CT of Lumbar Spine Disk Herniation: Correlation with Surgical Findings

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CT of Lumbar Spine Disk Herniation: Correlation with Surgical Findings

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Computed tomography (CT) of the lumbar spine was performed with selectively positioned 5-mm-thick axial cross sections to examine each disk level from the top of the neural foramen to the pedicle of the next caudad vertebra. One hundred consecutive patients with 116 surgical disk explorations were reviewed. There was agreement between the CT and surgical findings in 89 patients (104 explorations) in determination of presence or absence of a herniated nucleus pulposus (HNP). Discrepancy occurred in 12 instances (11 patients): two because of incorrect interpretations, five in previously operated patients, three in spondylolisthesis, and two in spinal stenosis. There were 97 true-positives, eight false-negatives, seven true-negatives, and four false-positives. If nine previously operated patients are excluded from the study, then CT was accurate in detection of presence or absence of an HNP in 93% of the disk explorations.

Computed tomography (CT) is currently the method of choice for evaluation of lumbar disk disease. Numerous CT examination protocols are currently in use for this purpose. These are evolving, and modifications are made as more experience is gained and the understanding of lumbar spine pathology is enhanced [1–9]. After a number of modifications, we have devised a tailored, pathology-oriented technique for evaluation of these patients. The following is the result of an assessment of this technique in 100 surgically documented patients.

Materials and Methods

Technique of CT Examination of the Lumbar Spine

The patient was positioned for scanning in the supine position, with the hips and knees flexed and supported. This lessened the lumbar lordosis, making the patient more comfortable and helping him to stay motionless during the examination. A GE 8800 CT/T unit was used. The technical factors were: 25 cm circular calibration; 250–400 mA; 120 kVp; 9.6 sec speed; and 5 mm slice thickness. The radiation to the patient per slice was calculated at 2.5–4.2 rad (2.5–4.2 hGy) depending on the milliamperage selected.

With the help of a lateral localizing image, CT slices were prescribed as follows. For evaluation of the intervertebral disk, the gantry was tilted to obtain axial cross sections parallel to the plane of the intervertebral disks. For evaluation of the vertebrae, the axial cross sections were obtained with the gantry tilted so that the slices were perpendicular to the long axis of the spinal canal. For evaluation of pathology associated with each intervertebral disk, the area examined extended from the top of the intervertebral neural foramen to the pedicle of the next caudad vertebra (fig. 1A).

Ordinarily, we examine the lumbar spine from the L3–L4 intervertebral disk to the S1 segment. Six slices of each interspace are obtained. Two slices (numbers 3 and 4) are obtained through each intervertebral disk; and one slice above and one below the disk (numbers 2 and 5) are about 2–3 mm from the vertebral end-plates. These slices (numbers 2–5) are positioned such as to reveal the pathologic changes affecting the spinal canal at the level of the disk and above and below it for 5–6 mm. Slices 2–5 also reveal the status of the lower part of the neural foramina and detect the possibility of compression of an exiting nerve

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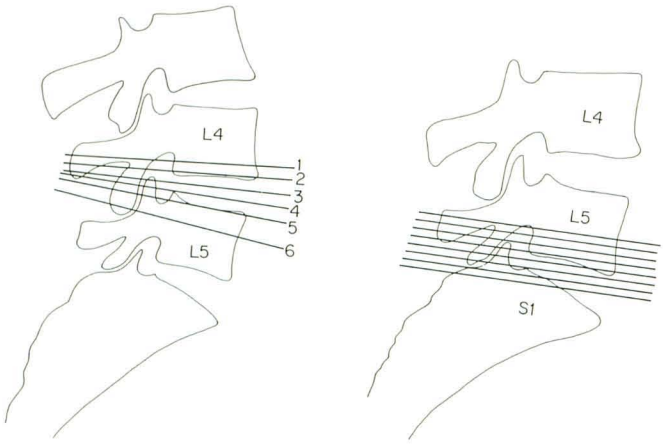

Fig. 1.—**A**, Typical position of slices for evaluation of each intervertebral disk when it is possible to tilt gantry sufficiently to obtain slices parallel to plane of the disk. **B**, Consecutive slices for evaluation of disk when slices parallel to plane of disk cannot be obtained (usually L5–S1).

