Evaluation of Multiplanar Reconstruction in CT Recognition of Lumbar Disk Disease

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Evaluation of Multiplanar Reconstruction in CT Recognition of Lumbar Disk Disease

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Axial computed tomographic (CT) images were compared with sagittal and coronal reformations and myelograms in 60 patients to evaluate the diagnostic usefulness of multiplanar reconstructions for the recognition of lumbar disk disease. The axial CT scans were most sensitive and specific. The sagittal scans were helpful in evaluating the neural foramina, the size of the disk bulge into the spinal canal, especially at L5–S1, and patients with spondylolisthesis. The coronal images were the least informative, although they contributed to the evaluation of lumbar nerve roots. The myelograms and the sagittal images were equally useful in the detection of herniated disk, but axial scans were superior to either. It was concluded that reformatted sagittal and coronal images are not required if all axial images are normal. However, when uncertainty exists or complex anatomy is being evaluated, reformatted images may be helpful, particularly for reassurance.

Computed tomography (CT) is effective in the evaluation of low back pain due to lumbar disk disease [1–4], facet joint disease [5], and spinal stenosis [6], and is now widely used for these problems. The examination technique that has generally been advocated for diagnosis of disk disease includes a recent-generation body scanner, gantry angulation parallel to the disk, 5-mm-thick section collimation, high milliamperage, and a limited number of contiguous scans, at least one of which is through the center of the disk [3], but not necessarily encompassing the entire spinal segment.

Results obtained by this method have been good [1–4]. In general, CT and myelography have been equally efficacious in detecting herniated nucleus pulposus [3, 7]. However, errors in diagnosis may occur with both techniques.

An alternative method of examining the lumbar spine is to obtain multiple contiguous or overlapping axial sections that can then be reformatted by computer into sagittal and coronal planes. This method offers better appreciation of the longitudinal dimension. Caudad or cephalad displacement of disk material may be better demonstrated, helping to distinguish disk herniation from disk bulges. The longitudinal course of some structures, for example, nerve root sheaths, is more readily comprehensible when displayed in reformatted planes. Such multiplanar reconstructions have been helpful in the diagnosis of a variety of conditions including disk disease [8, 9]. An additional advantage that has been claimed for this technique is that the lumbar CT examination can be entirely standardized. No levels or angles need be specifically chosen—potentially saving physician time.

Compared with the more widely used method of scanning, this technique requires a larger number of sections for each disk level. Scanning time and radiation dosage are thereby proportionally increased. The technique with our equipment results in a peak skin dose of 7.3 rad (0.073 Gy). With many currently available scanners, generation of reformatted images requires that scanning be interrupted. A recently available commercial service offers computer reformation of images via telephone lines. This is done after working hours, and does not compromise patient throughput.

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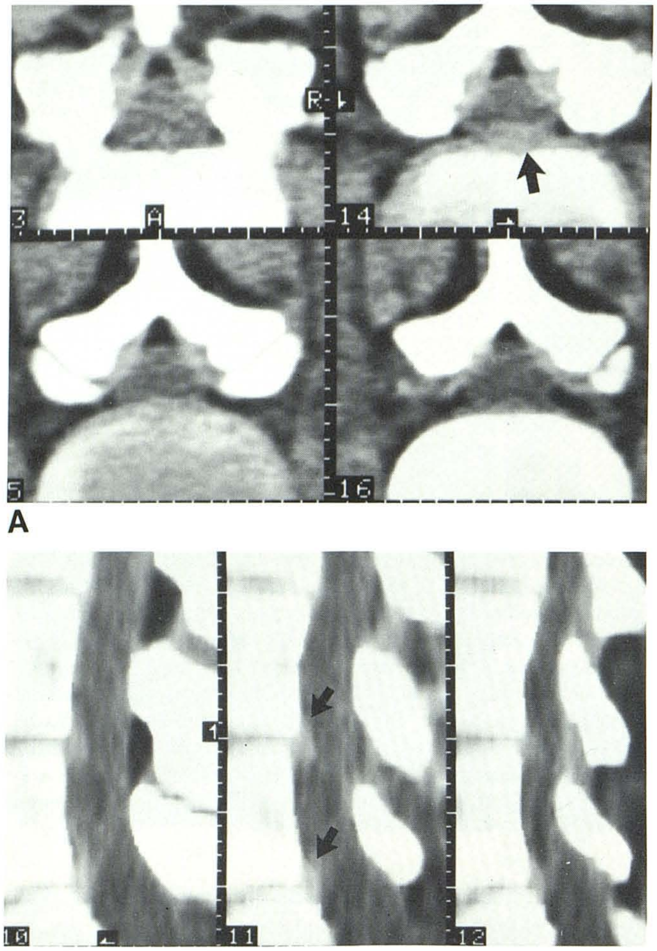


Fig. 1.—Bulging disk. **A**, Concentric disk bulge at L4–L5 seen on axial image (*arrow*) was confirmed on other scans in which total perimeter of disk was seen. **B**, Sagittal reformation confirms this observation and also reveals similar finding at L5–S1 (*arrows*).

