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Gd-DTPA–Enhanced MR Imaging of Spinal Tumors

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Forty-eight Gd-DTPA–enhanced MR examinations of the spine were performed in 40 patients referred for MR because of clinically suspected spinal tumor or for further evaluation of an expanded cord. The study group consisted of 32 patients with spinal tumors (seven ependymomas; seven astrocytomas; four hemangioblastomas; two arteriovenous malformations; two unidentified intramedullary neoplasms; four meningiomas; and single cases of metastatic breast carcinoma, cavernous hemangioma with associated hematomyelia, neurinoma, angiolipoma, drop metastasis from medulloblastoma, and epidermoid with diastematomyelia). In the remaining eight patients, other diagnoses were established: thoracic disk herniation (two patients), lumbosacral meningocele (one), syringomyelia secondary to arachnoiditis (four), and expanded cord secondary to gliotic tissue (one). All but two diagnoses were proved histologically by biopsy, surgery, or autopsy; in the two patients with arteriovenous malformations, the definitive diagnosis was made by spinal angiography. Contrast enhancement occurred in 30 of the 32 spinal tumors, and Gd-DTPA–enhanced T1-weighted images proved helpful in defining and outlining intra- and extramedullary spinal neoplasms. All ependymomas and astrocytomas (including low-grade astrocytomas) enhanced. In meningiomas, an immediate and uniform contrast uptake was demonstrated. Additional advantages of Gd-DTPA MR include the differentiation of solid tumor components vs syrinx or cyst or pseudotumoral areas of cord expansion, and the differentiation of residual or recurrent tumor from scar tissue in postoperative patients.

Our results suggest that IV-injected Gd-DTPA improves MR sensitivity and specificity in the evaluation of spinal lesions.

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Increasingly, MR imaging has become the method of choice in viewing the normal and diseased spinal cord. Although the effectiveness of MR imaging in the neuroradiologic evaluation of spinal tumors has been well documented, several problems remain unsolved: the low specificity of noncontrast MR, tumor vs edema differentiation, accurate delineation of the lesion, recognition of solid tumor nodule vs associated syrinx, and study of the postoperative spine. Several recent reports have indicated the usefulness of the paramagnetic MR contrast agent gadolinium-DTPA-dimeglumine (Gd-DTPA) in outlining spinal neoplasms [1–10]. The purpose of the present study of 40 patients was to determine to what extent the use of Gd-DTPA increases both the MR sensitivity in defining and localizing spinal tumors and the MR specificity in the diagnosis of spinal lesions.

Subjects and Methods

Forty-eight Gd-DTPA–enhanced MR examinations of the spine were performed in 40 patients with suspected spinal neoplasm (six patients had Gd-DTPA–enhanced studies both before and after surgery; one patient had three examinations). All patients were referred for MR, either because of clinically suspected spinal tumor or for further investigation of an expanded cord as detected by myelography, CT, or CT-myelography; spinal arteriography was performed in two patients. The patient population included 19 males and 21 females, 14–72 years old (mean age, 44.8).

TABLE 1: Histologic Diagnoses and Results of Gd-DTPA–Enhanced MR Imaging

Case No.	Age	Gender	Level	Diagnosis (Histology)	Enhancement
Intramedullary tumors:					
1	27	M	T10–T11	Ependymoma (grade 3)	+
2	58	F	C6–C7	Ependymoma	+
3	58	M	C5–T1	Ependymoma (grade 2)	+
4	39	F	C7–T1	Ependymoma	+
5	40	M	C2–C5	Ependymoma	+
6	35	F	C2–C5	Ependymoma (poorly differentiated)	+
7	47	F	C1–T1	Ependymoma	+
8	21	M	C1–C5	Astrocytoma (low grade)	+
9	15	F	C1–C3	Astrocytoma (low grade)	+
10	33	M	T9–T12	Astrocytoma (grade 2)	+
11	68	M	Conus medullaris	Astrocytoma (grade 1)	+
12	22	F	C1–C4	Astrocytoma (low grade)	+
13	28	F	Conus medullaris	Astrocytoma (low grade)	+
14	60	M	T9–L1	Astrocytoma (low grade)	±
15	64	F	C2–C3	Unidentified intramedullary tumor + syrinx	+[a]
16	14	F	C4–C6	Unidentified intramedullary tumor (patient with neurofibromatosis)	+[a]
17	48	F	C4–C6	Metastasis from breast carcinoma	+
18	23	M	C5–C6	Hemangioblastoma + large syrinx	+
19	38	M	C4–C7	Hemangioblastoma + large syrinx	+
20	45	M	C7–T1 and T9–T10	Multiple hemangioblastomas + large syrinx (von Hippel–Lindau syndrome)	+
21	72	M	T6	Hemangioblastoma + associated syrinx	+
22	64	F	T5–T6	Cavernous hemangioma + hematomyelia	−
23	29	M	C4–C6	Arteriovenous malformation	+[b]
24	66	M	T7–T8	Arteriovenous malformation	+[b]
Extramedullary tumors:					
25	34	F	C1–C3	Meningioma	+
26	66	M	C1–C2	Meningioma	+
27	56	F	T3–T4	Meningioma	+
28	57	F	T3	Meningioma (psammomatous type)	+
29	50	F	L3–L4	Neurinoma	+
30	55	F	Sacrum	Drop metastasis from medulloblastoma	+
31	29	F	T12–L5	Epidermoid + diastematomyelia	−
32	37	F	T4–T8	Angiolipoma (posterior extradural space)	+
Other extramedullary lesions:					
33	20	F	L5–sacrum	Lumbosacral meningocele	−
34	55	F	T8–T9	Disk herniation	−[c]
35	51	M	T6–T7	Disk herniation	−[c]
Tumorlike conditions:					
36	57	M	T3–T10	Syringomyelia secondary to arachnoiditis	−
37	59	M	T3–T7	Syringomyelia secondary to arachnoiditis	−
38	62	M	T5–L1	Syringomyelia secondary to arachnoiditis	−
39	28	F	T4–T8	Syringomyelia secondary to arachnoiditis	−
40	62	M	C1–C6	Gliosis (unspecified)	±

[a] No definitive histology available.

[b] In the two patients with arteriovenous malformations, the definitive diagnosis was made by spinal angiography. In the 38 other patients the diagnosis was established histologically by biopsy, surgery, or autopsy.

[c] The thoracic disk as such did not enhance, but enhancement of the posterior longitudinal ligament was observed, as well as triangular areas of contrast uptake above and below the herniated disk. At surgery, these areas were found to correspond to engorged epidural veins with stagnant blood flow and vascular granulation tissue along the inflamed posterior ligament.

