# Spinal cord pial metastases: MR imaging with gadopentetate dimeglumine.

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# Spinal Cord Pial Metastases: MR Imaging with Gadopentetate Dimeglumine

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**The purpose of this investigation was to describe gadopentetate-dimeglumine–enhanced MR findings in metastatic disease to the pial lining of the spinal cord. Correlation was made with clinical data, other radiologic studies, and pathologic findings. Eighty-six patients with a known malignancy and unexplained neurologic signs or symptoms were studied with pre- and postcontrast T1-weighted images. In seven of these patients, abnormal enhancement of the pial lining of the cord was seen on the sagittal postcontrast T1-weighted images. This appeared as a thin rim of enhancement along the surface of the cord in six patients and as a focal, thick rim of enhancement in addition to the thin rim of enhancement in the seventh patient. Axial images confirmed the location along the pial lining in each case. Precontrast T1-weighted images in all seven cases and precontrast T2-weighted images in five cases failed to detect any focal abnormalities of the pial lining of the cord. Pathologic confirmation was available in five of the seven patients. Pirmary malignancies in these patients included breast carcinoma (two), lymphoma (one), leukemia (one), adenocarcinoma of the lung (one), prostate carcinoma (one), and malignant melanoma (one). Three of seven patients had metastatic disease evident only within the CNS, while four patients had widespread disease outside the CNS.**

**We conclude that contrast-enhanced MR imaging is useful in the diagnosis of pial spread of metastatic disease in patients with a known primary malignancy and unexplained neurologic signs or symptoms.**

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MR imaging is rapidly replacing myelography in the evaluation of patients with suspected metastatic disease to the spine. The MR appearances of extradural, intradural, and intramedullary metastases have been described previously [1–8]. However, the MR appearance of pial metastases has heretofore received little or no attention in the radiology literature. In this report we describe seven patients with malignant disease who demonstrated abnormal enhancement of the pial lining of the spinal cord, and we correlate this finding with clinical and pathologic findings. The purpose of this report is to describe the appearance of spinal cord pial metastases on gadopentetate-dimeglumine–enhanced MR imaging.

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## Subjects and Methods

One hundred and thirty-five patients underwent MR of the spine during a 12-month period from August 1988 to August 1989 to evaluate for possible spinal metastases. Forty-nine of these patients presented with back pain or a positive radionuclide bone scan but had no neurologic signs or symptoms. These patients had noncontrast studies only. Eighty-six patients had unexplained neurologic signs or symptoms in association with a history of a primary malignancy; these patients underwent MR both with and without gadopentetate dimeglumine. In each patient the examination was targeted to the sites of clinical suspicion. Twenty-four of these 86 patients had surveys of the entire spine, 43 had thoracic/lumbar

surveys, 13 had cervical/thoracic examinations, and six patients had thoracic studies. In seven of the 86 patients, gadopentetate dimeglumine MR studies demonstrated abnormal contrast enhancement of the pial lining of the spinal cord. These seven patients form the basis of this report.

MR studies were performed on a GE Signa 1.5-T system. Precontrast sequences consisted of sagittal T1-weighted, 400–600/20 (TR range/TE), images of the cervical, thoracic, and lumbar spine. Gadopentetate dimeglumine was then administered IV at a dose of 0.1 mmol/kg. Postcontrast images were initiated at the same levels using the same TR and TE immediately after contrast injection. A slice thickness of 5 mm with a 1-mm skip was used throughout with two excitations and a matrix of 128 × 256 or 256 × 256 precontrast, and 256 × 256 postcontrast. Axial images were obtained either before or after contrast injection whenever it was deemed necessary to complement the findings on sagittal scans. Abnormal pial enhancement was always confirmed with axial images. Precontrast sagittal T2-weighted images (2000–2500/30,90) were obtained in five of the seven patients with pial enhancement.

