Preoperative Evaluation of Cervical Radiculopathy and Myelopathy by Surface-Coil MR Imaging

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Preoperative Evaluation of Cervical Radiculopathy and Myelopathy by Surface-Coil MR Imaging

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During a 2-year period, 256 patients were screened for cervical radiculopathy and myelopathy with surface-coil MR images and plain films. Selected patients had follow-up examinations including CT, myelography, and CT myelography. Thirty-four of these patients underwent cervical spine surgery after MR imaging, which disclosed a total of 50 abnormalities in three major categories: herniated disks, bony canal stenoses, and intradural lesions. MR correctly predicted 88% of all surgically proved lesions compared with 81% for CT myelography, 58% for myelography, and 50% for CT. Missed herniated disks on either MR or CT myelography usually were the result of technically suboptimal studies caused by motion artifacts on MR and beam-hardening artifacts on CT myelography. Small osteophytes adjoining herniated disks sometimes were not predicted on MR, although such osteophytes invariably were seen on plain films and were palpable during standard anterior cervical diskectomy procedures. Herniated disks in the lateral root canals found in two patients appeared to be detected more readily by CT myelography than by MR. All proved lesions were detected by either screening MR images and plain films or by follow-up CT myelograms. MR replaced invasive evaluations by myelography and CT myelography in 32% of preoperative patients.

We conclude that MR images, combined with plain films, offer an accurate, noninvasive test for the preoperative evaluation of cervical radiculopathy and myelopathy, while CT myelography is the preferred follow-up examination.

Current diagnostic approaches to evaluating patients with symptoms and signs of cervical radiculopathy and myelopathy rely primarily on radiographic examinations that are either invasive (e.g., myelography), involve ionizing radiation (e.g., CT), or both (e.g., CT myelography). The advent of MR imaging with surface coils designed for imaging the cervical spine has suggested the possibility of noninvasively screening patients with suspected cervical spine lesions. However, the clinical significance of cervical spine abnormalities shown by MR scans has been questioned [1]. Furthermore, the comparative accuracy of MR relative to well-established invasive tests such as CT myelography has been controversial, especially in patients with cervical radiculopathy [2, 3].

In the past 3 years numerous technical MR refinements have appeared in such areas as surface-coil design, software, and scanning technique [3–6]. Such MR refinements have been noted to improve the accuracy of MR in evaluating causes of cervical myelopathy [7] and in delineating anatomic structures within the lateral root foramina [4, 8, 9]. Furthermore, MR screening of suspected cervical spine lesions can be followed by invasive examinations when MR does not explain clinical findings or permit confident surgical planning.

On the basis of the above considerations, we adopted the strategy of screening all patients presenting with cervical radiculopathy and myelopathy with surface-coil MR and cervical spine plain films. MR and plain-film screening was followed by cervical myelography, CT myelography, and CT in all cases in which neurologists, neurosurgeons, or radiologists believed that follow-up or corroborative studies after MR were indicated. The predictions of MR and other imaging tests were then

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compared with surgical findings in an attempt to use the most objective standard possible for assessing the ability of imaging tests to detect cervical spine lesions. The current report is based on a retrospective review of our 2-year experience with MR and plain-film screening for surgically proved lesions in the cervical spine.

Materials and Methods

During a 2-year period (April 1985 to April 1987) a total of 256 patients with cervical radiculopathy or myelopathy were referred for imaging studies and screened with cervical spine plain films followed by surface-coil MR images. This report describes the 34 patients who underwent cervical spine exploration within 2 months of MR because of severe, unremitting clinical symptoms and abnormalities on MR or other imaging tests. Other preoperative studies were performed after MR in 28 of the 34 patients, including CT, cervical myelography, and CT myelography.

Views obtained on plain films included anteroposterior, lateral, and right and left anterior oblique. MR examinations were performed on a 0.6-T Technicare scanner with either 5-in. (12.7-cm) flat or 5-in. (12.7-cm) saddle-shaped surface coils. Scans included T1-weighted spin-echo images 550/30/6 (TR/TE/excitations), in both sagittal and axial planes with a slice thickness of 5 mm, an interslice gap of 1 mm, and a 192 × 256 acquisition matrix. Axial images were obtained through the anatomic region of interest as defined by sagittal MR scans, plain-film abnormalities, or clinical findings. When initial T1-weighted images were nondiagnostic owing to motion artifacts, repeat T1-weighted images were obtained with two to four signal averages to reduce imaging time. In selected cases, sagittal T2-weighted images, 1500/60/4, were also obtained with 5-mm slice thicknesses and a 128 × 256 matrix.

Angled axial 1.5- or 3-mm-thick CT scans were obtained through cervical spine levels of interest on a GE 9800B scanner with 120 kV, 200 mA, a 3-sec scan time, a 12.8-cm field of view, a 512^2 display matrix, and a Standard reconstruction matrix. Myelography was performed with 8–10 ml of iopamidol 200 injected via C1–C2 puncture in 11 cases, while three patients had iopamidol 300 injected via lumbar puncture. Anteroposterior, cross-table lateral, and right and left anterior oblique myelograms were obtained. CT myelography was performed within 1–4 hr after cervical myelography with the CT techniques described above except for the use of Bone algorithm. After myelography and CT myelography, all patients were admitted for overnight observation.