After obtaining written informed consent, a standard Gd-DTPA-dimeglumine solution* was injected IV in a dosage of 0.1 mmol/kg body weight. There is evidence that this is a well-tolerated and effective dose for MR imaging [11–15]. All examinations were performed on a superconductive unit,† initially operating at a 0.5 T field strength (10 patients) and subsequently at 1.5 T (30 patients).

Both T1- and T2-weighted images were obtained before contrast administration with the use of spin-echo sequences, 250–600/30 and 2000/30, 100 (TR/TE), respectively. After IV Gd-DTPA injection, sequential T1-weighted scans were obtained with short TR spin-echo sequences and in some instances a fast-field-echo technique. All patients were examined within 5–40 minutes after administration of Gd-DTPA. The acquisition matrix was 256 × 256 with two to four averages. The slice thickness was 5 mm in all instances. Patient tolerance to the Gd-DTPA injection was excellent. There were no side effects during the MR examination or in the subsequent 24–48 hr. Patients with impaired renal and/or hepatic function were excluded from the study.

* Schering AG, Berlin, W. Germany.

† Gyroscan S15, Philips Medical Systems, Eindhoven, Netherlands.

Results

Our results are summarized in Table 1. Spinal tumors were identified in 32 of 40 patients, including seven ependymomas

(cases 1–7); seven astrocytomas (cases 8–14); two unidentified intramedullary neoplasms (cases 15 and 16; case 16 was a patient with neurofibromatosis who presented with a large posterior fossa meningioma and an unidentified cervical intramedullary tumor); metastatic breast carcinoma (case 17); five hemangioblastomas with a large syrinx cavity (cases 18–21); cavernous hemangioma with associated hematomyelia (case 22); two arteriovenous malformations (cases 23 and 24); four meningiomas (cases 25–28); and single cases of neurinoma (case 29), drop metastasis from posterior fossa medulloblastoma (case 30), epidermoid with associated diastematomyelia (case 31), and angiolipoma (case 32). All except two diagnoses were established histologically (biopsy, definitive surgery, or autopsy). All tumors showed contrast enhancement with Gd-DTPA, except for the epidermoid and the cavernous hemangioma.

Thoracic disk herniations were found in two patients (cases 34 and 35) and a large lumbosacral meningocele was found in one patient (case 33).

The remaining five patients had tumorlike conditions (widening of the cord on nonenhanced MR scans), but no evidence of an underlying neoplastic lesion was found. This group included four patients (cases 36–39) with a syrinx cavity and irregular thickening of the cord secondary to arachnoiditis, initially believed to represent an intramedullary neoplasm. The lesions did not enhance. The diagnosis was surgically confirmed in all four patients. One patient (case 40) was diagnosed as having an infiltrating intramedullary tumor on nonenhanced MR; there was heterogeneous contrast enhancement throughout the cervical spine. A surgical biopsy revealed diffuse gliosis, without evidence of a true neoplasm.

Discussion

Intramedullary Tumors

The diagnostic usefulness of paramagnetic contrast agents such as Gd-DTPA in the evaluation of intraaxial (i.e., intramedullary) gliomas is based on the fact that they do not cross the intact blood-brain barrier (BBB). Thus, in order for a tumor to enhance, there must be an active breach of the BBB. Because the hydrophilic contrast agent, which has a high molecular weight, leaks out of the vascular compartment into the interstitial spaces, progressive contrast enhancement is to be expected. This gradual increase in signal intensity produced by Gd-DTPA on T1-weighted images reaches a plateau and then signal intensity drops slowly. This pattern has been well established in brain tumors [16]. Variations in time-dependent contrast enhancement have also been described in spinal tumors [17].

In summary, Gd-DTPA is a marker for alterations of the BBB, like a conventional CT contrast agent.

Ependymomas ($n = 7$) are seen on plain MR studies as areas of widening of the cord. On T1-weighted images, ependymomas are isointense with respect to the spinal cord; therefore, their boundaries are difficult to define, unless they are outlined, as is sometimes the case, by syrinx cavities capping the upper and lower poles of the tumor. On T2-weighted sequences, ependymomas may have a multinodular appearance, but the differentiation of tumor vs surrounding edema is virtually impossible, since both have prolonged T2 relaxation times, presumably reflecting increased water content.

The use of Gd-DTPA allows better definition of the upper and lower limits of these intramedullary tumors. In our experience, ependymomas as a rule showed intense, homogeneous, and sharply marginated focal enhancement (Fig. 1). They tend to occupy the whole width of the spinal cord in the affected segment, which is consistent with a centrifugal expansion originating in the ependymal cells lining the central canal or in cellular components scattered in the white matter of the spinal cord.

In some instances, ependymomas have intratumoral cavities. In these cases, Gd-DTPA not only brings out superb tumor-border definition but is also highly accurate in the delineation of central low-signal-intensity components, corresponding to intratumoral cysts [1]. These areas of cystic degeneration were identified after Gd-DTPA injection in three of seven ependymomas in our series and subsequently confirmed at surgery.

Conversely, astrocytomas ($n = 7$) tend to enhance in a more patchy, irregular way, consistent with a more diffusely infiltrating tumor. All astrocytomas, even low-grade astrocytomas, did enhance. The areas of contrast enhancement are often eccentrically located (usually in the posterior aspect of the spinal cord) and are less well defined with slightly fuzzy margins; they may be separated by regions of low signal intensity consistent with areas of necrosis or cystic change (Fig. 2). In addition, in some astrocytomas an exophytic tumor component may be identified as an area of contrast enhancement, which could be verified readily at surgery.

These slightly different patterns of contrast uptake had initially suggested that Gd-DTPA might prove to be a useful tool in predicting the histology of intraspinal neoplasms. However, there is considerable overlap. Of particular interest are some of the errors we made when using our own criteria as described above. Figure 3 illustrates the case of a 28-year-old woman with a tumor at the level of the conus medullaris that showed marked, homogeneous, and sharply marginated contrast enhancement both on sagittal and coronal sequences. The tumor appeared very well defined. We expected this tumor to be an ependymoma, especially since ependymomas (particularly of the myxopapillary type) are common in this location. Surgery revealed an infiltrating intramedullary lesion; there was no clear cleavage plane and the tumor could not be completely resected. Pathologic examination showed a well-differentiated (low-grade) astrocytoma. A follow-up Gd-DTPA–enhanced MR scan was clearly superior to plain MR in the delineation of residual tumor tissue (Figs. 3E and 3F).