We also reviewed gadopentetate dimeglumine–enhanced T1-weighted MR scans of the cervical, thoracic, or lumbar spine in 50 control patients who underwent MR to exclude a myelopathy and who had no history of a malignant, infectious, or inflammatory disease. In each patient we looked specifically for the presence or absence of pial enhancement.

## Results

Clinical data and imaging results from our seven patients are presented in Table 1. Abnormal enhancement appeared

**TABLE 1: Pial Metastases: Clinical, Pathologic, and MR Findings**

| Case No. | Age (years) | Sex | Diagnosis and Documentation | Neurologic Signs and Symptoms | CSF* | Location of Pial Enhancement: Precontrast T1/ Postcontrast T1/T2 | Other MR Abnormalities |
|---|---|---|---|---|---|---|---|
| 1 | 30 | M | Malignant melanoma, Clark IV; lumbar arachnoid biopsy positive for melanoma | Headache, nausea and vomiting, photophobia, left face/arm weakness | Protein 600 mg/dl, glucose 14 mg/dl, 400 wbc/cu mm, 15 rbc/cu mm (90% lymphocytes, 10% monocytes), cytology negative for melanoma | −/+/− Diffuse | Cranial nerves 7/8, clumped lumbar nerve root with abnormal root and arachnoid enhancement |
| 2 | 72 | M | Chronic lymphocytic leukemia, positive biopsy of leptomeninges and CSF | Low back pain, right greater than left; lower extremity weakness | Cytology positive, no chemistry or cell count | −/+/− Thoracic lumbar-conus | Lumbar nerve roots enhanced with clumped roots, herniated nucleus pulposus |
| 3 | 72 | M | Prostate carcinoma, widespread metastases | Headache, cranial nerve palsies | Not performed | −/+/not performed Diffuse | Clivus plus right cavernous sinus involvement dural and arachnoid |
| 4 | 62 | F | Breast carcinoma with diffuse bone metastases | Bilateral lower extremity decreasing sensation, cauda equina syndrome | Not performed | −/+/not performed Low thoracic | Postradiation changes in thoracic/lumbar spine-compression of T11 and bone metastases in L3–L5 |
| 5 | 72 | F | Breast carcinoma with malignant pleural effusion and rib metastases; postmortem examination was positive | Polyneuropathy both upper and lower extremities, decreased bladder control | Protein 700, glucose 45 cytology showed atypical cells | −/+/− Dorsal cervical spine only | Not applicable, sequence not performed |
| 6 | 39 | M | Lung adenocarcinoma with metastasis to brachium pontis | Seizures, neck pain, confusion, decreased bowel/bladder control | Protein 73, glucose 23, 21 wbc/cu mm/ rbc/cu mm (51% lymphocytes, 47% monocytes), cytology positive | −/+/− Diffuse | Not applicable, sequence not performed |
| 7 | 48 | M | Hi-grade large-cell lymphoma, Postmortem examination positive) | Low back pain, bilateral sciatica with lower extremity numbness | Not performed | −/+/− Diffuse | Retroperitoneal mass |

* Normal total protein = 15–45 mg/dl, normal glucose = 40–80 mg/dl

as a thin rim on the cord periphery in six patient (Figs. 1–3). One of these had focal linear enhancement along the dorsal aspect of the cervical cord (Fig. 4). In the seventh patient, linear enhancement was observed in conjunction with a focal area of thick enhancement along the surface of the cord (Fig. 5). In three patients the enhancement was observed at one segment of the cord only, whereas in the other four patients it involved the entire cord. Two of the seven patients also had clumping of the cauda equina with nerve root and arachnoid enhancement (Figs. 1 and 2). In the patient with linear enhancement on the dorsum of the cervical cord, pathologic examination revealed circumferential pial infiltration with focal areas of invasion into the cord substance (Figs. 4E and 4F). Long TR, long TE sequences performed on this patient and four other of the seven patients failed to demonstrate any focal cord or pial abnormalities (Fig. 4D).