For 22 patients with cervical herniated nucleus pulposus (HNP) who underwent anterior diskectomies, abnormal findings described in surgical reports were used to assess the predictive accuracy of imaging tests. In nine patients with bony canal stenoses caused by osteophytosis, posterior total laminectomies were performed that precluded direct visualization of osteophytes at surgery. In these patients with bony canal stenoses, the final postoperative diagnosis on surgical reports was used to assess the accuracy of imaging study predictions. For three patients with intradural lesions who underwent syrinx shunting or neoplasm resection, abnormal findings noted in surgical reports were used to assess the accuracy of imaging tests.

A blinded retrospective review of preoperative plain-film, MR, CT, myelography, and CT myelography reports was performed jointly by two of us (one radiologist and one neurosurgeon) prior to review of operative reports. For each imaging test, films were reviewed to confirm abnormalities described in the reports. Abnormalities noted on imaging reports but not seen on film review and abnormalities seen during film review but not described on imaging reports were excluded from study data.

TABLE 1: Predictive Value of Imaging Tests in Detecting Cervical Disk Herniations, Bony Canal Stenoses, and Intradural Lesions

Surgical Diagnosis or Finding	No. Detected/Total No.			
	MR	CT Myelography	Myelography	CT
Cervical disk herniation (*n* = 22):				
Posterior disk herniation	14/15	7/10	3/9	0/3
Lateral disk herniation	1/2	2/2	0/1	1/1
Herniated disk	3/3	–	1/2	1/1
And adjoining osteophyte	1/3	–	1/2	0/1
Herniated disk	1/1	–	–	0/1
And adjoining syrinx	1/1	–	–	0/1
Subtotal (%)	22/26 (85)	9/12 (75)	5/14 (36)	2/8 (25)
Bony canal stenosis (*n* = 9):				
Single-level	2/2	2/2	1/2	2/2
Multilevel	17/19	5/5	7/7	2/2
Subtotal (%)	19/21 (90)	7/7 (100)	8/9 (89)	4/4 (100)
Intradural lesion (*n* = 3):				
Intramedullary neoplasm	2/2	1/1	1/1	–
Syringohydromyelia	1/1	0/1	–	–
Subtotal (%)	3/3 (100)	1/2 (50)	1/1 (100)	–
Total (%)[a]	44/50 (88)	17/21 (81)	14/24 (58)	6/12 (50)

Note.—Of the 22 patients with cervical disk herniation, 17 presented with radiculopathy and five with myelopathy; of the nine patients with bony canal stenosis, two presented with radiculopathy and seven with myelopathy; all three of the patients with intradural lesions presented with myelopathy. A dash (–) indicates the study was not performed.

[a] Either CT or CT myelography was accurate in 50 (100%) of 50 studies.

After review of imaging studies, all operative reports were reviewed and each abnormal surgical finding and postoperative diagnosis was tabulated. For each surgically proved abnormality, the accuracy of all preoperative imaging tests was rated: + = imaging test predicts surgical abnormality, − = imaging test does not predict surgical abnormality, and 0 = imaging test not done at site of surgical abnormality.

Imaging test predictions for unexplored cervical spine levels were excluded from study data.

Results

The 50 abnormalities described at surgery in 34 patients were tabulated in terms of primary surgical diagnosis (HNP, bony canal stenosis, or intradural lesion) (Table 1). Table 1 compares surgical findings and imaging test predictions in 22 patients with HNPs, of whom 17 presented with cervical radiculopathy and five presented with cervical myelopathy. MR detected 20 of 22 HNPs (Fig. 1), including one of two lateral root canal HNPs. MR also detected two unsuspected lesions in patients with HNPs, including a thyroid colloid cyst and a syrinx (Fig. 2), that were not seen by other studies. Suboptimal MR studies done with reduced signal averages missed one lateral and one posterior HNP seen by CT myelography (Fig. 3). In two cases MR detected HNPs but missed adjoining posterolateral osteophytes of vertebral endplates and uncinate processes. Both of these osteophytes were apparent on plain films during retrospective film review but had not been described on plain-film reports (Fig. 4).

CT myelography performed in 12 patients with HNPs, missed three HNPs detected by MR. All three false-negative CT myelograms were through lower cervical HNPs at C5–C6 and C6–C7 and were inadequate because of image degradation by beam-hardening artifacts in patients with large shoulders (Fig. 5). The percentage of true-positive CT myelograms in Table 1 may be artificially low since follow-up CT myelography was not performed in 12 patients in whom MR detected obvious HNPs, though CT myelography probably would have been accurate. Nevertheless, more HNPs were missed by CT myelography (three cases) than by MR (two cases).