We have attempted to evaluate the role of multiplanar reconstructions in the diagnosis of lumbar disk disease. The information gained from the axial sections was compared with the incremental gain from sagittal and coronal reformations. Our primary concern was with the display of anatomic information. Clinical relevance was not directly addressed. Thus, narrowing of a neural foramen, which was demonstrated by sagittal CT images, was regarded as correct information if it was confirmed by myelography or surgery, whether or not the lesion was symptomatic. Positive clinical data were used for corroboration of radiographic findings.

Subjects and Methods

Sixty patients were scanned on a General Electric 8800 scanner. No intrathecal or intravenous contrast material was used. Patients were included in the study if myelography was performed within 3 months of CT, and if there had been no intervening surgical therapy or change in symptoms.

Patients were scanned in the supine position with the gantry vertical. Anteroposterior (AP) and lateral digital radiographs were used for localization. Five millimeter sections were performed every 3 mm from the midportion of the first sacral vertebra to the midportion of L3. A 9.6 sec scanning time with 614 mAs was used. In the average patient, about 28 to 32 sections constituted a complete study. At the end of the workday, raw CT data were transmitted by telephone lines to Multiplanar Diagnostic Imaging (Torrance, CA) for reformatting. Sagittal, coronal, and axial reconstructions were received, photographed by us the next morning, and displayed as life-size images. All scans were reformatted as contiguous 3 mm images. A complete study consisted of about 30 axial, 20 sagittal, and 15 coronal images.

Scans were photographed for bone detail with a 1000 H window width centered at 250 H. Soft-tissue windows were photographed at a 350 H width and a level of 60.

Each scan was reviewed retrospectively by at least three of the authors. Differences in interpretation were resolved by discussion. Although surgical confirmation was available in a few cases, for most the myelogram was the gold standard of truth for lesions within its reach. If a CT finding was beyond the extension of the myelographic contrast column, it was regarded as true if it was clearly positive and not explainable as a technical artifact.

The axial scans were first reviewed independently of all other data. Disk abnormalities were classified as bulges if there was symmetric, concentric extension of the disk beyond the vertebral margin. Herniation was diagnosed when disk extended beyond the bone in a focal and usually unilateral manner. A judgment was made about whether the nerve root images were displaced or obliterated. The neural foramina and lateral recesses were studied for bony encroachment.

Attention was then turned to the sagittal scans. The disks were assessed for symmetry or asymmetry. This was done by comparing the left, midline, and right tomographic images. A judgment was made as to whether the disk protruded at the level of an interspace, above, or below. The disk bulge and the vertical dimension of the adjacent vertebral body were measured. The latter was done to permit comparison to the myelogram by correcting for magnification.

The same procedure was followed for the coronal reformations. In each case, note was made whether the additional reconstructed images confirmed the previously made diagnoses from the axial scans, disputed them, or were noncontributory.

A noncontributory image neither confirmed nor refuted a previous diagnosis. Thus, a myelogram showing a nondeformed thecal sac widely separated from the posterior vertebral margin neither proved nor disproved a disk lesion at the level of interest. We classified coronal reconstructions in this way when they failed to demonstrate a disk bulge or herniation seen on other views. It could be argued that such scans should be categorized as contradictory, but, because the coronal projection is not well suited to disk visualization, we preferred to regard the image as noncontributory.

The myelograms were evaluated by the same stepwise procedure. Disk lesions were classified as bulges or herniations according to the criteria recently summarized by Kieffer et al. [10]. The disk prominence was measured in millimeters from the posterior vertebral border to the displaced opaque column and corrected for magnification by comparing the size of the adjacent vertebral body with the size of the same vertebral body as measured on the CT scan.

Results

Ninety-two abnormal disks were recognized in 60 patients. There were 68 disk bulges recognized on axial CT scans (fig. 1). Of these, 64 were confirmed on sagittal reconstructions,