The onset of clinical symptoms ranged from 6 months to 17 years from the time of initial diagnoses. Three of the seven

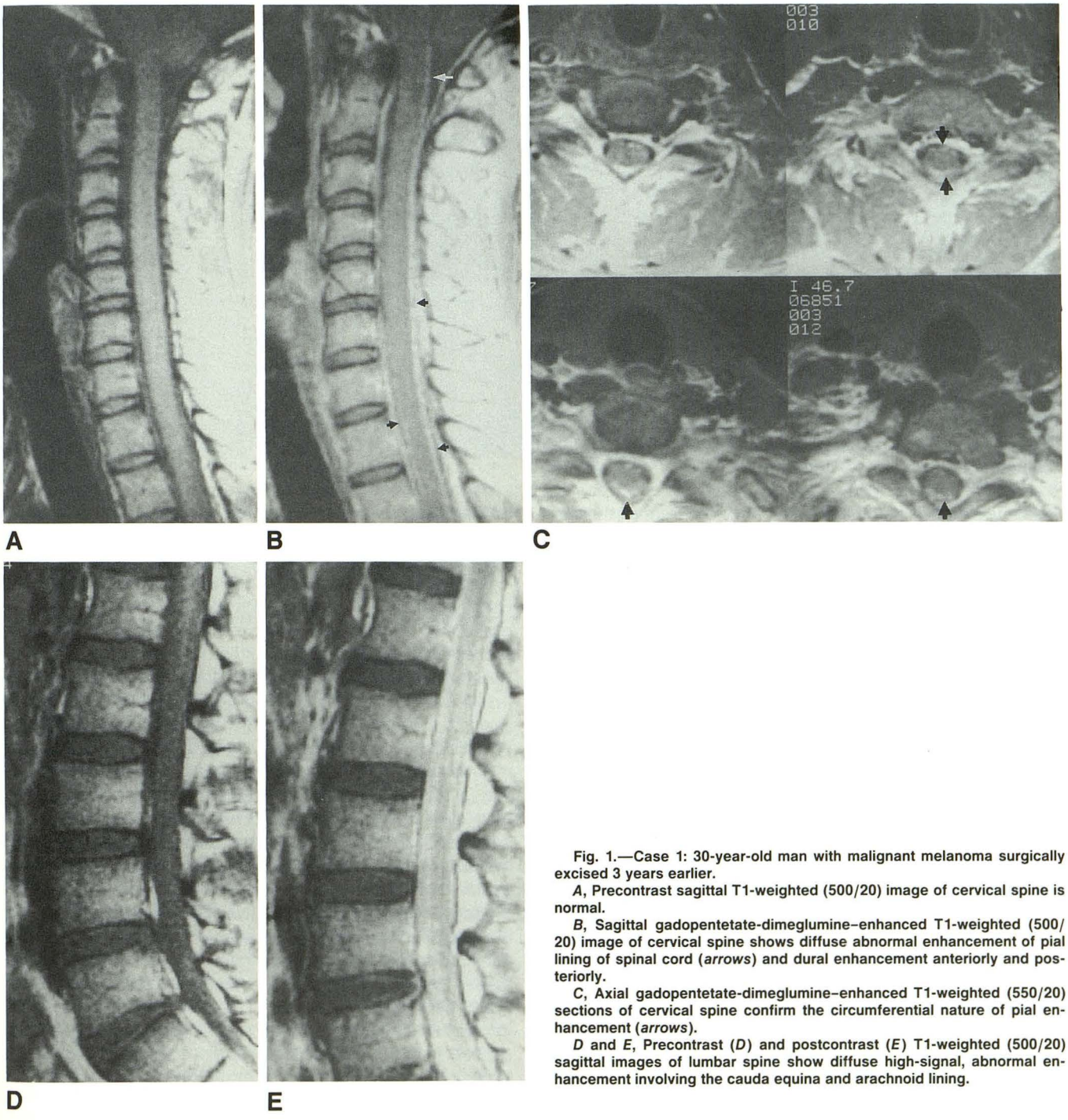


**Fig. 1.—Case 1: 30-year-old man with malignant melanoma surgically excised 3 years earlier.**

***A*, Precontrast sagittal T1-weighted (500/20) image of cervical spine is normal.**

***B*, Sagittal gadopentetate-dimeglumine–enhanced T1-weighted (500/20) image of cervical spine shows diffuse abnormal enhancement of pial lining of spinal cord (*arrows*) and dural enhancement anteriorly and posteriorly.**