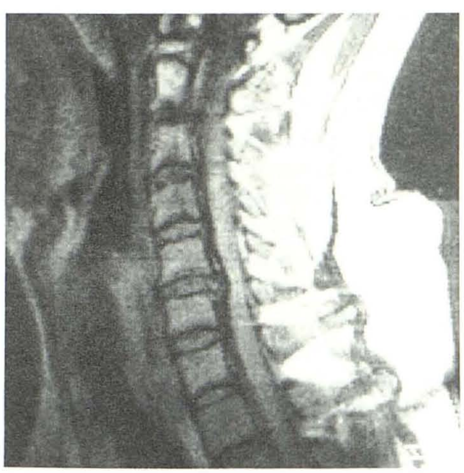


Fig. 1.—Midsagittal MR image shows proved posterior central herniated nucleus pulposus causing cord compression at C5–C6. Plain films were normal. Anterior diskectomy was performed without preoperative myelography or CT myelography.

Cervical myelography, performed in 14 patients with HNPs, missed eight HNPs, of which all were detected by MR and five were detected by CT myelography (Fig. 6). Two false-negative myelograms were suboptimal because the faint opacification of the subarachnoid space achieved via lumbar puncture made nerve-root sleeve cutoff impossible to evaluate. Myelography also missed one lateral HNP, missed one HNP adjoining an osteophyte, and incorrectly predicted osteophytes in two cases with proved HNPs. In another case, myelography detected an HNP but failed to predict an adjoining osteophyte. Myelography never detected an HNP missed by CT myelography.

CT, performed in eight patients with HNPs, missed four lower cervical HNPs at C5–C6, C6–C7, and C7–T1 detected by MR. CT myelography detected one HNP missed by CT. Although CT clearly depicted facet and uncovertebral joint osteophytes, beam-hardening artifacts obscured the interface between lower cervical disks and the adjoining thecal sac to a greater extent on CT scans than on CT myelograms. Therefore, CT was rarely used during the second year of our study unless detailed evaluation of cervical osteophytes was needed.

Table 1 summarizes the agreement of imaging test predictions with final postoperative diagnoses in nine patients with bony canal stenoses, of whom seven initially presented with myelopathy and two presented with radiculopathy. MR agreed with postoperative diagnoses of bony canal stenosis at 19 levels in eight patients and disagreed in only one patient. In the latter case MR in the supine position showed two-level stenosis at C3–C4 and C6–C7, while CT myelography in the prone position showed four-level stenosis at C3–C4 through C6–C7 (Fig. 7). CT myelographic prediction of C4–C5 and C5–C6 stenoses may have been affected by position-related ectasia of the posterior longitudinal ligament and ligamenta flava during prone hyperextension of the neck. Nevertheless, MR was rated false negative after a four-level posterior laminectomy and a final postoperative diagnosis of four-level bony canal stenosis. Final postoperative diagnoses of bony canal stenosis were correctly predicted in three patients who had CT myelography, two patients who had CT, and three of four patients who had cervical myelography. However, neurosurgeons appeared to rely heavily on CT-myelographic and CT findings in deciding on the extent of posterior laminectomies, which in turn influenced postoperative diagnoses. As anterior canal osteophytes were not seen during posterior laminectomies, direct correlation of imaging test predictions and anatomic abnormalities was not obtainable for patients with bony canal stenoses.

Table 1 also shows that, for three patients with intradural lesions who presented with myelopathy, MR was consistently more sensitive and specific in evaluating abnormalities than other imaging tests were. MR detected one large syrinx cavity (C3–T3) missed on follow-up CT myelography, which showed only cord widening but no syrinx cavity opacification on immediate and delayed scans obtained 6, 12, and 18 hr after administration of intrathecal contrast material. MR showed a