Conversely, in one patient with an ependymoma, the slightly inhomogeneous pattern of contrast enhancement as well as the asymmetric appearance of the tumor led us initially to consider a low-grade astrocytoma as the first differential diagnosis.

In summary, although we did find different patterns of contrast enhancement in some ependymomas and astrocy-

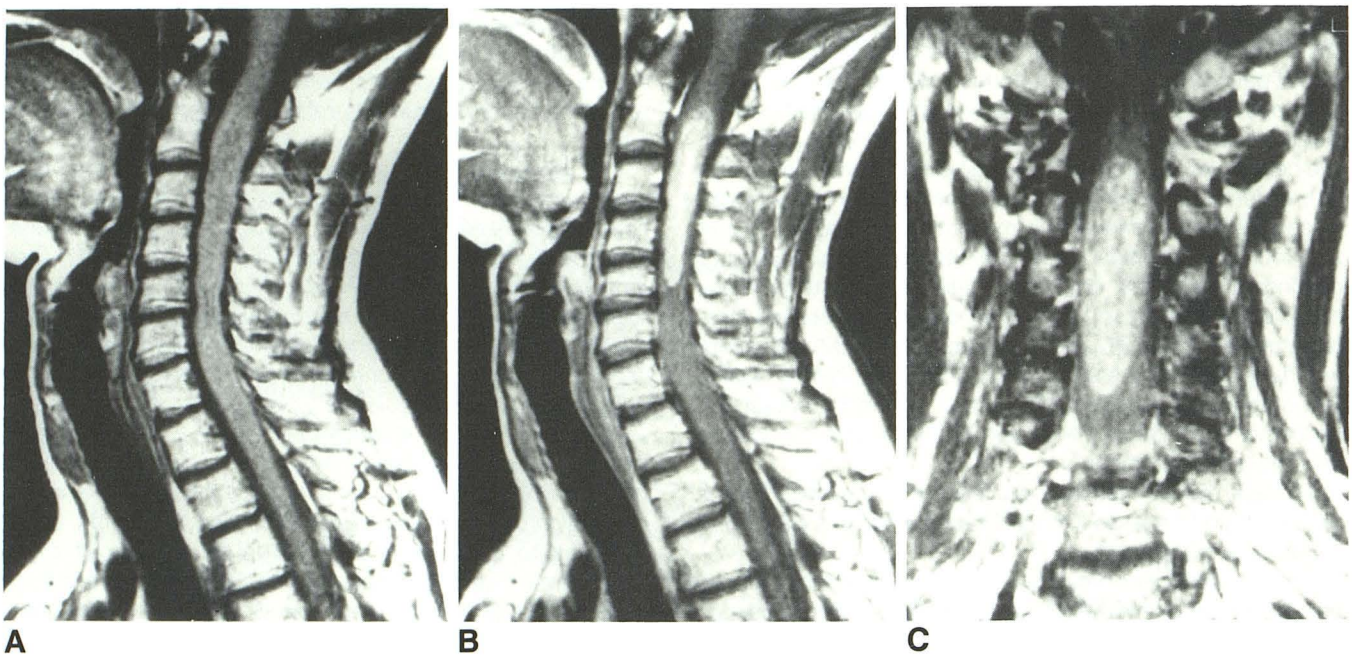

Fig. 1.—Case 6: Ependymoma.

A, Nonenhanced sagittal T1-weighted spin-echo image, 400/30, reveals widening of cervical cord from C1 to T2, suggesting intramedullary tumor.

B, Sagittal T1-weighted spin-echo image, 400/30, immediately after Gd-DTPA injection shows well-defined, oval area of contrast uptake extending from C2 to C5.

C, Enhancing lesion is confirmed on coronal T1-weighted spin-echo image, 400/30, 13 min after contrast injection.

At surgery, an ependymoma was found, sharply defined and limited to region of contrast uptake. Swelling of cord above and below tumor was found to represent edema.

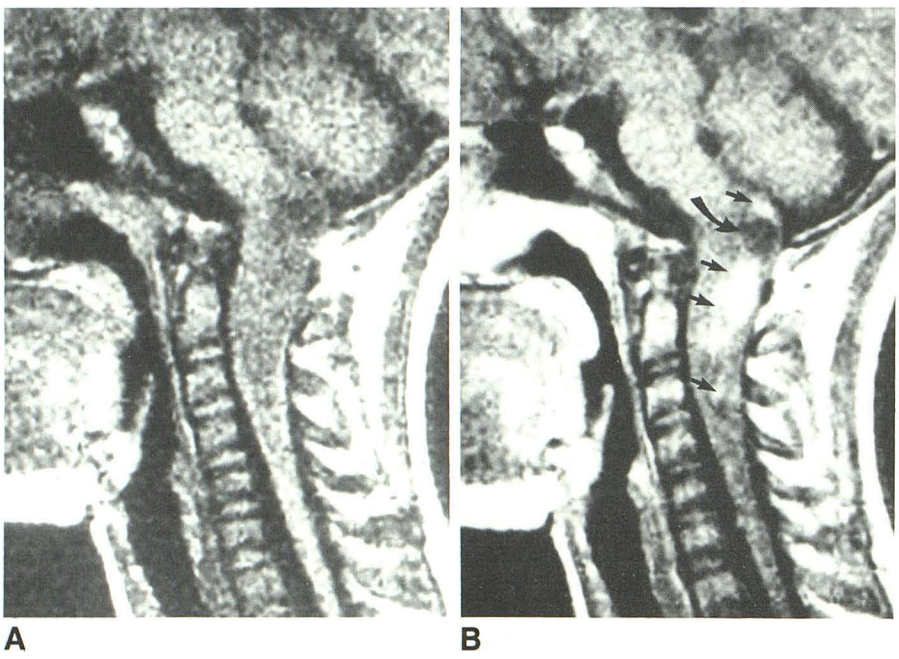

Fig. 2.—Case 9: Partially cystic low-grade astrocytoma.

A, Precontrast sagittal T1-weighted spin-echo image, 250/30, shows widening of upper cervical spinal cord with relatively low-signal-intensity area extending into medulla oblongata.

B, Postcontrast T1-weighted spin-echo image, 250/30, shows irregular areas of contrast uptake (*straight arrows*), with predilection for posterior aspect of cord. Hypointense, presumably cystic component is seen posteriorly (*curved arrow*) at junction of upper cervical cord and medulla oblongata. The use of Gd-DTPA allows sharp demarcation between nonenhancing cystic-necrotic component and enhancing tumor infiltration.