***C*, Axial gadopentetate-dimeglumine–enhanced T1-weighted (550/20) sections of cervical spine confirm the circumferential nature of pial enhancement (*arrows*).**

***D* and *E*, Precontrast (*D*) and postcontrast (*E*) T1-weighted (500/20) sagittal images of lumbar spine show diffuse high-signal, abnormal enhancement involving the cauda equina and arachnoid lining.**

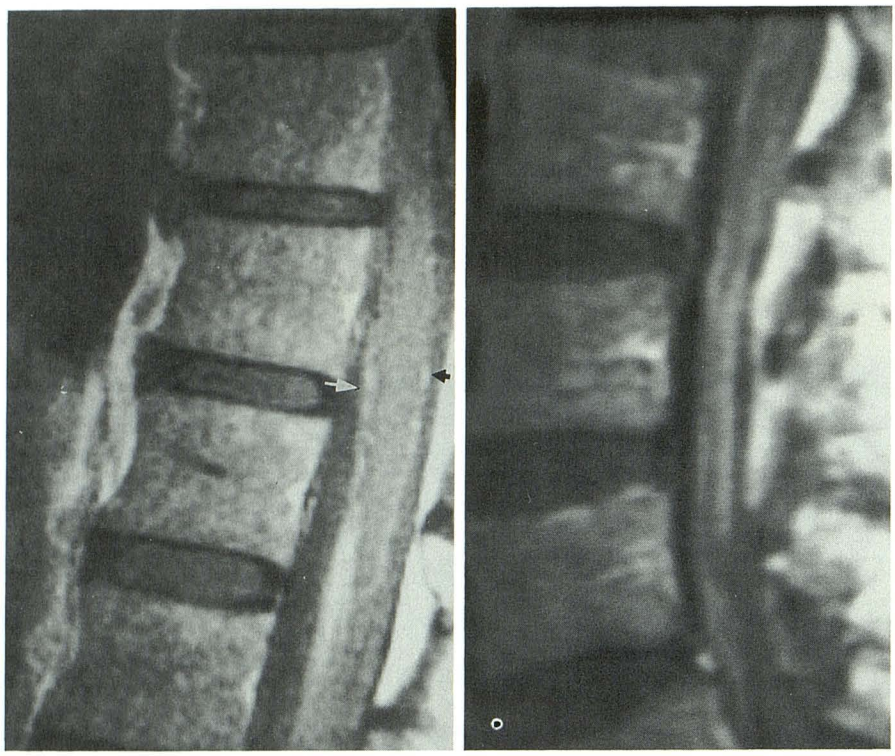


**Fig. 2.—Case 2: 72-year-old man with chronic lymphocytic leukemia.**

***A*, Sagittal gadopentetate-dimeglumine–enhanced T1-weighted (500/30) image of lumbar spine shows abnormal rim of enhancement outlining the conus (*arrows*) with involvement of the proximal cauda equina.**

***B*, Sagittal gadopentetate-dimeglumine–enhanced T1-weighted (500/20) image of lumbar spine shows clumping and abnormal enhancement of lumbar roots.**

patients died within 4 months of their MR examination. Two of these patients had received treatment with intrathecal methotrexate after the MR studies were performed. One of these two patients died 2 months after therapy from an unknown cause. The other patient withdrew from all therapy after one dose of intrathecal methotrexate and died a week later with postmortem examination revealing terminal pneumonia, urinary tract infection, pleural metastases, and metastatic breast cancer involving the pia/arachnoid and nerve roots of the entire spinal cord (case 5). At the time of this report, three patients were undergoing radiation therapy to the spine, two with a combination of osseous and pial involvement by malignancy and one with pial/arachnoid involvement by melanoma. One patient was undergoing experimental systemic chemotherapy.