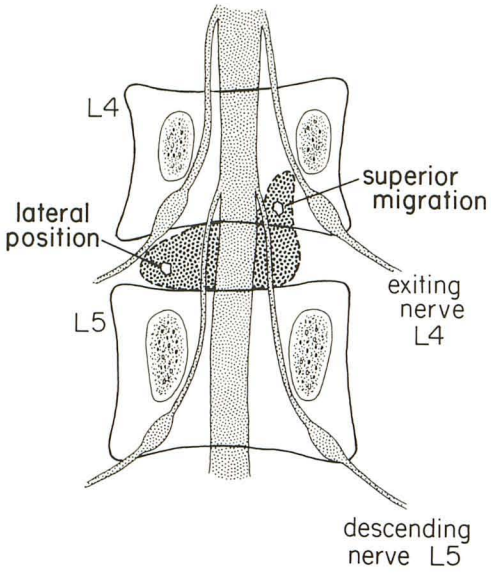

Fig. 2.—Exiting nerves (L4) and descending nerve roots (L5) at L4–L5 disk level. Lateral L4–L5 HNP in right neural foramen compresses right L4 exiting nerve, and upward migration of L4–L5 HNP compresses left L4 exiting nerve below pedicle of L4.

in this region. The apophyseal joints are usually best seen at the disk levels (slices 3 and 4). Slice 1 reveals the upper parts of the neural foramina and the exiting nerves as they begin to emerge below the pedicle through the top of the neural foramina. The pedicle image (number 6) is useful for evaluation of the size of the spinal canal and detection of spinal stenosis, spondylolysis, and a migrated herniated nucleus pulposus (HNP). Slices 2 and 3 are also important for evaluation of the lateral recess.

In most patients, at the L5–S1 level, and occasionally at L4–L5, lumbar lordosis is such that the gantry cannot be tilted sufficiently to obtain axial cross sections parallel to the plane of the disk. The maximum tilt of the GE 8800 CT/T gantry is 15°. In these patients, we obtain six to eight parallel 5-mm-thick slices, overlapped to yield 3 mm spacing, from a point 6–8 mm below the S1 superior end-plate through the L5 pedicle (fig. 1B). Then transaxial images parallel to the plane of the L5–S1 disk and sagittal and coronal images of this region are reformatted. For evaluation of the three lower lumbar segments, ordinarily, 13 to 16 slices are needed. If there are clinical indications for pathology at other intervertebral disks, then each one of these disk spaces is also studied as described. All of the CT slices are imaged at wide windows (1000 H) for evaluation of bony structures and narrow windows (100–300 H) for evaluation of soft-tissue structures.

Patient Population

We reviewed 100 consecutive patients who underwent surgery for sciatica and had had CT of the lumbar spine before surgery. The 61 men and 39 women were 19–76 years old (mean, 49 years). The patients were referred for back pain or radiculopathy, usually recurrent or of several years duration. The original CT reports of these patients were retrieved and compared with the findings at surgery. All the patients were operated on by the same neurosurgeon (V. B.) at New York University Medical Center. A description and drawing of the surgical findings were recorded at the conclusion of the surgery for each patient.

Criteria for Diagnosis of HNP and Radiculopathy

We attempted to determine the presence of HNP, spondylosis, spondylolisthesis, or other pathology leading to compression of spinal nerve roots, spinal nerves, or thecal sac at each level. There are ordinarily two pairs of nerves that may be associated with the pathology of each lumbar intervertebral disk. To avoid confusion, we designated these the *descending* and *exiting* nerves.

Descending nerve. At each lumbar intervertebral disk, there is usually only one spinal nerve root outside the dural sac in the spinal canal descending behind the intervertebral disk to exit below the pedicle of the vertebral body forming the lower surface of that disk. At the L4–L5 intervertebral disk, for example, the descending nerve would be the L5 nerve root.

Exiting nerve. The exiting nerve is the nerve leaving the spinal canal through the top of the neural foramen below the pedicle of the vertebral body sitting on top of the disk. At the L4–L5 disk, for example, the exiting nerve would be the L4 nerve, which usually leaves the dural sac at about the level of the lower part of the body of L3, descends behind the L3–L4 disk, and exits the spinal canal below the pedicle of L4 through the top of L4–L5 neural foramen (fig. 2).