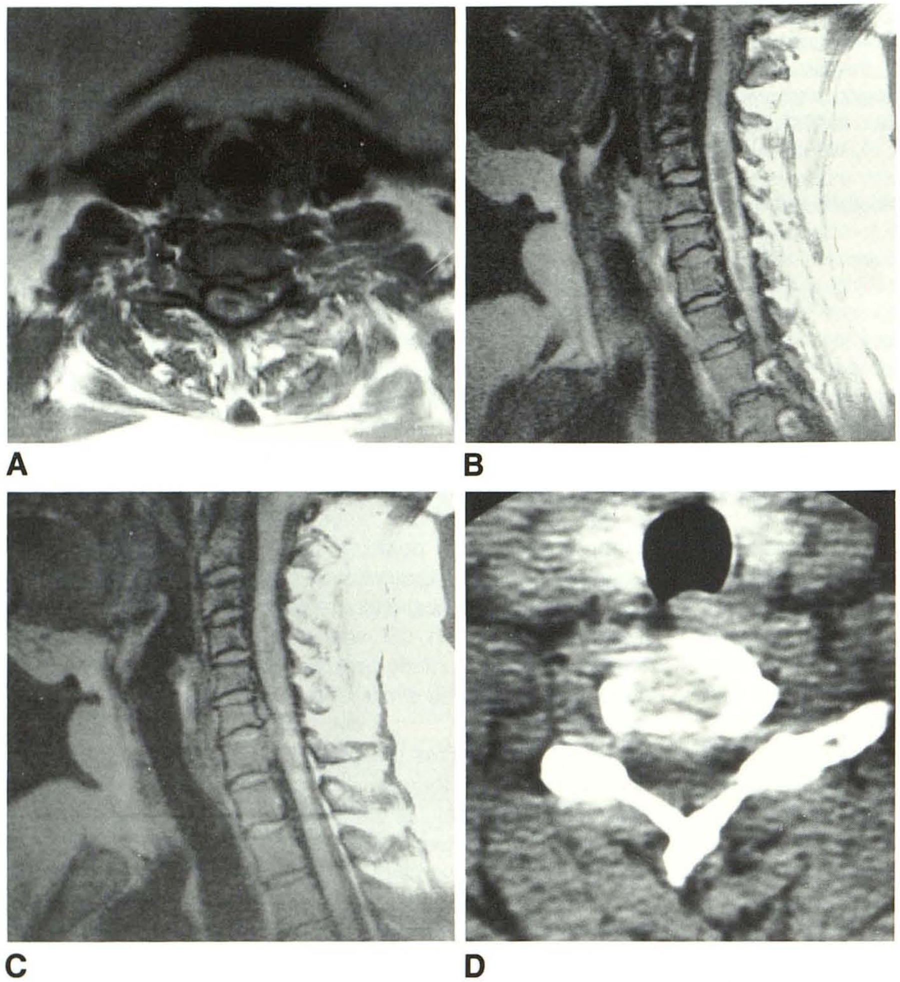


Fig. 2.—*A*, Axial MR image shows left posterolateral herniated nucleus pulposus at C6–C7 and unsuspected syrinx cavity in cord.

B, Right parasagittal MR image confirms presence of syrinx extending from C3 to C7.

C, Midsagittal MR image confirms C6–C7 herniated nucleus pulposus.

D, CT scan through C6–C7 is nondiagnostic owing to marked beam-hardening artifacts in patient with large shoulders.

cystic mass of mixed signal intensity in another patient with an intramedullary astrocytoma, while myelography showed only cord widening. In a third patient, both MR and CT myelography depicted an intramedullary ependymoma extending from the fourth ventricle to the C2 level.

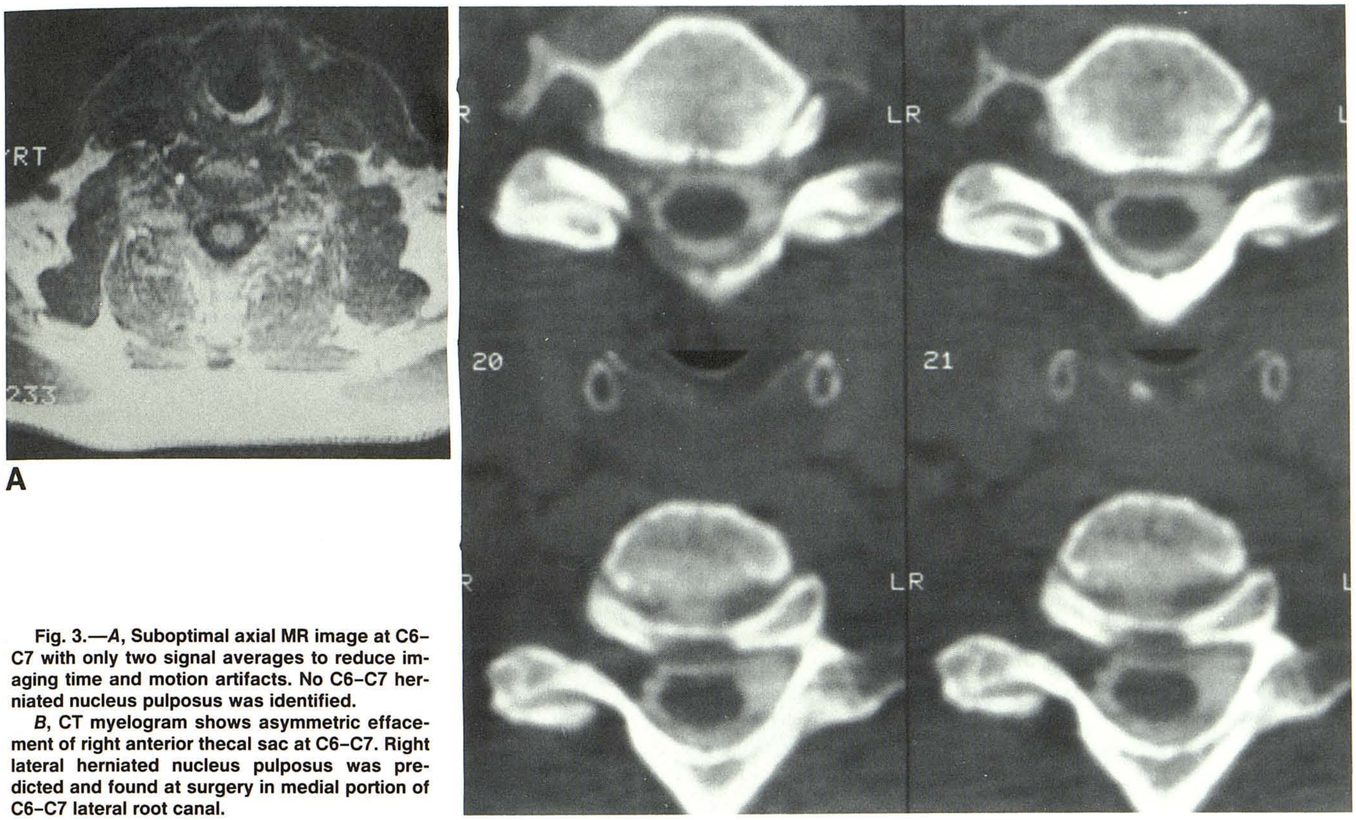
Table 1 indicates that MR was the most accurate imaging test for detecting proved lesions causing radiculopathy and myelopathy in our patients. All proved lesions were detected either by screening with MR images and plain films or by follow-up CT myelography. Table 2 shows that one-third of our patients underwent cervical spine exploration following exclusively noninvasive imaging workups limited to plain films, MR images, and, in three cases, CT scans. Such noninvasive preoperative workups became increasingly common during the course of our study as neurosurgeons and radiologists gained familiarity with and confidence in MR findings.

