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Contrast Enhancement in Spinal MR Imaging

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We evaluated 44 patients with suspected spinal tumors or previous laminectomies with gadolinium-DTPA MR imaging in order to characterize the enhancement in normal, postoperative, and neoplastic intraspinal tissue. Using the signal intensity of CSF as an internal control, we calculated the percentage increase in signal intensity from pre- to postgadolinium studies. Tumors (astrocytoma, ependymoma, schwannoma) enhanced 70–350%; epidural scar, normal epidural venous plexus, and dorsal root ganglion enhanced up to 200%. Contrast enhancement does not per se distinguish neoplastic from normal tissue. Enhancement with gadolinium-DTPA appeared to increase the conspicuousness of intramedullary tumors but not intraosseous metastases.

We believe that gadolinium-enhanced MR imaging is a valuable adjunct to routine MR imaging in the evaluation of intraspinal neoplastic processes and may be useful in delineating normal and postoperative structures in the spinal canal.

Gadolinium (Gd)-DTPA is under evaluation by the FDA as a contrast medium for MR imaging of the spine. Enhancement of spinal tumors has been shown previously [1–5]. The purpose of this study was to measure the degree of contrast enhancement in neoplasms as compared with normal and nonneoplastic spinal tissues after Gd-DTPA administration.

Materials and Methods

Forty-two patients were studied under two different phase III protocols. In one protocol (group I), 22 patients with suspected spinal tumors were studied. Of the 22 enrolled, 15 had surgical or postmortem verification of the diagnosis. Among these patients there were three astrocytomas, three ependymomas, three schwannomas, two metastases, and four cysts not associated with a tumor. One of the 15 patients had previously undergone resection of an ependymoma and was evaluated for a presumed recurrence but has not yet been reoperated. Four of the 22 patients had negative MR studies without anatomic confirmation, and three had positive studies. In a second protocol (group II), 20 patients who had previously undergone laminectomy were studied to investigate possible scar tissue or recurrent disk herniations. Eight patients with MR evidence of epidural scar at one or more levels had surgical confirmation of epidural scar (with or without herniated disk). Measurements of contrast enhancement were made in the 14 tumor tissues in group I, in epidural scar in group II, and in normal tissues in both groups.

MR was performed on a 1.5-T cryogenic imager with surface coils. Each patient had sagittal or axial images with 800/20/2 (TR/TE/excitations), then with 2500/25/2 and 2500/80/2 plus additional images as needed. Gd-DTPA was injected intravenously in a dose of 0.1 mm/kg body weight. The 800/20 images were then repeated in the same planes with the same number of acquisitions, field of view, and so on. Transmit and receive attenuation were optimized with the system's automatic tuning software for both pre- and post-Gd-DTPA acquisitions. The signal intensity was measured in regions of interest in the images pre- and post-Gd-DTPA. The signal intensity of CSF (which was assumed not to enhance [4]) was used as an internal standard to which signal intensity in pre- and post-Gd-DTPA images could be normalized. Signal intensity for all tissues in the enhanced study was multiplied by a factor

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to nullify any change in CSF signal intensity between pre- and post-Gd-DTPA images. The contrast enhancement in each tissue was expressed as a ratio of the difference between post- and pre-Gd-DTPA signal intensities to the signal intensity in pre-Gd-DTPA scans (i.e., percent enhancement). All contrast-enhancement measurements were rounded to the nearest 10%, and tissues were grouped into 0–20% enhancement, 21–100%, or greater than 100%. One investigator assessed contrast enhancement qualitatively by comparing the pre- and post-Gd-DTPA images (displayed at similar window width and level); and for each tumor or tissue, assigning grade 0 for no visible enhancement, 1 for moderate enhancement, and 2 for marked enhancement.