Bulging anulus fibrosus. This diagosis was made when a smooth, more or less circular extension of the disk margin was noted beyond the margins of the vertebral end-plates. Bulging of the anulus fibrosus may be generalized, that is, be along the entire circumference of the vertebral end-plate; in a symmetric fashion with a smooth outline paralleling the contour of the vertebral end-plate; or eccentric. Generally, a bulging anulus is considered to be associated less with sciatica than an HNP [10].

Herniated nucleus pulposus. This diagnosis was made when the disk was noted to extend beyond the margins of the vertebral end-plates with a focal area of irregularity or a bump [6, 7, 9]. An HNP may be accompanied by displacement of the epidural fat; displacement, indentation, or distortion of the thecal sac or the descending nerve roots (HNP in the canal) (fig. 3A); or the exiting spinal nerves (HNP in the neural foramen) [11] (fig. 4). The irregularity of the contour of an HNP may not be localized; it may involve the entire posterior surface of the herniating intervertebral disk. An HNP may be associated with osteophytes or it may contain calcification or nitrogen (vacuum phenomenon) [12]. An HNP may extend upward or

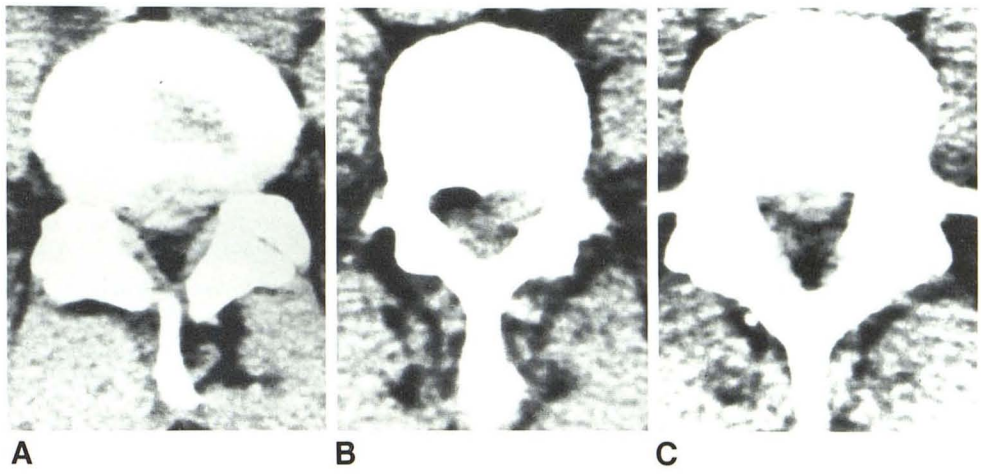

Fig. 3.—Herniated disk with extruded fragment. **A**, L4–L5 disk level. Large central-left HNP with moderate extension into left neural foramen. **B**, At inferior margin of L4 pedicle. Extruded fragment has migrated upward and is adjacent to lower edge of left pedicle of L4, where L4 exiting nerve crosses below pedicle to enter neural foramen. **C**, At level of L5 pedicle. Extruded fragment has migrated inferiorly to level of L5 pedicle.