At surgery, partially cystic well-differentiated low-grade astrocytoma was discovered.

tomas, as described earlier, an accurate prediction of tumor histology is impossible. At the present time, we must conclude that these two neoplasms cannot be differentiated by MR. Both histologic types can be either solid or cystic with nodules [18].

In a patient with an intramedullary metastasis (metastatic breast carcinoma), the precontrast MR examination (T1- and T2-weighted images) revealed widening of the cord contour and changes in signal intensity. After Gd-DTPA administration, a small localized enhancing nodule was discovered. This

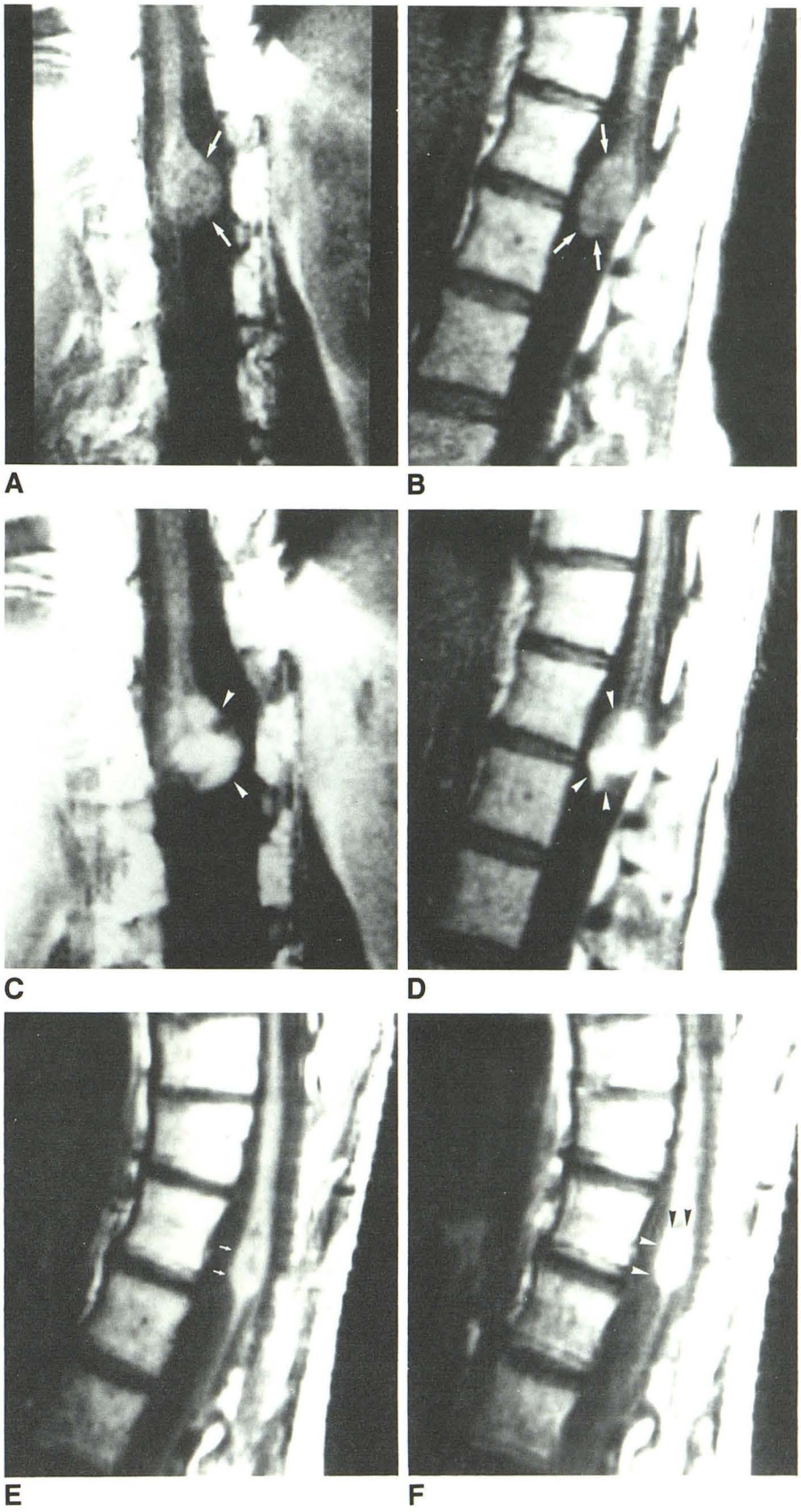

Fig. 3.—Case 13: Low-grade astrocytoma.

A and *B*, Nonenhanced coronal (*A*) and sagittal (*B*) T1-weighted spin-echo images, 400/30, of thoracolumbar spine. Mass lesion is clearly identified (*arrows*). Tumor is appended to conus medullaris and is lateralized to left, displacing upper part of cauda equina to right.

C and *D*, After Gd-DTPA administration, coronal (*C*) and sagittal (*D*) T1-weighted spin-echo images, 400/30, show sharply defined, homogeneous contrast uptake throughout tumor (*arrowheads*). At surgery, a low-grade astrocytoma was partially resected; there was no cleavage plane.

E, Nonenhanced sagittal T1-weighted image 3 months after surgery shows increased diameter of conus medullaris (*arrows*), with heterogeneous signal intensity.

F, After Gd-DTPA injection, residual tumor appears as sharply marginated area of contrast uptake (*arrowheads*), clearly outlined from conus medullaris.

finding indicates that much of the cord enlargement is due to perifocal edema.

In the patients with hemangioblastoma (n = 5, in four patients), noncontrast MR displayed irregular and diffuse widening of an apparently infiltrated spinal cord in its cervical and thoracic segments. The intrinsic cord signal was heterogeneous, with low-intensity areas supposedly representing a vast syrinx cavity, alternating with isointense areas of thickening of the cord. In one patient, the syrinx extended from the upper cervical to the lower thoracic cord.

The use of IV-administered Gd-DTPA allows accurate recognition of the highly vascular tumor nidus within a large area of cystic change, thus providing the neurosurgeon with very useful information and directing surgery to the level of the solid tumor component. Some authors have described how the signal characteristics of a tumor nodule may be separated from those of the cyst by using long TR and long TE sequences, since the T2 of the cyst is usually longer [8, 18]. However, in our experience, T2-weighted pulse sequences also are more apt to show artifacts and often are of poorer quality; the Gd-DTPA–enhanced T1-weighted image was superior in highlighting a vascular tumor nodule within an associated cyst. In our limited experience, the association of a strongly enhancing solid tumor nodule within a vast syrinx is very suggestive of hemangioblastoma.