Pial enhancement was not observed in the control patients except for minimal enhancement anterior to the conus in 30% of patients. We believe this was probably related to the anterior spinal artery (Fig. 6). Gibbs artifact was considered less likely, since this finding was not seen on the precontrast images.

## Discussion

Leptomeningeal metastases may be seen with CNS neoplasms or with primary malignancies outside the CNS. The diagnosis can be difficult to establish, as both CSF cytologic analysis and myelography have significant false-negative rates [9–11]. Patients may present with nonspecific symptoms—including headache, neck or back pain—or with focal neurologic deficits, including cranial nerve palsies, motor or sensory dysfunction, and loss of sphincter control. Early recognition and treatment of this disease, usually with intrathecal chemotherapy or radiation, can offer these patients palliation and in some cases improved survival rates [9, 11].

Gadopentetate-dimeglumine–enhanced MR imaging has been shown to be superior to noncontrast images in the evaluation of intramedullary and intradural extramedullary processes [1–5, 8]. However, little distinction is made in the literature between clinical findings and significance of metastases involving the arachnoid lining of the dural sac, the pial lining of the nerve roots, and the pial lining of the brain and spinal cord.

In this report, we focus on metastases to the pial lining of the spinal cord although coexisting involvement of the arachnoid, dura mater, or nerve roots was present in at least three patients. Autopsy proof of spinal cord pial metastases was available in two of the seven patients. Two patients had positive arachnoid biopsies, two patients had positive CSF cytology including one of the two patients who underwent arachnoid biopsy, and two patients had widespread metastatic disease with no evidence of an infectious or inflammatory process. Pial enhancement with gadopentetate dimeglumine was not observed in the control population except for minimal enhancement seen occasionally along the anterior aspect of the conus. Therefore, the enhancement that we observed along the surface of the spinal cord can be consid-