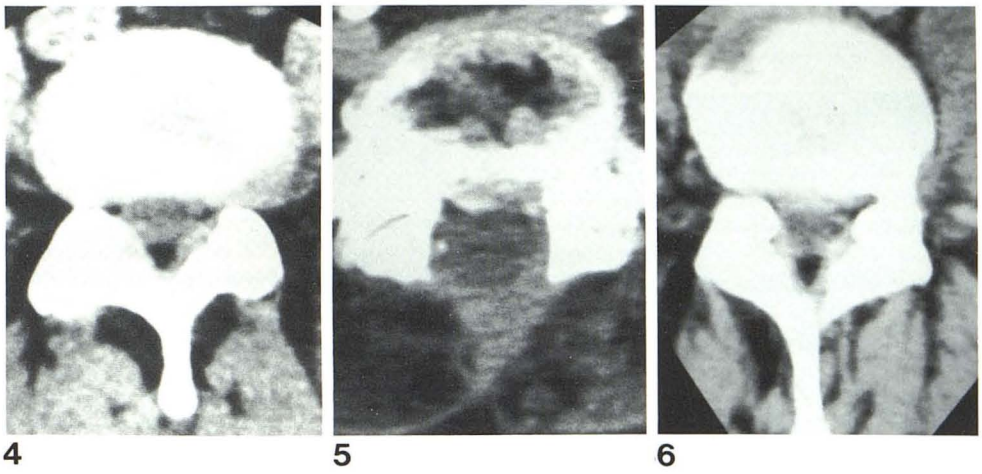

Fig. 4.—HNP extending into left neural foramen, L4–L5 level. Left L4 exiting nerve is surrounded by HNP. Left L5 descending root sheath is displaced slightly posteriorly.

Fig. 5.—After surgery. Vacuum phenomenon of disk, laminectomy, and scarring. Moderately calcified density projecting into canal was found to be recurrent HNP at surgery.

Fig. 6.—Post L4–L5 diskectomy at L4–L5 level. Density projecting into canal was thought to represent HNP. At surgery only scarring was found.

downward (figs. 3B and 3C) in the spinal canal, usually stopping at the level of the respective vertebral pedicles because of the relative natural constriction of the spinal canal at this level [9]. However, a sequestered fragment of an HNP may migrate farther on rare occasions. An upward migrating HNP may not only compress the descending nerve root but may also compress the exiting nerve as it curves below the vertebral pedicle to enter the intervertebral foramen [9] (fig. 3B). The exiting nerve leaves the spinal canal below the pedicle, emerges at the top of the neural foramen, travels in it inferiorly and slightly laterally, and leaves the neural foramen at about the level of the intervertebral disk. Thus, an exiting nerve may be affected by an HNP extending laterally into the neural foramen or beyond it [9, 11] [fig. 4]. A large, central HNP may not only compress the descending nerves, but it may also indent the dural sac and produce findings related to two or more nerve roots.

Results

One hundred sixteen disk explorations were performed. Presurgical prediction of HNP by CT yielded 97 true-positives, eight false-negatives, seven true-negatives, and four false-positives (table 1). CT diagnosis and surgical findings of HNP agreed in 89 patients.

Nine patients had had previous spine surgery. A correct CT diagnosis was made of recurrent HNP in one patient (fig. 5), scarring in another, and normal postoperative status in two. In the other five patients, it was not possible, even retrospectively, to determine whether an HNP existed or if abnormalities were from scarring (fig. 6). At surgery, two recurrent HNPs were found. For the purpose of this discussion, we considered three of the CT reports with suggestion of HNP as false-positives and two as false-negatives. We assumed the surgical findings to be correct.

Five patients had spondylolisthesis. CT revealed spondylosis or spondylolysis, spondylolisthesis, and the resulting distortion of the spinal canal in five patients. At surgery, three HNPs with extruded fragments were found in two patients (fig. 7). In two patients with spinal stenoses, CT was unable to detect an HNP (fig. 8). However, two HNPs were found at surgery. In the other two patients in whom a discrepancy existed between the CT and surgical findings (one false-positive and one false-negative) a retrospective evaluation of the CT studies revealed the original interpretations to be incorrect.

Extension of an HNP for more than 5 mm, cephalad or

TABLE 1: **Preoperative CT and Surgical Findings in the Diagnosis of HNP**

Level: Status of HNP	No. CT/Surgical Findings			
	True-Positive	False-Negative	True-Negative	False-Positive
L2–L3:				
Central	1/1	...	...	...
L3–L4:				
Central	1/1	...	...	...
Central-lateral or lateral	2/2	...	...	...
L4–L5:				
Central	12/13	1/13	4/6	2/6
Central-lateral or lateral	36/38	2/38	1/2	1/2
Extruded	3/5	2/5	...	...
L5–S1:				
Central	9/10	1/10	2/2	...
Central-lateral or lateral	30/31	1/31	...	1/1
Extruded	3/4	1/4	...	...

Note.—HNP = herniated nucleus pulposus. An extruded HNP is an HNP fragment without detectable attachment to the donor HNP. There were no extruded HNPs at the L2–L3 and L3–L4 levels; there were no central-lateral or lateral HNPs at the L2–L3 level.