In the patient with a cavernous hemangioma, plain MR revealed an ovoid intramedullary lesion with heterogeneous signal characteristics. A large area of hematomyelia extended below the lesion. The mixed high- and low-signal-intensity components of cavernous hemangiomas presumably indicate the presence of mixed subacute and chronic hemorrhage [19]. After IV Gd-DTPA administration, no definite contrast uptake could be seen. It is likely that in this patient the characteristic crescent-shaped high-signal-intensity hemorrhagic focus (as a result of the formation of methemoglobin) and the surrounding low-signal rim (important concentration of hemosiderin) may mask an area of contrast uptake [8].

The arteriovenous malformations (n = 2) had a markedly heterogeneous appearance, both on the pre- and postcontrast MR examinations, due to the presence of old hemorrhagic components and calcifications. The lesions contained serpiginous areas of signal void, reflecting vascular structures with rapidly flowing blood. There was some contrast uptake after Gd-DTPA injection. The final diagnosis was made by spinal angiography.

Extramedullary Intradural Tumors

The mechanism of contrast enhancement in extraaxial tumors is different, since these lesions have no BBB. Therefore, the degree of T1 shortening after IV injection of Gd-DTPA is a function of tumor vascularization, in much the same way that highly vascular extraaxial tumors such as meningiomas and neurinomas will enhance on CT. Theoretically, one might predict a more immediate contrast enhancement, as opposed to the progressive contrast enhancement in intraaxial gliomas, which is based on the gradual leaking of Gd-DTPA molecules through a ruptured BBB.

Meningiomas (n = 4) most often appear isointense with respect to the spinal cord on nonenhanced T1-weighted images and may have a slightly higher signal intensity on T2-weighted images [20, 21]. The isointense mass may be seen in a typical extramedullary intradural location displacing and compressing the cord.

After IV injection of Gd-DTPA, and with the use of a fast-field-echo technique to obtain rapid sequential scans, we could demonstrate immediate and uniform contrast enhancement, as evidenced by marked T1 shortening (Fig. 4). Indeed, because meningiomas are highly vascular extraaxial lesions and have no BBB, they are ideal candidates for enhancement with a paramagnetic contrast agent [22, 23]. This type of contrast uptake is similar to what is reported in the CT literature.

Our series included one patient with a neurinoma, at the left L3–L4 level. After injection of Gd-DTPA, the lesion enhanced homogeneously.

Gd-DTPA has also been reported to be helpful in the evaluation of metastatic disease of the spine, including leptomeningeal tumor spread, where contrast-enhanced MR scans were far superior to examinations performed without contrast agents [24–26]. Our series included one patient with a drop metastasis from a vermian medulloblastoma (Fig. 5). The lesion is identified on T1-weighted images as a mass lesion within the sacral canal, encasing and narrowing the distal caudal sac. There is marked destruction of the sacrum. The T2-weighted images reveal heterogeneous signal intensity within the tumor. After Gd-DTPA injection, areas of T1 shortening are identified; at surgery they are found to be richly vascularized parts of an otherwise highly vascular drop metastasis of a medulloblastoma. The areas of enhancement correlate well with the regions of prolonged T2 on T2-weighted images.

No contrast enhancement was seen in a single patient with an intradural epidermoid (with associated diastematomyelia) in the lumbar spine. These congenital tumors with associated bony malformations are essentially avascular in nature and therefore do not enhance.

Extradural Lesions

Marked contrast uptake was present in a patient with a large tumor in the posterior extradural space, extending from T4 to T8. At surgery this lesion was found to be an angiolipoma.

In two patients with suspected spinal tumor, thoracic disk herniations were found. The herniated disk material as such did not enhance. However, in both patients we observed triangular areas of contrast uptake above and below the herniated disk, as well as enhancement of the posterior longitudinal ligament. At surgery they were found to correspond to engorged epidural veins with stagnant blood flow and vascular granulation tissue along the inflamed posterior longitudinal ligament.

Tumorlike Conditions

Of particular interest were four cases of syringomyelia secondary to arachnoiditis. In these patients, nonenhanced