Results

In each of the spinal tumors, contrast enhancement was evident qualitatively and quantitatively (Table 1). Metastases to the vertebrae (prostate, breast) showed grade 1 or 2 enhancement qualitatively and 130–300% contrast enhancement quantitatively (Fig. 1). Although the metastatic tumors enhanced, they were less conspicuous in the enhanced images. The three astrocytomas showed grade 1 or 2 enhancement and 110–150% increase in signal intensity with IV Gd-DTPA (Fig. 2). The two proved and one presumed recurrent ependymomas (Fig. 3) showed grade 1 qualitative enhancement and 70–100% increase in signal intensity. The three schwannomas showed marked or moderate enhancement (Fig. 4) and 100–350% enhancement. The intramedullary and intradural extramedullary tumors were more conspicuous in the enhanced than in the unenhanced images (800/20, 2500/20 or 2500/80 sequences).

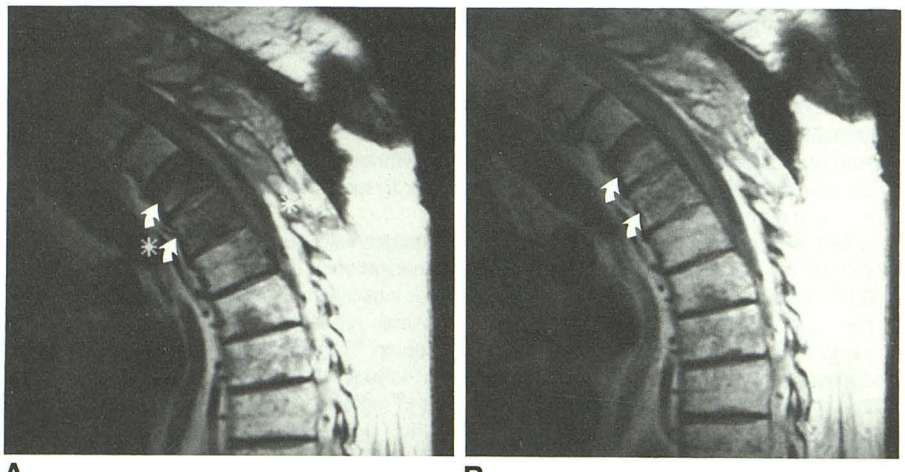
TABLE 1: Contrast Enhancement in Spinal Tumors

	Enhancement	
	Qualitative (Scale = 0–2)	Quantitative (Percent)
Metastases	2	300
	1	130
Astrocytoma	2	150
	2	110
	1	110
Ependymoma	1	100
	1	70
	1	70
Schwannoma	2	350
	2	300
	1	100

Enhancement in normal tissues is summarized in Table 2. Among normal tissues, greatest enhancement was observed in bladder urine (940%). The epidural plexus enhanced inconsistently. Enhancement could usually be detected quantitatively or qualitatively in the cervical epidural plexus (Fig. 5) and sometimes in the lumbar venous plexus. The dorsal root ganglion enhanced qualitatively and quantitatively (Fig. 6). Measurements in 12 cases showed enhancement of 100–140%, which was qualitatively assessed as grade 1. The ganglion's contrast with respect to the surrounding fat was diminished in enhanced images. Scar enhanced to a variable degree (Fig. 7). In eight cases with surgically verified epidural scar tissue, enhancement averaged 80% (range, 0–240%). On qualitative assessment it appeared most commonly as grade 1. No correlation with age of scar was attempted because of the small number of cases. Enhancement in bone marrow, muscle, and ligamentum flavum could be measured, but not usually detected by inspection of images at conventional windows.

Discussion

Less precision is achieved in studying MR signal intensities from the spine than from the head [6]. Because of the nonuniform signal reception in a surface coil, signal intensity measured from a region of interest in the spine is distorted by any movement of the patient. The radiofrequency pulses generated by a round head coil have a higher degree of homogeneity than those from a surface coil in which the radiofrequency signal is dependent upon the coil geometry and position. For small spinal structures such as ganglia,



A B

Fig. 1.—*A* and *B*, Vertebral metastatic prostatic carcinoma (*arrows*) in pre- (*A*) and post- (*B*) Gd-DTPA spin-echo 800/20/2 MR images. Both metastatic tumors in the study were more evident in unenhanced images.