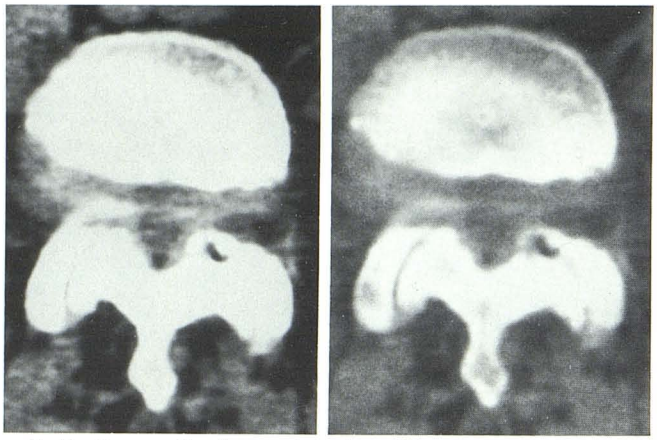

Fig. 7.—Degenerative disease of apophyseal joints with vacuum phenomenon on left side, elongation of spinal canal, and spondylolisthesis, L4–L5 level. At surgery, an extruded HNP was found in addition to these abnormalities.

caudad, was noted in 31 patients. There were six patients with extruded HNP fragments migrating more than 12 mm. Various degrees of spondylosis were noted in 21 patients, four with moderate to marked associated stenosis of the spinal canal [13–15], three neuroforaminal stenoses [16, 17], and two lateral-recess stenoses [18–20].

Discussion

To detect the pathologic changes of the spine and the disks affecting the thecal sac, nerve roots, and spinal nerves, the involved intervertebral disk level must be studied from the top of the intervertebral neural foramen to the pedicle of the next caudad vertebra. This region contains the exiting nerves, as they enter the neural foramina superiorly and leave them laterally at about the disk level; and the descending nerve roots, which, after emerging from the dural sac, run inferiorly, anteriorly, and laterally in the spinal canal, descend behind the disk, enter the lateral recess to descend further, cross the pedicles, and enter the next neural foramina. Consecutive 5-mm-thick slices covering this area, or selectively positioned slices as described in our technique, will detect the pathologic changes in this region. The consecutive-slice method, without selective positioning, does not require meticulous attention to technique as our method demands and may require six to eight additional CT slices.

A potential drawback of our technique is the possibility of missing an extruded HNP fragment that has migrated beyond the boundaries of the visualized parts of the spinal canal. The region between the vertebral pedicle and the disk caudad to it, where most migrated extruded HNP fragments are found, is adequately covered by our technique. The region that may not be fully covered is that part of the spinal canal immediately cephalad to the vertebral pedicle. This is a relatively uncommon location for entrapment of the extruded HNPs because of relative constriction of the spinal canal in this area. The distance between cross-sectional slices 5 and 6 is 8–14 mm depending on the patient's anatomy. Thus, a 4–10 mm ex-