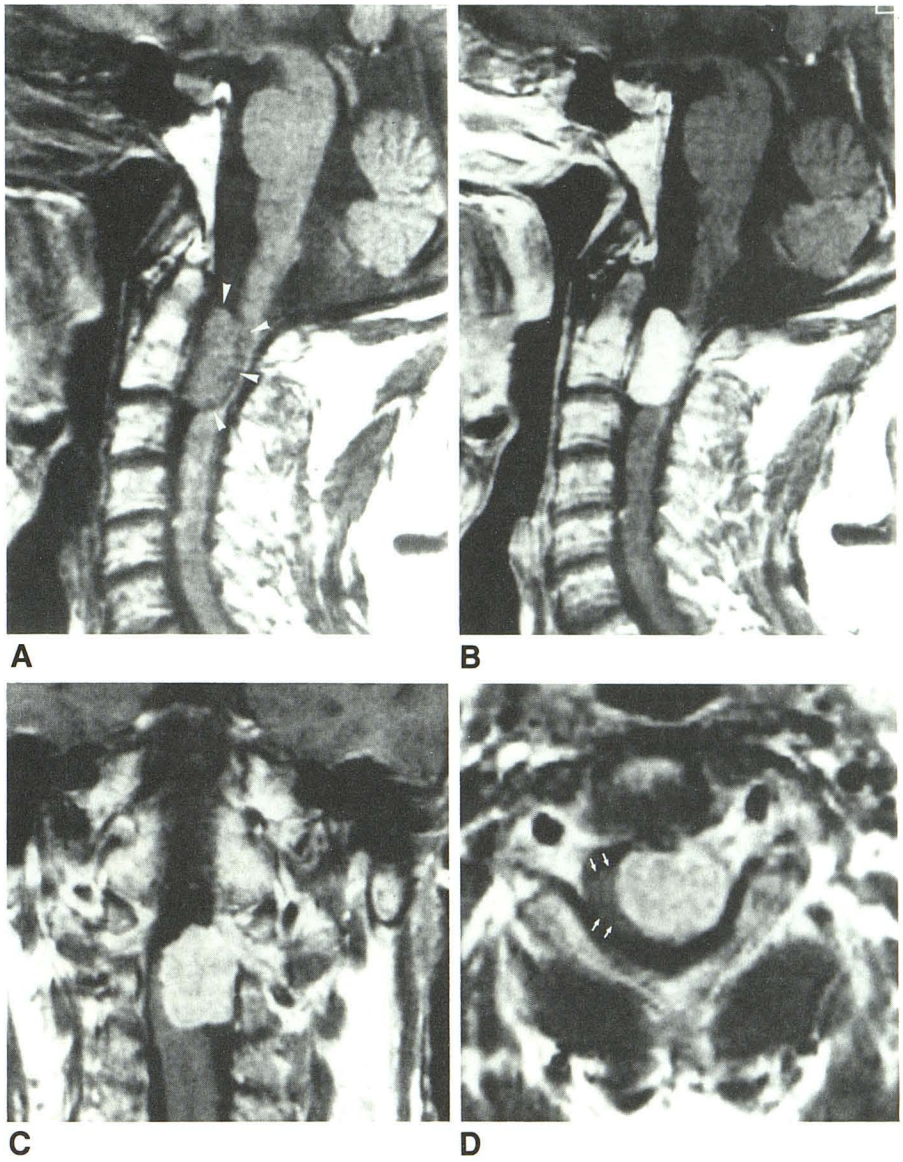

Fig. 4.—Case 26: Meningioma.

***A*, Nonenhanced sagittal T1-weighted image, 600/30, cervical spine shows soft-tissue mass (*arrowheads*), which is slightly hypointense with respect to spinal cord.**

***B–D*, After IV injection of Gd-DTPA, sagittal (*B*), coronal (*C*), and axial (*D*) T1-weighted images, 600/30, reveal rapid, intense, and homogeneous contrast uptake, providing superior discrimination between tumor and cord. Note enhancement of thickened dura behind C2 vertebral body (*B*). Tumor has typical intradural extramedullary topography. Spinal cord is flattened and displaced posteriorly and to the right (*arrows*).**

The lesion was a meningioma at C1–C2.

MR was highly suggestive of intramedullary tumor: focal swelling of the spinal cord and central low-signal area compatible with an area of necrotic/cystic change (Fig. 6). However, whereas in our experience the majority of intramedullary tumors did enhance, no T1 shortening was seen in these cases after Gd-DTPA injection. In two patients (cases 36 and 37), the arachnoiditis was presumed to be secondary to an episode of tuberculous meningitis many years before; one patient (case 38) had a history of spinal trauma. The patient illustrated in Figure 6 (case 39) was clinically asymptomatic and underwent the MR examination as a "normal" volunteer. Surgical exploration revealed an area of adhesive arachnoiditis covering the cord, with a subjacent syrinx, but no tumor could be identified. No specific cause for the arachnoiditis was identified. This early experience suggests that Gd-DTPA can help to distinguish neoplastic from benign disease.

In one patient MR was suggestive of an intramedullary tumor. There was minimal heterogeneous contrast enhancement throughout the cervical spine. A surgical biopsy revealed what was broadly defined as "gliotic tissue," but no true neoplasm could be found (case 40).

No contrast enhancement was present in a lumbosacral meningocele that initially was misdiagnosed as a spinal tumor, because the cyst fluid had signal characteristics different from those of CSF.

In conclusion, paramagnetic contrast agents such as Gd-DTPA offer a means of positive contrast enhancement of spinal tumors, as opposed to the displacement of contrast material in myelography and CT-myelography. There is little doubt that Gd-DTPA–enhanced MR imaging is superior to plain MR (T1- and T2-weighted images) in the diagnosis and anatomic definition of spinal lesions and in assessing tumor vascularity [4, 5, 7, 9, 10]. The increased sensitivity of Gd-DTPA–enhanced MR examinations of the spine is the result of several factors: greater inherent tissue contrast with improved tumor border definition, possibility of lesion vs edema differentiation, identification of foci of necrosis, and intratumoral cystic components.