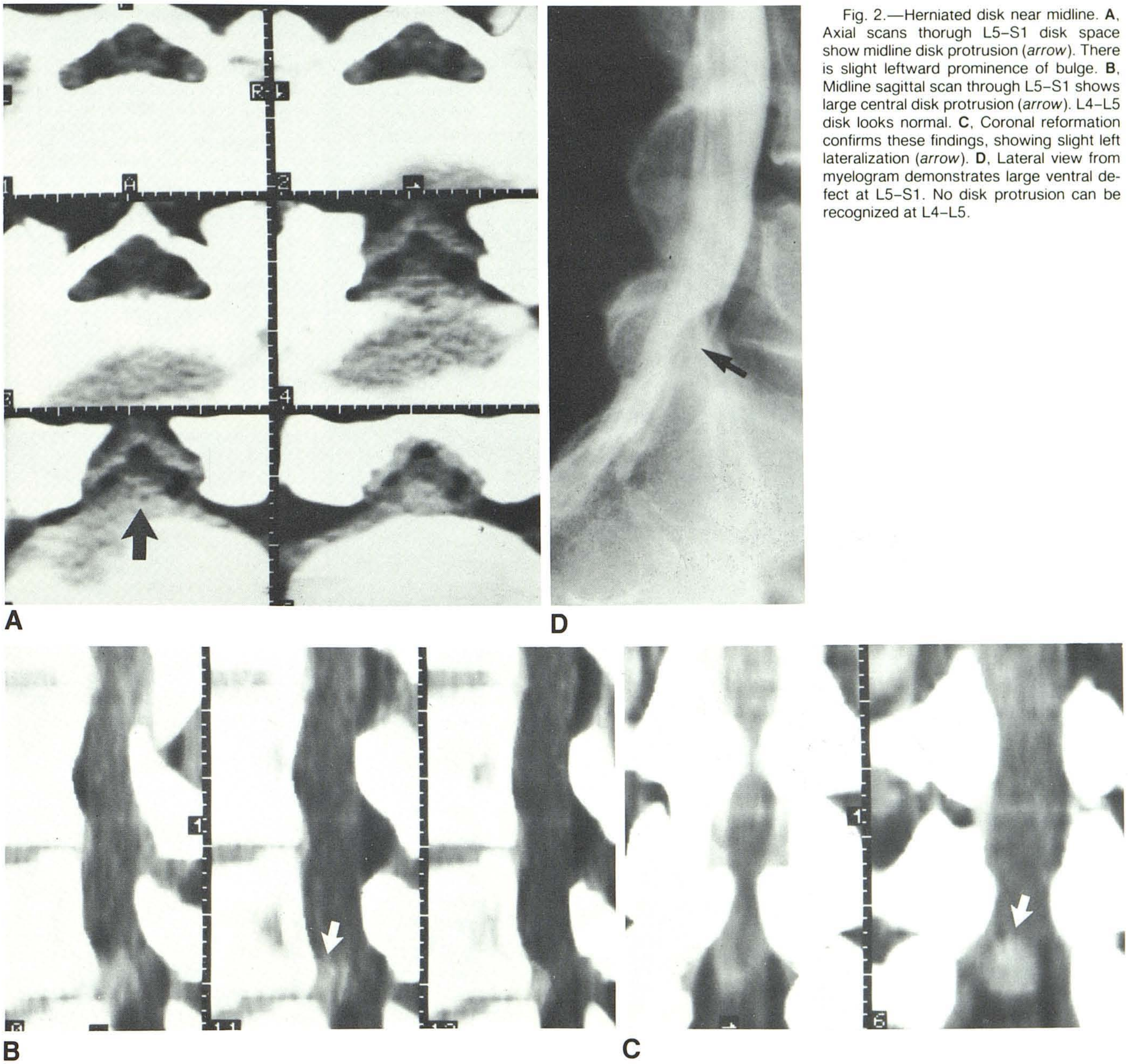
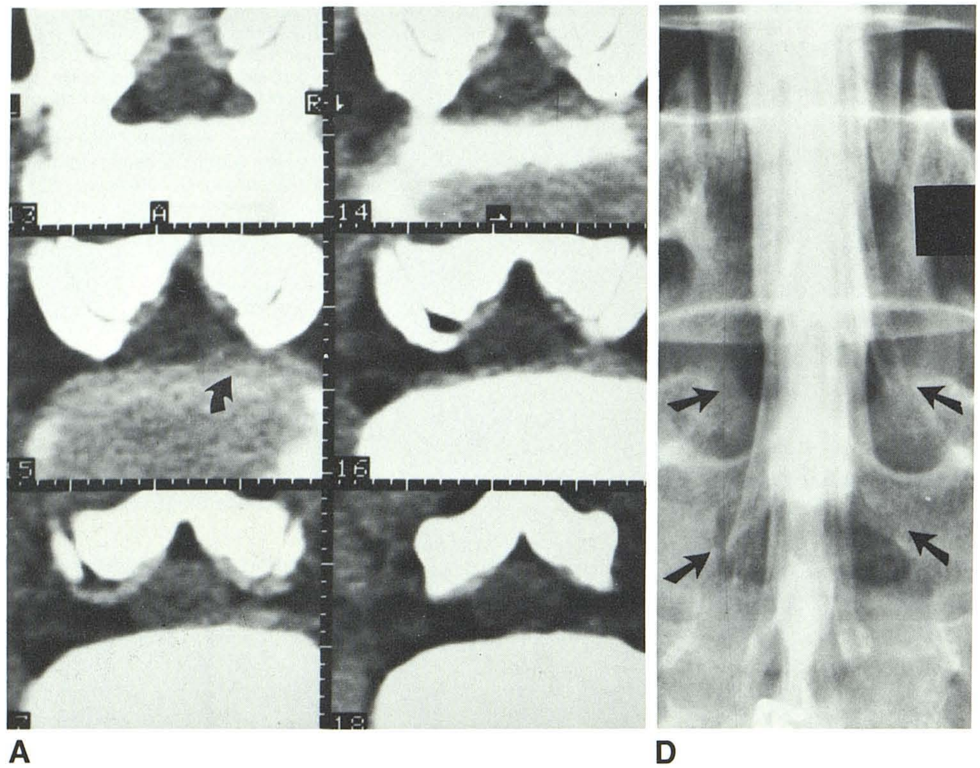


Fig. 2.—Herniated disk near midline. **A**, Axial scans thorugh L5–S1 disk space show midline disk protrusion (*arrow*). There is slight leftward prominence of bulge. **B**, Midline sagittal scan through L5–S1 shows large central disk protrusion (*arrow*). L4–L5 disk looks normal. **C**, Coronal reformation confirms these findings, showing slight left lateralization (*arrow*). **D**, Lateral view from myelogram demonstrates large ventral defect at L5–S1. No disk protrusion can be recognized at L4–L5.