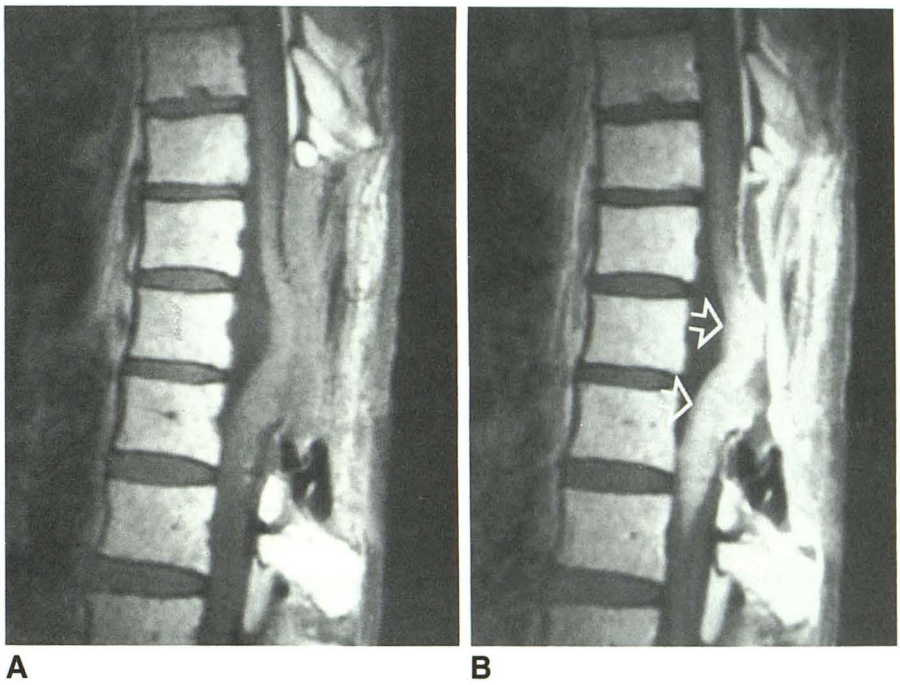


Fig. 2.—*A* and *B*, Recurrent astrocytoma (*arrows*) demonstrated with pre- (*A*) and post- (*B*) Gd-DTPA spin-echo 800/20/2 MR images. The tumor had grade 1, 110% enhancement. Autopsy confirmed tumor in the spinal cord. The cord adheres posteriorly to scar tissue, which also enhances after Gd-DTPA.

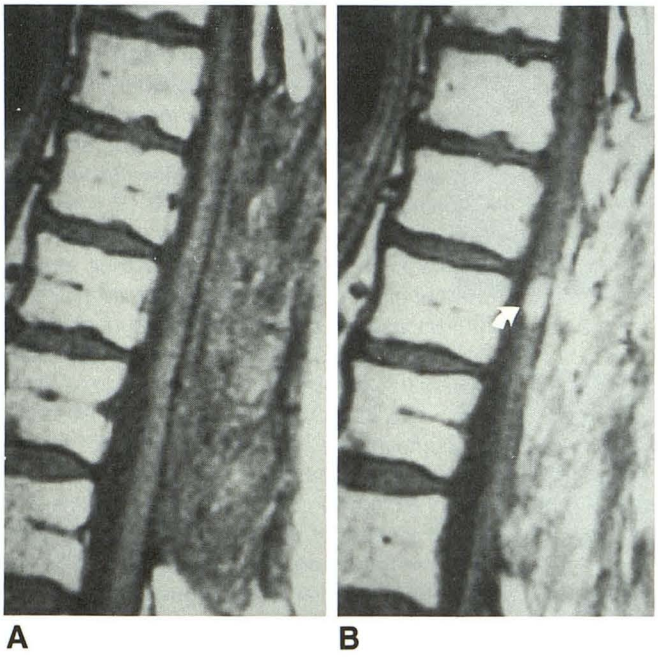


Fig. 3.—Presumed recurrent ependymoma.
A, MR image, 800/20/2, shows normal diameter and signal intensity in spinal cord of 56-year-old man with increasing weakness after resection of a spinal cord ependymoma.
B, Post-Gd-DTPA MR image, 800/20/2, shows enhancement in the cord (*arrow*) and in scar tissue dorsal to the spine. High signal in vertebral bodies represents fatty marrow replacement caused by radiation therapy.