Discussion

MR offers several advantages over CT myelography in screening for operable cervical spine lesions. MR is able to survey the entire cervical spine, while CT myelography, with narrow axial slices, is usually limited to evaluating three levels. MR is a noninvasive outpatient examination, while CT myelography requires a cervical or lumbar puncture and intrathecal contrast material. CT myelography may require postprocedure inpatient observation since delayed adverse reactions to contrast material may occur [10–12], even when low-osmolality media are used. In our series two of 23 patients developed adverse contrast reactions 4–6 hr after CT myelography, including headaches, nausea, confusion, and blurred vision, which required 24–36 hr of inpatient medical management before resolution.

MR has proved capable of detecting a variety of cervical lesions usually associated with myelopathy, including syringomyelia [13–15], spondylosis [8], and neoplasm [16–19]. For patients with HNPs who often present with radiculopathy, the best screening examination remains controversial, with one recent study favoring MR [20] and two prior studies favoring CT myelography [2, 4]. Selection of different optimal screening examinations for patients with radiculopathy and myelopathy is an option compromised by inexact correlation between clinical findings and anatomic lesions. In our series, 22.7% of patients with HNPs presented with myelopathy, while 22.2% of patients with bony canal stenoses presented with radiculopathy. Thus, a single accurate screening test for evaluating both patients with radiculopathy and with myelopathy remains a desirable goal.

Most recent studies have concluded that CT myelography



A

B

Fig. 3.—*A*, Suboptimal axial MR image at C6–C7 with only two signal averages to reduce imaging time and motion artifacts. No C6–C7 herniated nucleus pulposus was identified.