17 were confirmed on coronal reconstructions, and 55 were confirmed by myelograms. In 13 cases the myelogram offered no information because of "insensitivity" at the abnormal level. A myelogram was called insensitive when the anterior epidural space was wider than 3–4 mm.

Of the *bulging disks* recognized on the axial CT scans, only three were disputed by the myelogram or sagittal scans. In one case a herniated disk was diagnosed on the sagittal scan because of apparent caudad displacement of the disk material. Neither the myelogram nor the symptoms corroborated a disk herniation, and the sagittal interpretation was presumed to be a false-positive. Two cases diagnosed as disk bulges on the axial scans appeared to be herniations on myelography because of nerve root displacement. In both cases axial CT showed the nerve root involvement, but indicated that it was due to a large concentric bulge in one case and osteophytic encroachment on a narrow neural foramen in the other. Surgery was performed in the latter case and confirmed the CT diagnosis of nondiskogenic nerve root displacement. There were several small L5–S1 bulges that were seen on sagittal reconstructions and myelography, but not recognized initially on axial sections. Retrospective review of the axial sections confirmed that the findings were present, but had been overlooked. It was not unusual for the disk to appear larger on the axial than on the sagittal image, especially at L5–S1. Findings on myelography were more consistent with



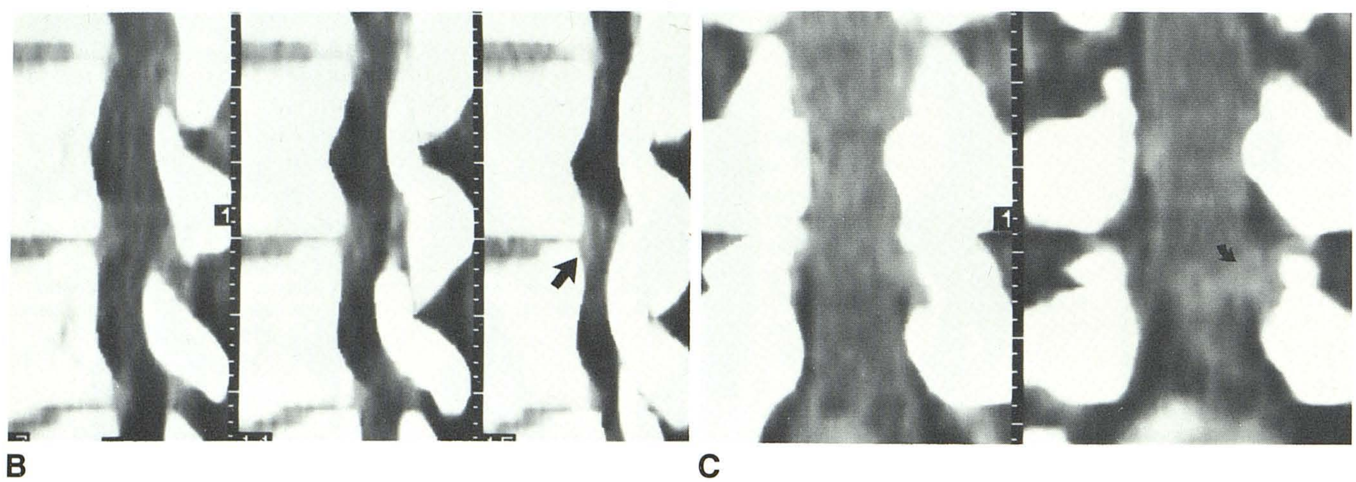


Fig. 3.—Herniated disk, lateral displacement, in same patient as in fig. 2. **A**, L4–L5 disk lesion, markedly lateralized in right neural foramen, is seen on axial scan (*arrow*). **B**, Sagittal reformation demonstrates lesion to right of midline (*arrow*). Disk herniation was not apparent in midline images (fig. 2B). **C**, Coronal reformation shows disk fragments in neural foramen and suggests entrapment of right L5 nerve (*arrow*). **D**, Right L5 nerve sheath fails to fill. (*Arrows* show L5 and S1 nerve sheaths.) This is a nonspecific finding that may accompany either disk bulges or hernias [10]. Surgery confirmed CT diagnosis of disk herniation.

the sagittal images. We believe that the tendency for the axial images to cause overestimation of disk prominence may be partly due to the fact that no effort was made to correct for lumbar lordosis by gantry angulation.

In summary, the axial image detected more disk bulges than the sagittal reformation or the myelogram and substantially more than the coronal image. As judged by the clinical and surgical information available, it was also the most specific image for the distinction beween bulge and herniation.

Twenty-four *disk hernias* were diagnosed by CT: 14 were at L5–S1 and 10 were at L4–L5. All 24 were seen on the axial scans. Of these, the sagittal scans confirmed 21 and the coronal scans confirmed 13, all but one of which was positive on sagittal reformations as well. In 10 cases the coronal scans offered no useful information. Myelography demonstrated 21 of the 24 herniations seen on CT. In figure 2 a disk herniation at L5–S1 is shown in all CT projections and myelography. In three cases myelograms were insensitive at the abnormal level. Of the latter, one case was CT-positive in all three projections (fig. 3), and two were positive on axial projections only. The sagittal reformation was sometimes helpful in appreciating longitudinal displacement of herniated disk fragments (fig. 4), but in other cases reconstruction artifact was misleading (fig. 5).