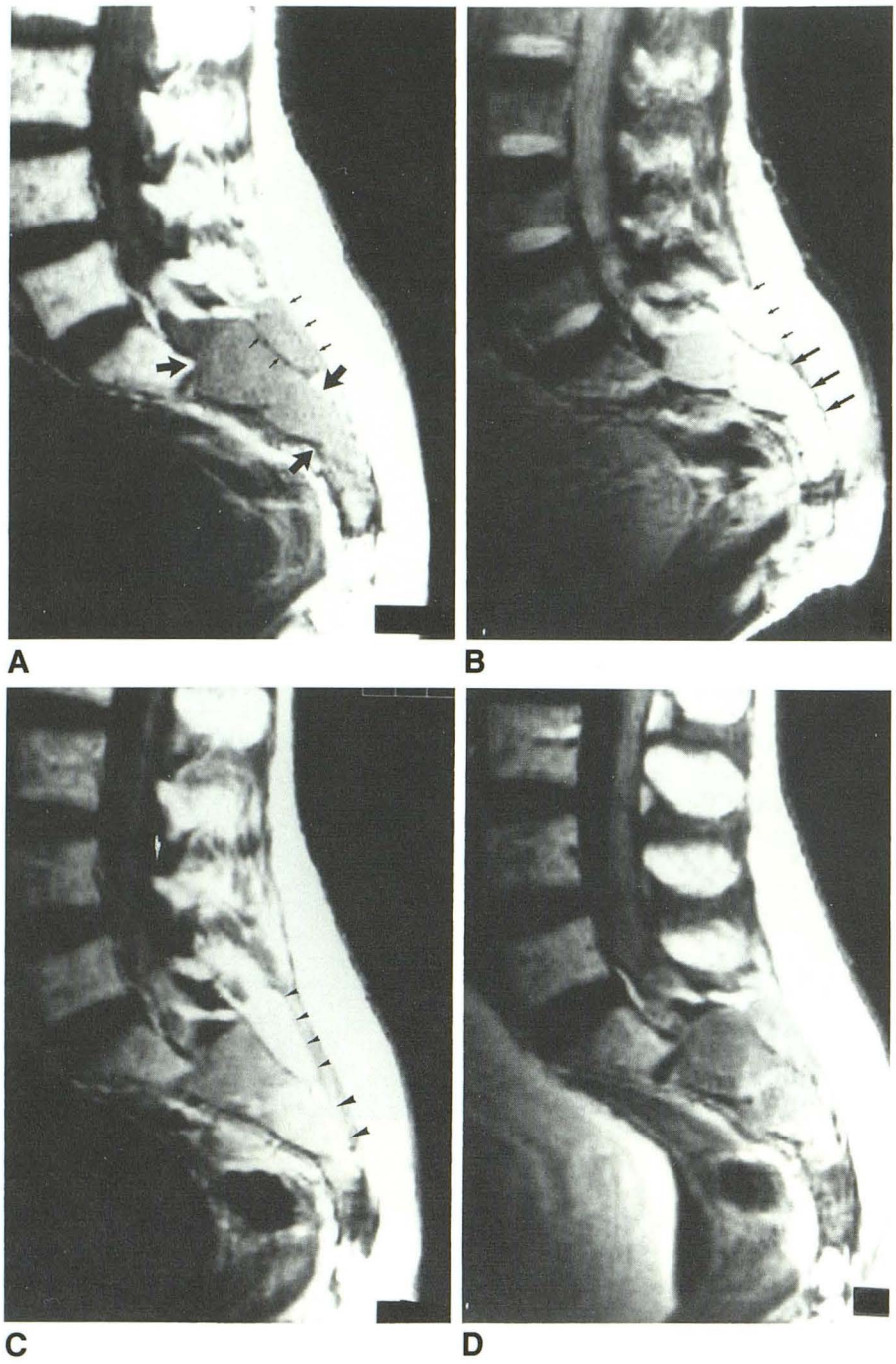

Fig. 5.—Case 30: Drop metastasis from posterior fossa medulloblastoma.

***A*, Nonenhanced sagittal T1-weighted image, 400/30, displays mass lesion with large anterior component infiltrating in sacral canal and destroying bone (*large arrows*) and smaller posterior component (*small arrows*).**

***B*, Moderately T2-weighted image, 2000/50, reveals heterogeneous signal intensities within tumor. Posterior component (*small arrows*) and inferior portion of intrasacral lesion (*large arrows*) are markedly hyperintense.**

***C*, Sagittal T1-weighted spin-echo image, 400/30, 3 min after IV injection of Gd-DTPA. Contrast uptake is seen to correspond to those regions that had a prolonged T2 (*arrowheads*).**

***D*, 13 min after injection, degree of enhancement has diminished, but differences in contrast uptake between different parts of tumor remain.**

Surgery revealed strongly vascularized drop metastasis from posterior fossa medulloblastoma.

It has been suggested that precontrast T2-weighted images might be more sensitive than postcontrast T1-weighted images, since the former identify all lesions with an increased water content, both with and without an active BBB breakdown, whereas the contrast enhancement in the latter depends on an active disruption of the BBB and a viable blood supply. This may be true in the brain, but in the spine our experience shows that the Gd-DTPA–enhanced MR studies were superior to scans obtained without contrast material. Indeed, even when the disease is obvious on a standard MR scan and the lesion is clearly identified on the T2-weighted image, a Gd-DTPA–enhanced study may still be useful in helping to characterize the lesion or in tumor vs edema differentiation. In addition, the enhanced spin-echo T1-weighted images have shorter acquisition times and fewer artifacts than do the longer T2-weighted spin-echo images, thereby allowing more accurate visualization of spinal lesions.

The improved visualization and delineation of spinal tumors on the Gd-DTPA–enhanced MR examination often guides the neurosurgical approach [10]. We found this to be particularly

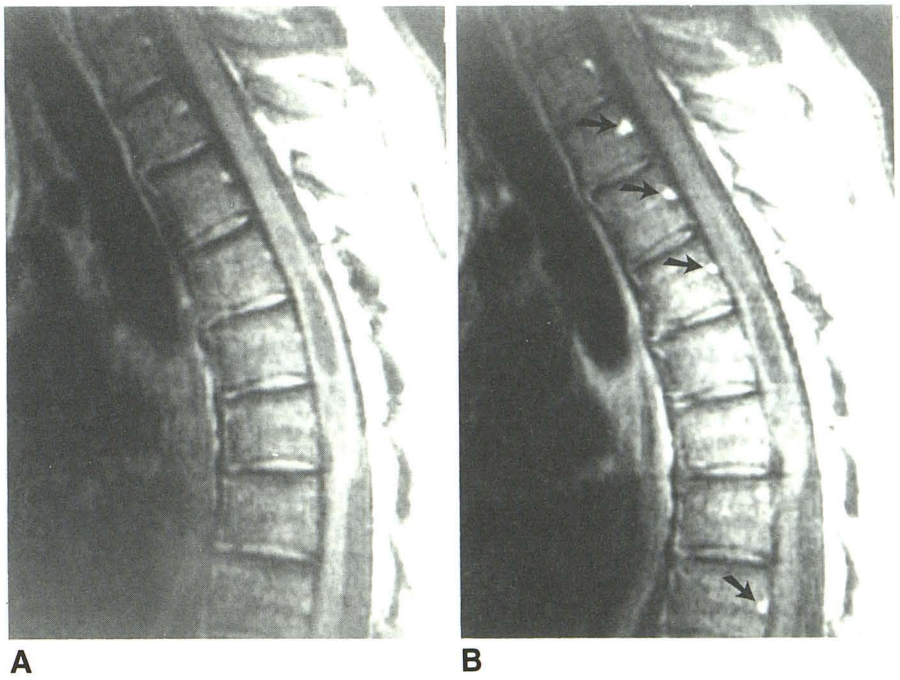

Fig. 6.—Case 39: Adhesive arachnoiditis with syrinx.

***A*, Nonenhanced sagittal T1-weighted image, 400/30, shows increased diameter of midthoracic spinal cord with central area of cavitation. Posterior subarachnoid spaces are partially obliterated. Intramedullary tumor was suspected.**

***B*, After IV injection of Gd-DTPA, no contrast uptake is seen within intramedullary lesion (identical pulse sequence). Note enhancement of basivertebral veins (*arrows*).**

Surgical exploration revealed adhesive arachnoiditis, with syrinx cavity, believed to be secondary to arachnoiditis. There was no intramedullary tumor.

true for lesions with a solid enhancing tumor nodule within an associated intramedullary cavity (e.g., hemangioblastoma).

Another very promising result appears to be the possibility of differentiating residual or recurrent tumor from scar tissue in the postoperative spine [4, 7, 9].

We conclude that Gd-DTPA–enhanced MR imaging improves the reliability of spinal tumor diagnosis and increases MR sensitivity and specificity. It is still too early to conclude whether the pattern of enhancement may contain characteristic or even pathognomonic information regarding the differential diagnosis of intramedullary tumors (ependymoma vs astrocytoma). On the other hand, our findings show that contrast enhancement does occur in the vast majority of tumors, enabling differentiation of cystic tumor from nontumoral cyst or syrinx [6, 27, 28], including pseudotumoral syringomyelia secondary to arachnoiditis. In this way, Gd-DTPA can help differentiate neoplastic tissue from benign disease.