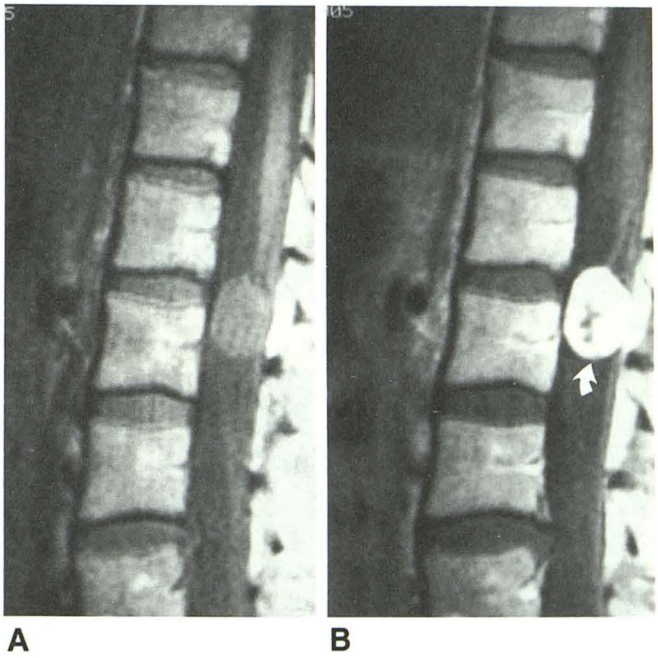


Fig. 4.—*A* and *B*, Schwannoma. Compared with pre-Gd-DTPA 800/20/2 MR image (*A*), the post-Gd-DTPA 800/20/2 MR image (*B*) shows 350% increase in signal intensity in the tumor (*arrow*).

roots, veins, and meninges, partial volume averaging is a significant source of inaccuracy in the measurements. Another variable was introduced by use of the automatic prescan. Attenuation constants were presumably not identical for pre- and post-Gd-DTPA imaging. External standards to which measurements can be normalized are not practical when surface coils are used. Therefore, an internal standard (CSF) was used to normalize measurements.

The degree of enhancement in spinal tissues and tumors was similar to that in intracranial tissues and tumors [6]. Enhancement of up to several hundred percent was seen in

TABLE 2: Contrast Enhancement in Tissues in and Near the Spine

	Enhancement	
	Qualitative (Scale = 0–2)	Quantitative (Percent)
Bladder	2	>200
Epidural plexus	2	100–200
Epidural scar	1	
Dorsal root ganglion	1	
Bone marrow	0	21–100
Paraspinal muscle	0	
Ligamentum flavum	0	
Epidural fat	0	0–20
Spinal cord	0	
Anulus fibrosus	0	
Nucleus pulposus	0	
Cortical bone	0	

spinal tumors. Although schwannomas seemed to enhance on the average more than astrocytomas or ependymomas, different types of tumors could not be differentiated by their degree of contrast enhancement. Some ependymomas and astrocytomas had the same degree of enhancement.