Lateralization of the disk could be difficult to determine from the sagittal scans because it entailed comparison of several different images. Herniations and bulges could be hard to differentiate using the sagittal scans alone. In contrast, axial images allow comparison of right and left on the same image. Three herniations correctly diagnosed on the axial

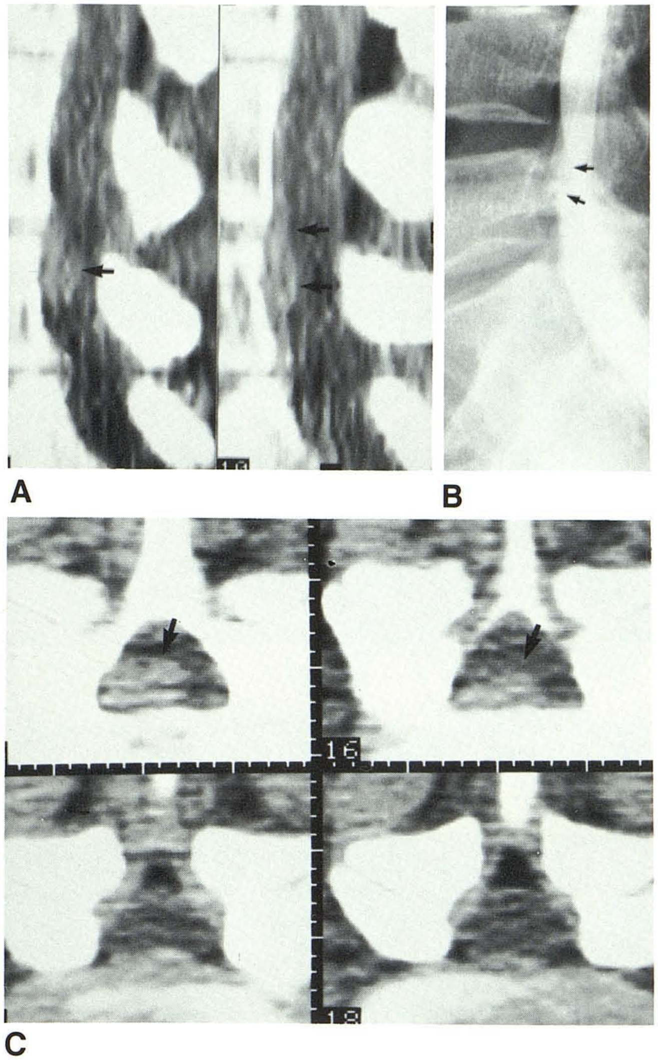


Fig. 4.—Herniated disk, caudad displacement. **A**, Sagittal reformation demonstrates caudad displacement of large herniated disk fragment (surgically proven) (*arrows*). **B**, Lateral myelogram confirms this finding. **C**, Axial CT images also reveal disk fragment inferior to interspace, but relation is less obvious (*arrows*).

scans were misinterpreted as bulging disks on sagittal reformation. In two of these, both the myelogram and the symptoms agreed with the diagnosis of hernia. In the other, both myelogram and symptoms were equivocal.

In summary, the axial image detected more disk herniations than the sagittal image and many more than the coronal image. Clinical data suggested that it was also more specific. The myelogram was equally specific, but less sensitive than the axial CT image.

Specific *nerve sleeve involvement* was recognized on CT in 27 cases. Fourteen of these were due to disk disease; the rest resulted from postoperative scar formation, except for one case of foraminal narrowing by bony stenosis. The axial images satisfactorily demonstrated all but one lesion. The coronal scans provided significant confirmation in 19 cases, but the sagittal images were unhelpful in 23 of 27. Nerve sheath involvement was recognized on CT by displacement or retraction of the image of the nerve or by obliteration of its contours by edema or extradural fibrosis (figs. 6 and 7). Myelography was able to confirm 24 instances of nerve root abnormality. In three cases, the lesion was too lateral to be visible on myelogram.

Abnormalities of the *neural foramina* were best depicted on the sagittal image. This was especially important in patients with spondylolisthesis in whom (fig. 8) anterior displacement of a vertebral element resulted in foraminal narrowing that could be best examined from the sagittal perspective.

Because of the CT-myelogram findings, 18 patients underwent surgery. Twelve herniated disks diagnosed by CT in 11 patients were confirmed. There was one false-positive CT diagnosis and one false-negative. One bulging disk was incorrectly diagnosed as a herniation on all CT images and on myelography because the bulge was asymmetric. One herniation was missed by both CT and myelography, presumably because it was obscured by a large osteophyte. All disk herniations that were seen on CT were visible on the axial images. Two other lesions were missed at myelography, one because of a large "blind area" anterior to the theca, one because of lateral disk herniation. One herniation was visible on myelography and axial CT, but on none of the reformatted images.

It is difficult to compare the accuracy of CT scanning with myelography from this data. Only 18 patients underwent surgery, and a number of different surgeons performed the procedures. We accepted the operative reports of herniated disk at face value, and therefore have less stringent criteria for surgical diagnosis than those of Kieffer et al. [10]. Using the surgeon's description in these 18 cases, the false-positive rate is the same for CT and myelography (one in each case), but the false-negative rate of myelography is higher than CT (three vs. one).