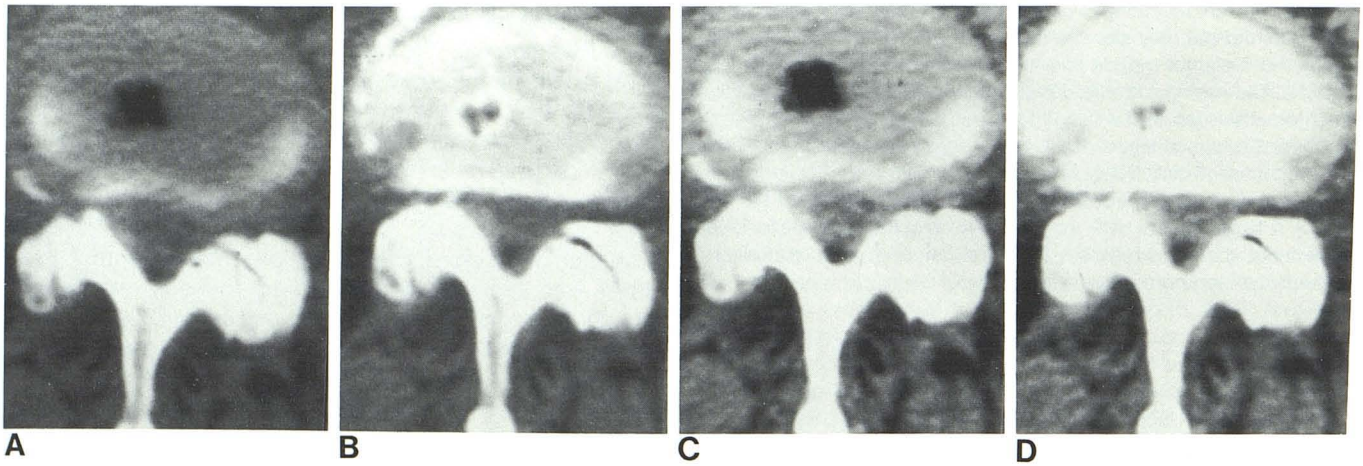

Fig. 8.—Vacuum phenomenon, bulging of disk containing calcification, stenosis of spinal canal, degenerative disease of apophyseal joints and stenosis of right neural foramen, L4–L5 level. At surgery, an extruded HNP was found also.

truded HNP fragment lodged in the midportion of this region may go undetected. To guard against this possibility, in patients in whom the distance between slices 5 and 6 is more than 8 mm, we take one or two more slices as necessary.

In our experience, there is less geometric distortion of the spinal canal if the CT slices are perpendicular to the long axis of the canal, and it is easier to evaluate the disks if the slices are obtained parallel to the plane of the disks. On the other hand, if the plane of the axial cross section passes through the posterior edge of the vertebral end-plate and the disk at an angle, the CT image may reveal an unsharpness of the posterior edge of the vertebral end-plate accompanied by a soft-tissue density that appears to protrude into the spinal canal [2, 7]. Rarely, this may be confused with an HNP. Although with experience one can usually differentiate between this image and a true HNP, we believe the extra time needed for the tilting of the gantry is well worth the confidence added to the interpretation of the study. Similarly, we believe, in selected instances, reformatting to create precise, through-the-plane-of-the-disk images at L5–S1 and occasionally at L4–L5 is well worth the effort.

The CT diagnosis of an HNP depends on the differential density of the HNP relative to the thecal sac and the nerve roots, as well as the presence of epidural fat. Most HNPs have a higher Hounsfield number than the thecal sac or the nerve roots. However, occasionally an isodense HNP is encountered [9]. In these patients, CT differentiation of the HNP from the thecal sac may not be possible. Occasionally, a massive HNP has practically obliterated the spinal canal, compressing the thecal sac against the posterior wall of the canal. In these patients, the CT diagnosis of HNP may not be possible because there may be no detectable displaced or distorted epidural fat and no visible interface between the HNP and the contents of the spinal canal. In patients with a paucity of epidural fat, CT detection of HNP may be very difficult. The epidural fat may be deficient in patients with spinal stenosis or in those with previous spine surgery. In previously operated patients, there may be a significant distortion of the epidural fat. Although surgical scarring may appear different and may have CT numbers higher than an HNP, in our experience, differentiation of recurrent HNP from scarring may not be possible in some of these patients.

Intravenous contrast administration is reported to be helpful in these patients by causing enhancement of the surgical scar [21]. We used intravenous contrast material (drip infusion) in three postoperative patients included in this series. It was not found to be helpful.

In patients with spondylolisthesis, an axial slice obtained through the midportion of the disk will reveal the soft-tissue density of the disk posterior to the posterior edge of the end-plate of the anteriorly displaced vertebra. This is expected because of the oblique course the posterior edge of the disk has to take to extend from the end-plate of the anteriorly displaced vertebra to the end-plate of the other vertebra. In patients with long-standing spondylolisthesis, disruption of the annular fibers may occur, leading to extrusion of the nuclear material. However, CT detection of an HNP in these patients may be difficult. The incidence of true HNP in patients with spondylolisthesis, either spondylotic or secondary to spondylolysis, deserves further investigation.

Our experience reveals CT to be the method of choice for evaluation of lumbar disk herniation, particularly in patients without prior spine surgery. In our series, if the nine patients with previous surgery are excluded from the study, then CT was accurate in 93% of instances (100 of 107 disk explorations) in predicting the presence or absence of HNP. In selected instances where CT findings are inconclusive, particularly in patients with previous surgery, spinal stenosis and spondylolisthesis, myelography, both conventional and CT myelography, may furnish additional information leading to the correct diagnosis [22].

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