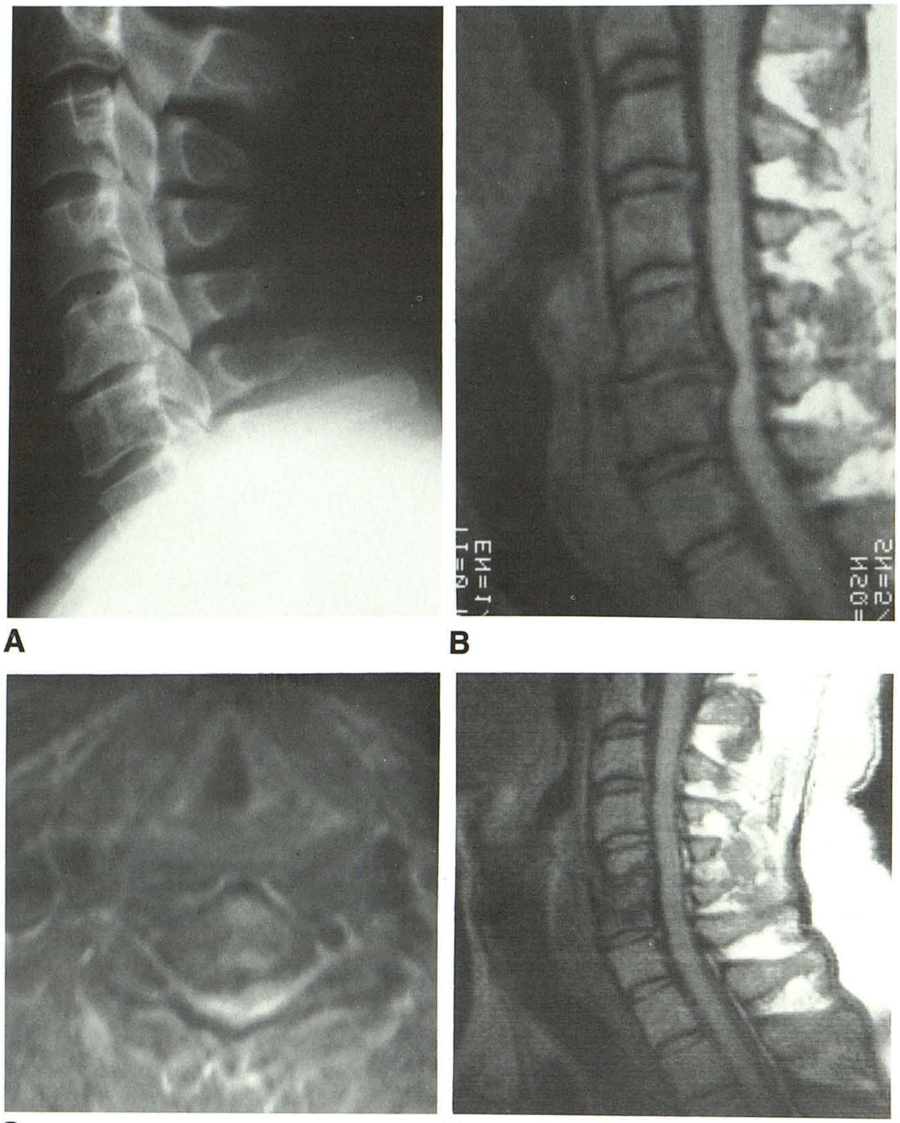
***B*, CT myelogram shows asymmetric effacement of right anterior thecal sac at C6–C7. Right lateral herniated nucleus pulposus was predicted and found at surgery in medial portion of C6–C7 lateral root canal.**

represents the neuroradiologic standard for evaluating cervical spine lesions [3, 12, 21–23]. These studies show that CT myelography provides images with excellent spatial and contrast resolution that exceed the accuracy of myelography [20–27] and CT [28–31] of the cervical spine. Our findings support these conclusions about the excellent image quality of CT myelography and its superiority relative to CT and myelography. Our data also indicate that MR with surface coils combined with cervical spine plain films appears to be more accurate than CT myelography in screening for operable lesions causing radiculopathy or myelopathy.

A recent prospective study comparing MR with CT myelography in patients with cervical radiculopathy [2] found that the tests were of equal value in detecting HNPs, although CT myelography was superior to MR in detecting osteophytes. The latter finding is corroborated by our data, which show that MR can miss osteophytes adjoining HNPs because osteophytes may show varying signal intensity, probably reflecting differences in marrow content. However, all osteophytes missed by MR in our series were seen on plain films. Furthermore, posterior and posterolateral osteophytes adjoining HNPs were routinely palpable by neurosurgeons during anterior cervical diskectomies, so preoperative identification of these lesions had little impact on surgical procedures. In our opinion clinically significant osteophytes adjoining posterior HNPs are unlikely to be missed by both combined plain-film/MR screening and standard anterior diskectomy operations.

Herniated disks in the lateral root canal are relatively uncommon causes of cervical radiculopathy and may be difficult to detect on MR. Narrow, obliquely oriented lateral root canals are poorly depicted on sagittal MR images and may not be consistently well evaluated by 5-mm-thick, nonangled axial MR scans. Symmetric, wide bands of high-signal fat surrounding nerve roots in the lateral root canal on axial T1-weighted images appear to reliably indicate normal lateral root canals. However, asymmetric narrowing of lateral root canal fat on axial MR images may either indicate lateral root canal stenosis (due to an HNP or osteophyte) or reflect partial-volume averaging of surrounding bone due to scoliosis or failure of scan centering through the lateral root canal. In our experience, CT myelography with 1.5-mm spacing was more reliable in detecting HNPs in the lateral root canal. Plain films are important for detecting lateral root canal osteophytes, and in some cases osteophyte configuration may be further elucidated by CT or CT myelography. The contribution of plain films, CT myelograms, and CT scans in evaluating lateral root canal lesions may diminish with technical MR advancements such as thin-slice angled axial scans [3, 32] and fast scanning with gradient-recalled echo techniques [20].