Six patients underwent surgery for diagnoses other than disk disease. There were four patients with perineural scarring due to previous surgery. In two cases the abnormality was seen on all CT projections and on myelography. In two cases the abnormality could be appreciated only on the axial CT images. In two cases of spondylolisthesis with neural foramen narrowing (fig. 8) sagittal CT images were especially helpful. In one of these the myelogram had been interpreted as normal.

Discussion

Reformation of data by an extramural computer is feasible and practical in a busy clinical setting. Although occasional technical problems delayed image availability by 72 hr, this was not considered to be a major objection to the technique. A set of axial images photographed at the time of the scan can circumvent this potential problem. An occasional discontinuity of the reformatted images resulted from patient movement. This was easily recognized and was not a significant problem in our series.

Reformatted images may exhibit a somewhat grainy or noisy appearance, especially in large patients. This results from two factors. To prevent excessive tube heating during

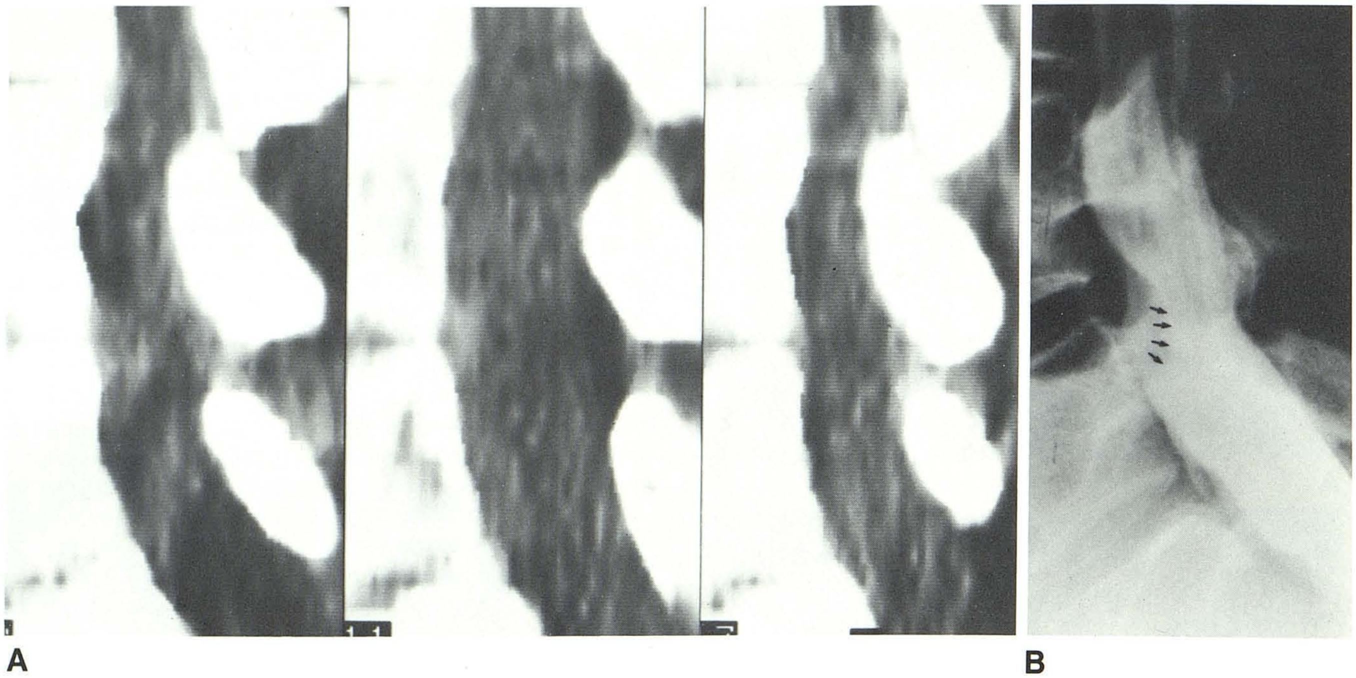


Fig. 5.—Herniated disk, caudad displacement. **A**, Sagittal image is misleading. Blurring of reconstructed image makes it difficult to observe that center of protruded disk is below interspace, as demonstrated by myelogram. **B**, Myelogram demonstrates caudad disk herniation, which was confirmed surgically.