Nonneoplastic tissues also enhanced. Normal dorsal root ganglion, muscle, and marrow enhanced because they have a fenestrated capillary endothelium, that is, no blood-brain barrier. For example, normal dorsal root ganglion may enhance to the same degree as some tumors; therefore, normal tissues, scar, and tumorous tissues cannot be identified by their degree of contrast enhancement alone. Although we found no contrast enhancement in the normal spinal cord, we did not evaluate the possibility of enhancement in the cord after trauma, surgery, or radiation therapy. Epidural scar, which enhanced inconsistently, could not be characterized accurately by its degree of enhancement. It enhanced incon-

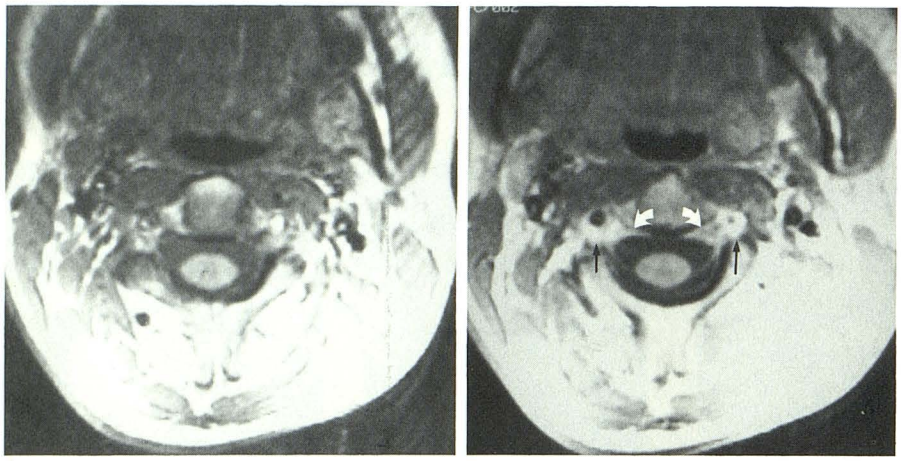


Fig. 5.—*A* and *B*, Enhancement in cervical spinal epidural plexus is shown in pre- (*A*) and post- (*B*) Gd-DTPA 800/20/2 MR images. Note increased signal intensity (*arrows*) in region of epidural plexus, dural sac, and root sleeves.

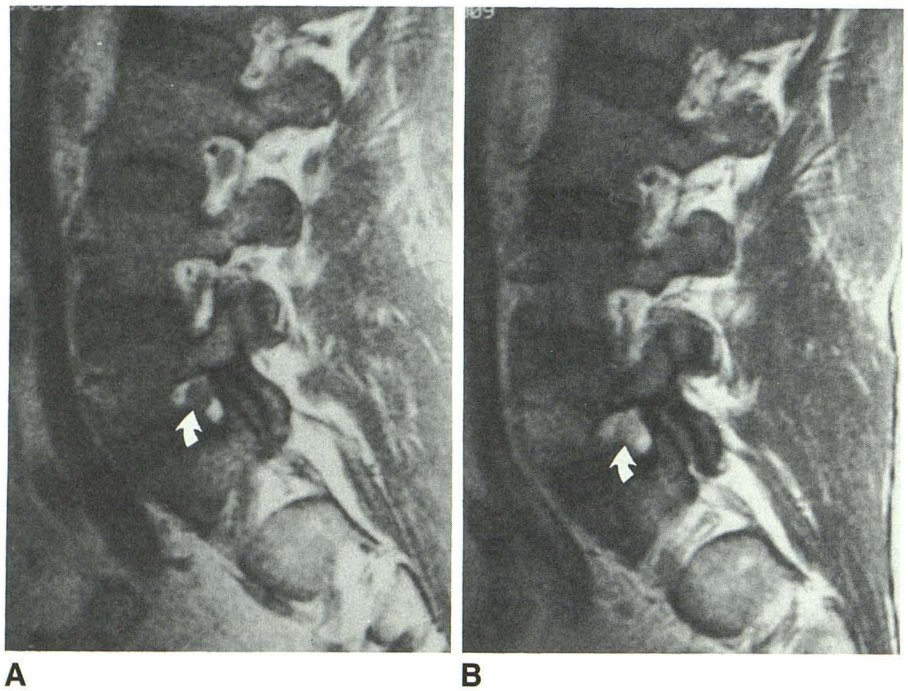


Fig. 6.—*A* and *B*, Enhancement of spinal dorsal root ganglia is shown in pre- (*A*) and post- (*B*) Gd-DTPA 800/20/2 MR images. The ganglia (*arrows*) are less conspicuous after enhancement. In the enhanced image, the ganglion has a higher signal intensity, which is similar to that of adjacent fat.

