.

DISCUSSION

Because intervertebral discs are not bounded superiorly and inferiorly by parallel planes, there is no single, exact disc height. A mean disc height might be defined with fair accuracy as, for example, total disc volume divided by midtransverse-plane, cross-sectional area, but there would still be some room for judgment in defining that area. In any event, a measurement of that kind would be quite difficult to obtain. In practical terms, any method of determining disc height will involve some ambiguity, and the clinically relevant question seems to be, how much?

Pope et al[4] in their study noted differences in measurement values when different measurement methods were used and the film-specimen-focus distances varied. The results of this study show that, even when those criteria are met, an ambiguity of 50% in the height measurement often still exists. There are two main sources of this ambiguity: differences in specimen orientation with respect to the central roentgen beam, and differences among readers of the roentgenographs. Differences because of specimen orientation occur because the x-ray beam is no longer parallel with the plane of the disc, so that a different image of the disc is produced. Differences among readers occur because the images of the vertebral bodies do not have well-defined corners, and considerable judgment must be used in selecting the four corner points. Other methods of measuring disc height have been found to be even less reliable.[4]

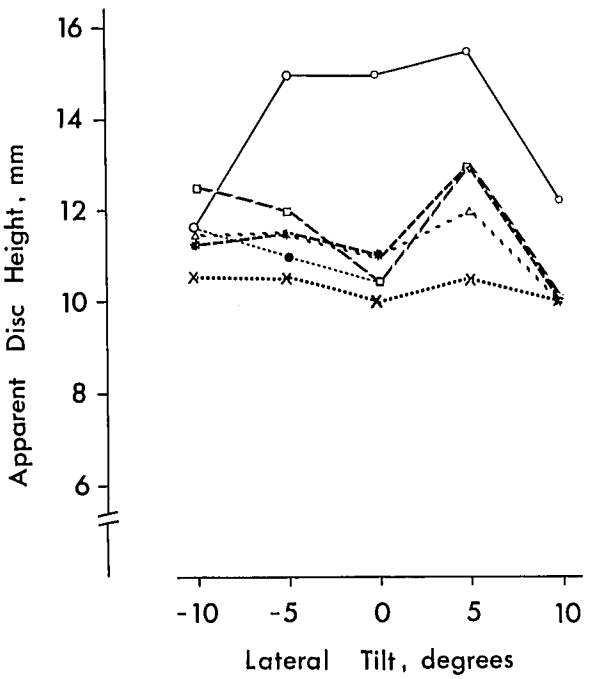

Fig 5. Illustration of interinterpreter differences in measuring the effect of lateral tilt on apparent disc height. L2 disc from a 35-year-old male, at 0 degrees of longitudinal axis rotation.

The 100-cm film-focus distance and the 18-cm specimen-to-film distance lead to a calculated roentgenographic magnification factor of 1.22. Longitudinal axis rotation should have almost no effect on this magnification. As for lateral tilt, some effect will occur, but even if the most superior disc in the spine segment was as much as 5 cm from the central roentgen beam, a 20-degree lateral tilt would only change the magnification factor to 1.25 if positive, and to 1.19 if negative. So differences in magnification factor would seem to account for at most a 6% difference in apparent disc height. The observed differences are far in excess of this.

It is clear from visual examination of the roentgenographs taken with the larger amounts of lateral tilt that the central x-ray beam was not parallel with the midtransverse plane of the disc. Most clinicians would recognize this, and be reluctant to make a measurement of disc height from such roentgenographs. Others would try to evaluate anteroposterior roentgenograms and combine the information from both views in their judgment. Our results show that even when the x-ray beam is parallel with the plane of the disc, and the roentgenographs seem to be of a quality adequate for disc height assessment, absolute measurements remain highly questionable. For example, any judgment that a disc space is "narrowed" compared to adjacent disc spaces should be made with great care in light of these results. Absolute measurements may clearly be misleading.

CONCLUSION

Disc height measurements made from lateral roentgenographs of the lumbar spine can vary widely. The effects of even small amounts of lateral tilt or longitudinal axis rotation, or the influences of reader judgment can frequently result in apparent height differences of one half of nominal disc height.

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