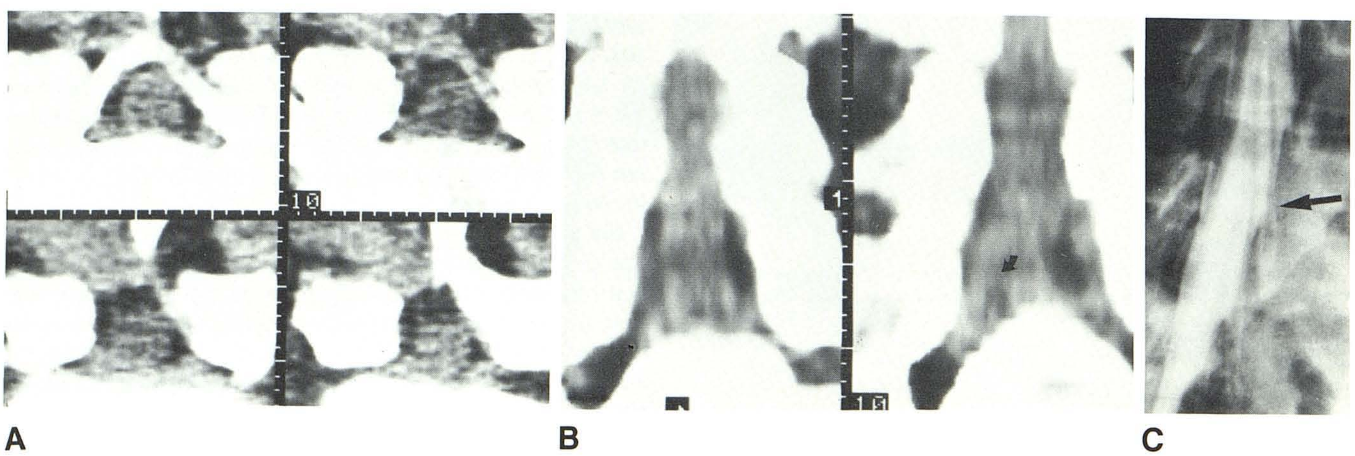
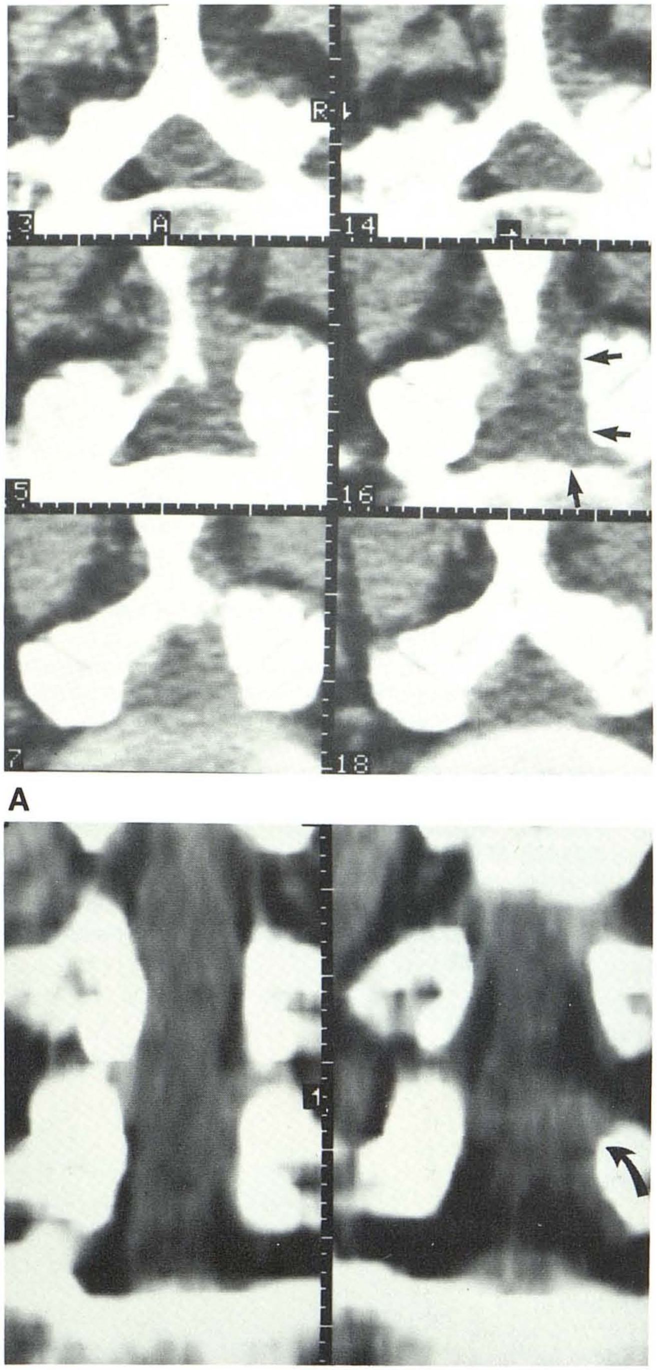


Fig. 6.—Nerve entrapment by postoperative scar. **A**, Axial scans show minimal asymmetry in distribution of epidural fat in this postoperative patient. **B**, Coronal reformation demonstrates scar formation around left S1 nerve root (*arrow*). **C**, Perineural scar is confirmed by myelogram. Localized constriction of nerve root sheath (*arrow*).

the large number of sections performed, maximum milliamperage is not used. Furthermore, presentation of the images in a life-size format eliminates the aesthetic advantage of minification. In our series, the noisy images did not result in misdiagnosis, although some degree of uncertainty was probably introduced.

In clinical practice, the sagittal and coronal reformations have served to increase the confidence level of the examiner. Less experienced observers find the sagittal images easy to understand, perhaps because of their similarity to conventional myelography. In some cases abnormalities may be easier to recognize from a sagittal perspective, although present on axial images. In general, sagittal images improved the demonstration of longitudinal continuity, neural foramina, and disk bulges at L5–S1. They were not helpful and were sometimes misleading in attempts to distinguish between herniation and disk bulge.