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REFERENCES

1. Bydder GM, Brown J, Niendorf HP, Young IR. Enhancement of cervical intraspinal tumors in MR imaging with intravenous gadolinium-DTPA. *J Comput Assist Tomogr* **1985**;9(5):847–851
2. Yoshikawa K, Aoki S, Momose T, et al. Gd-DTPA as contrast agent in MR imaging of spinal intramedullary tumors. Presented at the annual meeting of the Society of Magnetic Resonance in Medicine, Montreal, Canada, August **1986**
3. Fenzl G, Lissner J, Heywang SH, et al. MR of spinal lesions with Gd-DTPA as contrast medium. Presented at the annual meeting of the Society of Magnetic Resonance in Medicine, Montreal, Canada, August **1986**
4. Treisch J, Claussen C, Massih M, Kornmesser W, Felix R. Intraspinal tumours in plain and Gd-DTPA-enhanced magnetic resonance imaging. Presented at the annual meeting of the Society of Magnetic Resonance in Medicine, Montreal, Canada, August **1986**
5. Stimac GK, Porter BA, Olson DO, Gerlach R, Genton M, Nelson S. Gadolinium DTPA/dimeglumine-enhanced MR of spinal neoplasms: preliminary experience. Presented at the annual meeting of the Society of Magnetic Resonance in Medicine, New York City, August **1987**
6. Jenkins JPR, Stack JP, Watson Y, Isherwood I. Magnetic resonance imaging of spinal lesions: the role of gadolinium-DTPA. Presented at the annual meeting of the Society of Magnetic Resonance in Medicine, New York City, August **1987**
7. Balériaux D, Parizel PM, Niendorf HP, Rodesch GL, Segebarth C. Value of intravenous Gd-DTPA contrast injection in the MRI evaluation of spinal tumors. Presented at the annual meeting of the American Society of Neuroradiology, New York City, May **1987**
8. Sigal R, Halimi Ph, Doyon D, Hurth M, Pigeau I, Thibault M. High-field MR imaging of spinal cord tumors using contrast media. Presented at the annual meeting of the Radiological Society of North America, Chicago, November **1987**
9. Dillon WP, Bolla K, Mark AS, Tsudura JS, Norman D, Newton TH. Gd-DTPA MR imaging enhancement of spinal cord tumors. Presented at the annual meeting of the Radiological Society of North America, Chicago, November **1987**
10. Valk J. Gd-DTPA in MR of spinal lesions. *AJNR* **1988**;9:345–350, *AJR* **1988**;150:1163–1168
11. Laniado M, Weinmann HJ, Schorner W. Felix R, Speck U. First use of Gd-DTPA/dimeglumine in man. *Physiol Chem Phys Med NMR* **1984**;16:157–165
12. Weinmann HJ, Laniado M, Mutzel W. Pharmacokinetics of Gd-DTPA/dimeglumine after intravenous injection into healthy volunteers. *Physiol Chem Phys Med NMR* **1984**;16:167–172
13. Weinmann HJ, Brasch RC, Press WR, Wesbey GE. Characteristics of gadolinium-DTPA complex: a potential NMR contrast agent. *AJR* **1984**;142:619–624
14. Carr DH, Brown J, Bydder GM, et al. Gadolinium-DTPA as a contrast agent in MRI: initial clinical experience in 20 patients. *AJR* **1984**;143:215–224

15. Carr DH, Brown J, Bydder GM, et al. Intravenous chelated gadolinium as a contrast agent in NMR imaging of cerebral tumors. *Lancet* **1984**;1: 484–486
16. Schorner W, Laniado M, Niendorf HP, Schubert C, Felix R. Time-dependent changes in image contrast in brain tumors after gadolinium-DTPA. *AJNR* **1986**;7:1013–1020
17. Laniado M, Kornmesser W. Treisch J, Felix R, Deimling M. Gd-DTPA–enhanced fast magnetic resonance imaging of brain and spinal tumors: early clinical experience. In: Runge VM, et al., ed. *Contrast agents in magnetic resonance imaging. Proceedings of an international workshop, January 1986, San Diego, California*. Amsterdam: Excerpta Medica, **1986**:136–140
18. Scotti G, Scialfa G, Colombo N, Landoni L. Magnetic resonance diagnosis of intramedullary tumors of the spinal cord. *Neuroradiology* **1987**;29: 130–135
19. Fontaine S, Melanson D, Cosgrove R, Bertrand G. Cavernous hemangiomas of the spinal cord: MR imaging. *Radiology* **1988**;166:839–841
20. Scotti G, Scialfa G, Colombo N, Landoni L. MR imaging of intradural extramedullary tumors of the cervical spine. *J Comput Assist Tomogr* **1985**;9:1037–1041
21. Boisserie-Lacroix M, Kien P, Caille JM. L'imagerie des tumeurs intradurales et extra-medullaires: les neurinomes et les meningiomes. *J Neuroradiol* **1987**;14:66–81
22. Berry I, Brant-Zawadzki, Osaki L, Brasch RC, Murovic J, Newton TH. Gd-DTPA in clinical MR imaging of the brain: 2. Extraaxial lesions and normal structures. *AJNR* **1986**;7:789–793
23. Bydder G, Kingsley P, Brown J, Niendorf H, Young I. MR imaging of meningiomas including studies with and without gadolinium-DTPA. *J Comput Assist Tomogr* **1985**;9:690–697
24. Sze G, Abramson A, Krol G, Zimmerman R, Deck MDF. Metastatic disease of the spine: MR evaluation with Gd-DTPA. Presented at the annual meeting of the Radiological Society of North America, Chicago, November **1987**
25. Sze G, Abramson A, Krol G, et al. Gadolinium-DTPA in the evaluation of leptomeningeal tumor spread in the spine. Presented at the annual meeting of the Society of Magnetic Resonance in Medicine, New York City, August **1987**
26. Sze G, Abramson A, Krol G, et al. Gadolinium-DTPA in the evaluation of intradural extramedullary spinal disease. *AJNR* **1988**;9:153–163, *AJR* **1988**;150:911–921
27. Slasky BS, Bydder GM, Niendorf HP, Young IR. MR imaging with gadolinium-DTPA in the differentiation of tumor, syrinx, and cyst of the spinal cord. *J Comput Assist Tomogr* **1987**;11:845–850
28. Slasky BS, Niendorf HP, Steiner RE, Bydder GM, Young IR. Does Gd-DTPA help in separating tumor from syrinx or cyst in the spinal cord? Presented at the annual meeting of the Radiological Society of North America, Chicago, November **1987**