Most cervical HNPs occur in the lower cervical spine where MR enjoys the advantage of not sharing CT myelography's vulnerability to beam-hardening artifacts. While both MR and CT myelography are subject to motion artifacts and MR images occasionally may be degraded by swallowing artifacts, such artifacts often are correctable with the use of soft cervical collars, sedation, and antihistamine nasal sprays. In our experience MR is more accurate than CT myelography in detecting posterior HNPs because suboptimal scans in the



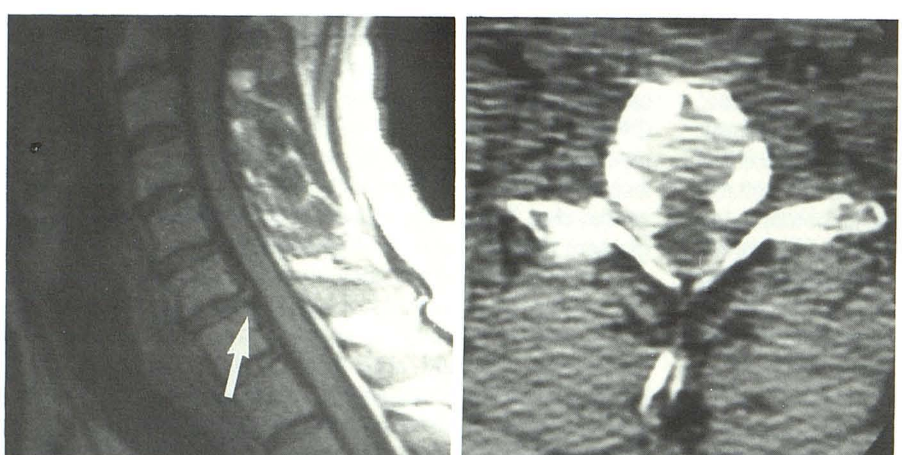
A B C D

Fig. 4.—*A*, Midsagittal plain film clearly shows small posterior inferior C5 osteophyte that was not mentioned in report.

B, Midsagittal MR image shows C5–C6 posterior central herniated nucleus pulposus. C5 osteophyte noted on plain films is visible on close inspection but was not described on MR report.

C, Axial MR image at C5–C6 confirms marked extrinsic compression of anterior cord. At surgery both C5–C6 herniated nucleus pulposus and adjoining C5 osteophyte were found.

D, MR image 4 weeks after anterior diskectomy and fusion shows interval appearance of small C6–C7 herniated nucleus pulposus.



A B

Fig. 5.—*A*, Sagittal MR image shows C6–C7 herniated nucleus pulposus (*arrow*).

B, CT myelogram at C6–C7 is markedly degraded by beam-hardening artifacts and was reported as nondiagnostic for herniated nucleus pulposus.

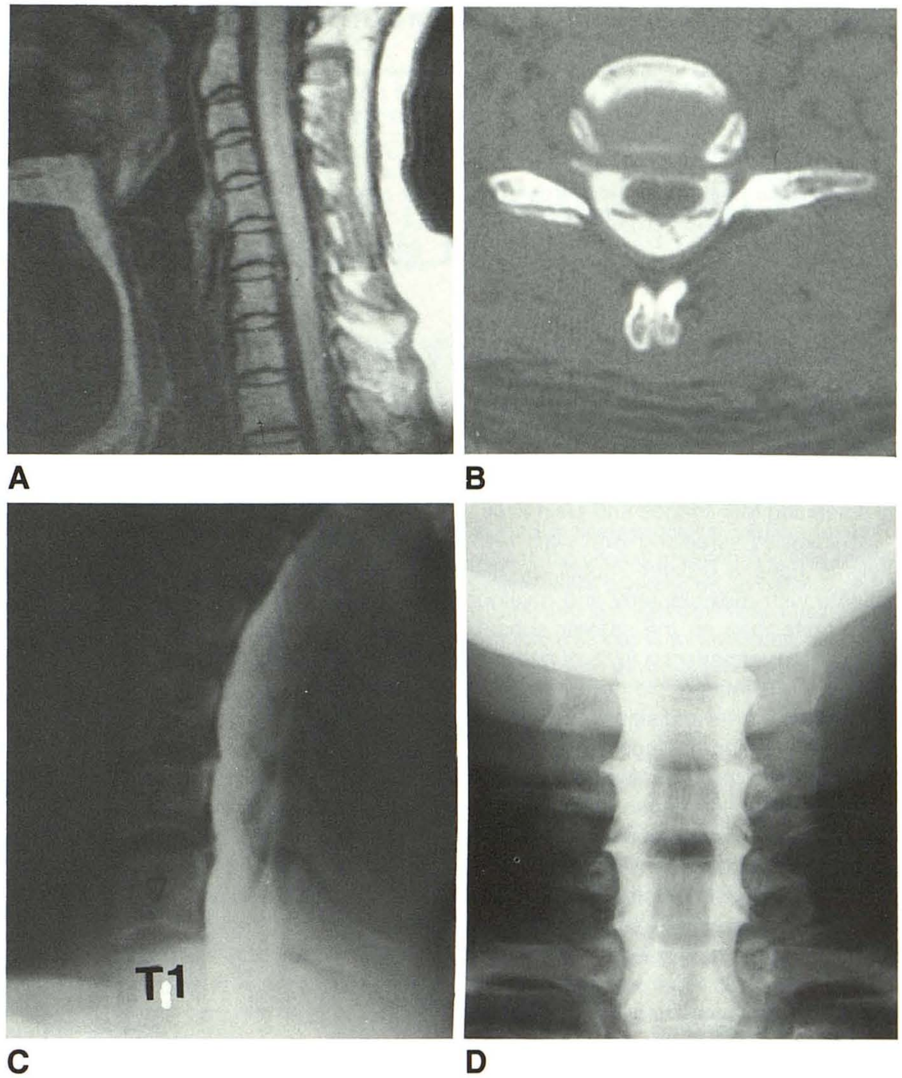


Fig. 6.—*A* and *B*, MR image (*A*) and CT myelogram (*B*) show herniated nucleus pulposus.