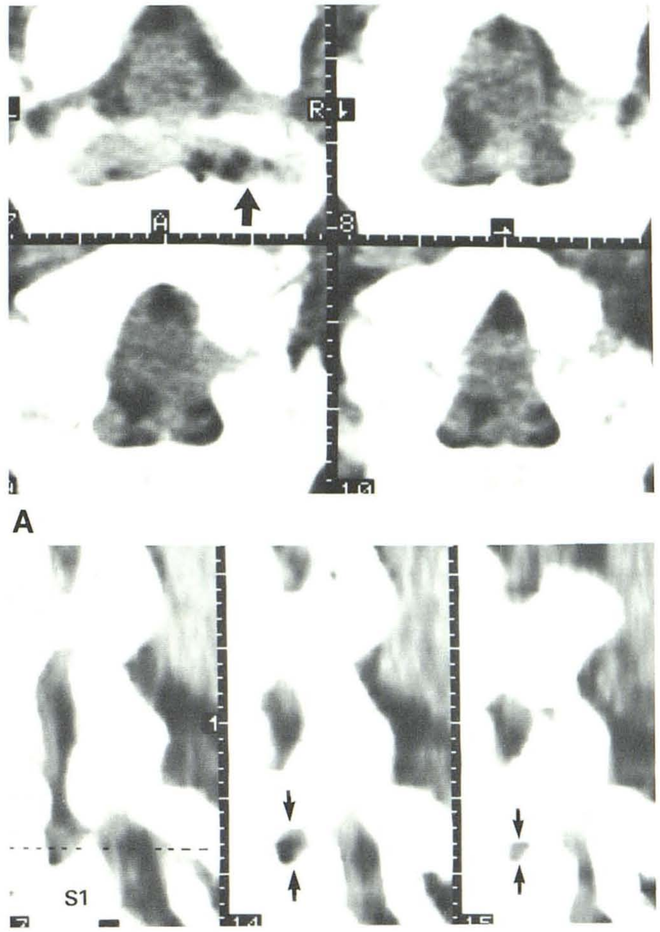
The coronal reconstructions did not reveal abnormalities when the axial scan was normal. However, observation of nerve sheath scarring (and conjoined roots) on coronal recon-



A

B

Fig. 7.—Nerve entrapment by postoperative scar. **A**, Axial scan demonstrates increased density in crescentic distribution extending from back to front on right side of spinal canal at L5 (*arrows*). Appearance is characteristic of postoperative scar. **B**, Right L5 nerve is obliterated by scar in coronal reformation (*arrow*).



A

B

Fig. 8.—Spondylolisthesis. **A**, Axial images may be difficult to interpret in patients with spondylolisthesis. Neural foramen appears to be divided into two parts by posterior margins of sacrum (*arrow*). **B**, Sagittal reformation helps clarify findings. *Dashed line* indicates plane of upper left scan in fig. 5A. There is critical narrowing of L5 neural foramen (*arrows*), a finding confirmed at surgery.

structions was sometimes easier than on axial scans.

Contrary to other reports [11], we have found that angulation of the gantry is not critical. With a small amount of practice, bulging or herniated disks were readily recognized on the nonangled scans. One important aspect of the nonangled scan is the fact that the posterior margin of the spinal canal is not necessarily seen on the same scan section as the anterior part to which it corresponds. Thus, in one case the axial images failed to reveal significant compression between disk and hypertrophied ligamentum flavum. In this case, the sagittal reconstruction proved quite helpful. Conventional lumbar CT with angled gantry may not have encountered this difficulty.

Our study confirms previous reports of the diagnostic usefulness of CT for lumbar disk disease. CT appears to be as effective as myelography for this indication.

We agree with the assertions of Glenn et al. [8] that multiplanar reformations can be of significant value for anatomic localization and for myelographic and surgical correlation. Axial images include all diagnostic information, but not necessarily in the most comprehensible form. Can the lumbar spine CT examination be effectively routinized by this "cookie cutter" approach? We believe that the high accuracy rate of our results indicates that it can. There have been times when additional images (e.g., different angulation, higher milliamperage, intravenous contrast) would undoubtedly have been obtained if the examination had been performed using a more individualized technique; however, we believe satisfactory results can be achieved by the method we describe.

Reformatted scans are an aid to physician acceptance. This is an important consideration that has had a major impact on CT use in our institution. However, our findings agree with the statements of Thoen et al. [12] that, for the average adult patient with lumbar disk disease, multiplanar reconstruction seldom contributes critical diagnostic information when axial images are carefully evaluated. Normal axial scans do not require reconstructions in sagittal or coronal planes. However, in equivocal cases confirmatory information provided by reformatting can be quite reassuring. It also appears probable that evaluation of patients in whom the anatomy is less familiar—that is, complex congenital malformations, complicated trauma cases, and patients with alignment abnormalities (spondylolisthesis)—may be greatly facilitated by sagittal and coronal reconstructions.

Should every lumbar scan be reformatted into three projections? The cost of the commercial service is about $50 per case. Alternatively, most scanners are capable of this type of reformation if one wishes to take the necessary time away from other activities. We believe that all lumbar CT should be performed in a manner that allows reformation if desired. Since the reformations may be needed in only a few cases, in the ideal setting the axial images would be reviewed to determine the need for additional projections. Whether this type of individualized approach is practical in a given hospital or office practice must be an individual decision.

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