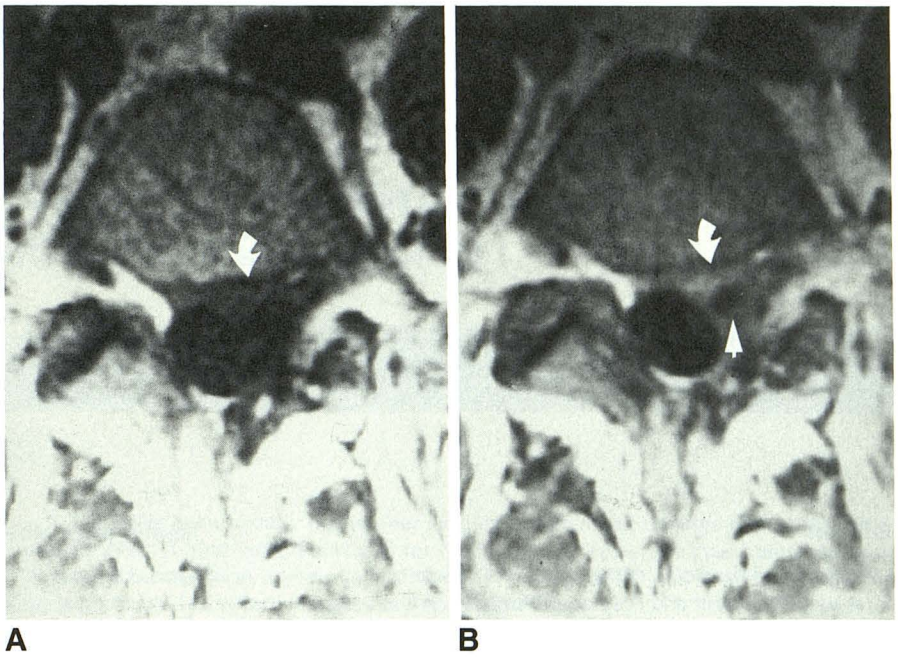


Fig. 7.—*A* and *B*, Enhancement in epidural scar. Axial images at L5–S1 level without (*A*) and with (*B*) IV enhancement. In the enhanced image, the scar (*arrows*) is more easily distinguished from the dural sac and root sheath (*arrowhead*).

spicuously in some cases, markedly in others. The extent of scar could be judged more accurately in some cases because of enhancement. The differentiation of root sheath and scar could be made more reliably on enhanced than unenhanced images; therefore, the characteristic pattern of epidural scar was often more evident on enhanced images.

Contrast enhancement in a tumor did not inevitably increase its contrast with respect to adjacent tissues. As others have noted [4, 5], the enhancement of intramedullary (astrocytoma and ependymoma) and intradural extramedullary (schwannoma) tumors increased their conspicuousness; enhancement in the intraosseous (metastatic) tumors decreased their conspicuousness because the enhanced tumors had a signal intensity similar to that of the adjacent bone marrow. Therefore, to obtain the greatest benefit of Gd-DTPA enhancement, patients must be selected thoughtfully.

The diagnostic benefit of enhancement in normal tissues needs further study. In the cervical spine, Gd-DTPA increases the signal from the large venous plexus in the neural foramina. Detection of herniated disk fragments in the neural foramen by MR imaging may be improved by enhancement, as some authors have suggested it is by CT [7].

The study emphasizes the need for a measurement of sensitivity of Gd-DTPA-enhanced MR versus unenhanced T1- or T2-weighted images. It shows that quantification of contrast enhancement in spine imaging has little clinical utility because of the variability in enhancement of normal spinal tissues and tumors and the imprecision in measurements of enhancement.

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