C, Lateral myelogram shows mild anterior extradural impression at C6–C7.

D, Anteroposterior myelogram fails to show nerve-root sleeve cutoff. Oblique views were normal. No disk herniation was predicted on myelography.

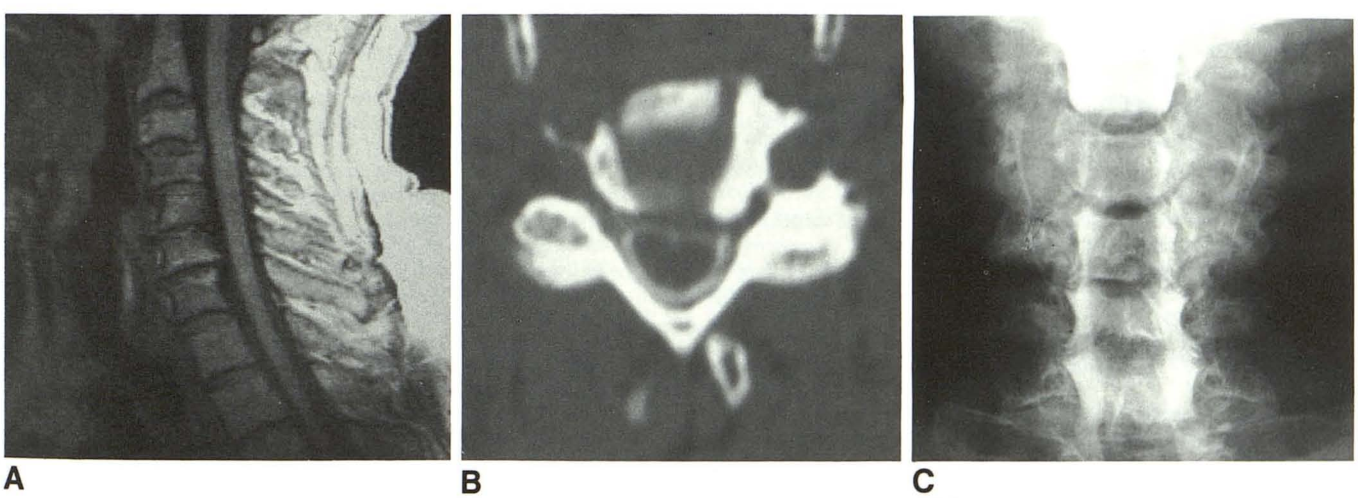


Fig. 7.—*A*, Sagittal MR image shows osteophytes at C3–C4 and C6–C7 causing bony stenosis of spinal canal. C4–C5 appears to be free of bony stenosis.

B, Axial CT myelogram through C4–C5 shows marked concentric stenosis at C4–C5, probably due to bulging of the anulus fibrosus and posterior longitudinal ligament hypertrophy.

C, Myelogram confirms stenosis at both C4–C5 and C3–C4. A four-level total laminectomy was performed from C3 to C7.

TABLE 2: Instances in Which Invasive Studies Were Replaced by MR Imaging

Lesion	MR plus Invasive Tests	MR plus Plain Films Only[a]
Cervical disk herniation	15	7
Bony canal stenosis	5	4
Intradural lesion	3	0
Total (%)	23 (67.6)	11 (32.4)

[a] Includes three cases studied by CT.

lower cervical spine are less common with MR than with CT myelography and because MR usually detects lower cervical HNPs missed on suboptimal CT myelograms. Selective follow-up by CT myelography appears capable of detecting operable cervical lesions missed in a small minority of patients by screening MR images and plain films.

Noninvasive screening with plain films and MR images is likely to have a greater impact on the total population of patients with radiculopathy and myelopathy referred for imaging tests than on the smaller subset of preoperative patients. In our experience 87% of patients screened with plain films and MR images did not undergo surgery because presenting symptoms and signs resolved with conservative management, imaging findings were normal or minimally abnormal, surgery was contraindicated, or surgery was declined. Although exact figures are unavailable, a substantial majority of nonoperative patients did not undergo myelography or CT myelography after plain-film and MR screening. We conclude that plain-film and MR screening with selective follow-up by CT myelography offers an accurate, low-risk, cost-effective strategy for detecting operable lesions in patients with cervical radiculopathy and myelopathy.

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