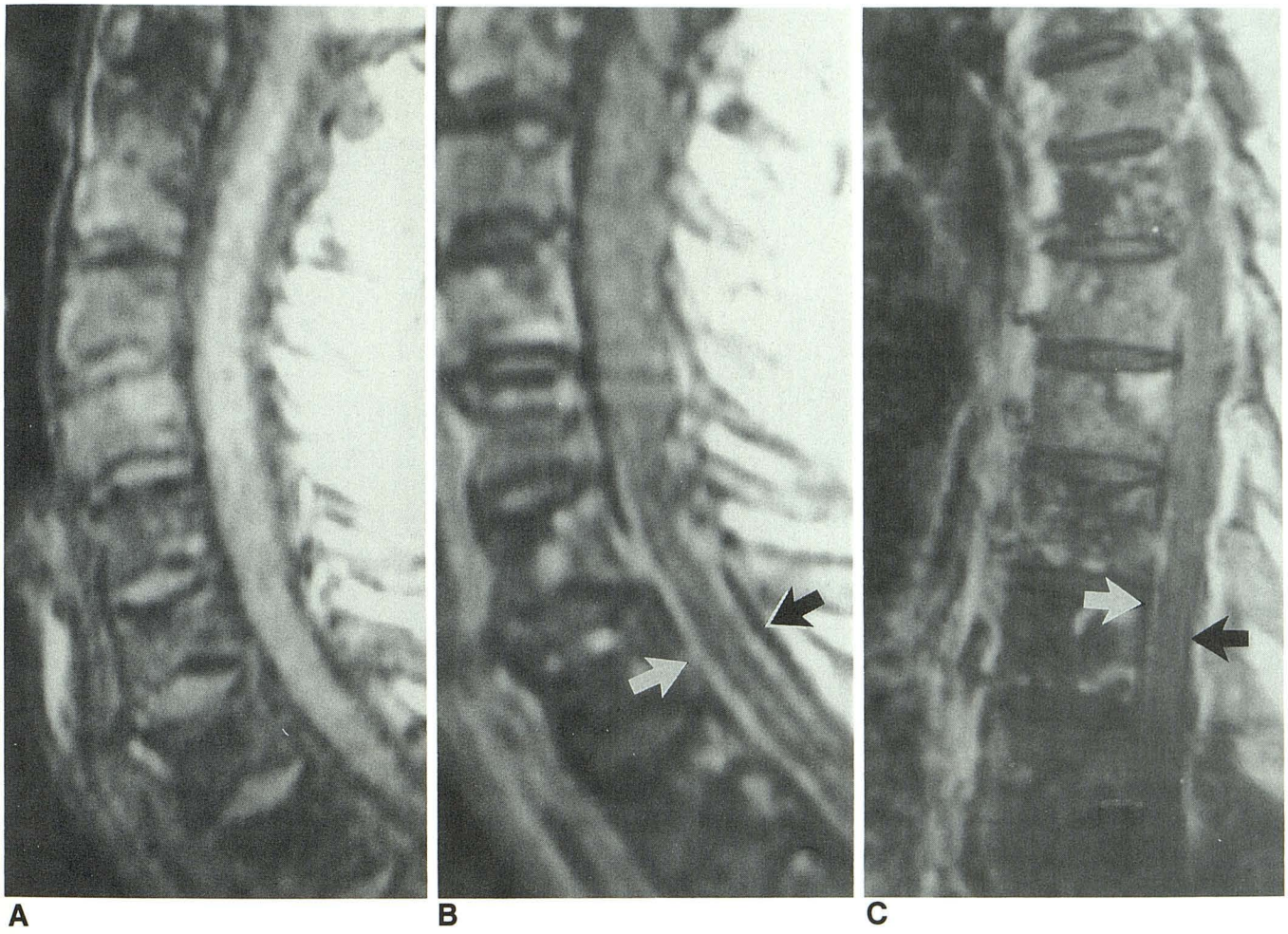


**Fig. 3.—Case 3: 72-year-old man with metastatic prostate carcinoma.**
***A*, Precontrast sagittal T1-weighted (600/20) image of cervical spine shows metastatic disease to cervical vertebrae and a normal appearance to cervical cord.**
***B*, Sagittal gadopentetate-dimeglumine–enhanced T1-weighted (600/20) image of cervical spine shows abnormal rim enhancement of cervical cord (*arrows*).**
***C*, Sagittal gadopentetate-dimeglumine–enhanced T1-weighted (500/20) image of thoracic spine shows continuation of abnormal rim enhancement of thoracic cord (*arrows*) and vertebral metastases. Pial location confirmed on axial images (not shown).**

ered abnormal and due to pial metastatic disease. When the enhancement is clearly applied to the surface of the cord on both sagittal and axial images, and is surrounded by low signal CSF on postcontrast T1-weighted images, it is thought to be pial in nature. This is to be distinguished from dural enhancement where there is enhancement of the outlying dural sac, and arachnoid enhancement where there is enhancement within the CSF space between the pial and dural lining of the sac or along nerve roots. In some patients, all three may coexist.

Our observations are further supported by a recent report of an animal tumor model that demonstrated similar-appearing pial enhancement on postcontrast T1-weighted images. Serial MR examinations of rabbits inoculated with tumor suspension into the cisterna magna demonstrated pial and arachnoidal enhancements synchronous with the development of neurologic dysfunction [12]. T2-weighted images were nondiagnostic in the rabbits as in our series, since meningeal involvement by tumor cannot be distinguished from CSF on the basis of signal intensity.

While it can be argued that radiation therapy may have contributed to the abnormal enhancement in the patient with a thick rim of enhancement and radiation changes in the bone (case 4), no evidence of radiation-induced arachnoiditis was seen. Furthermore, pial enhancement was not observed in other patients who had received similar spinal radiation for bony metastases.

All seven of our patients had focal neurologic findings or symptoms; however, this number is biased since we did not administer contrast material to patients with nonfocal com-

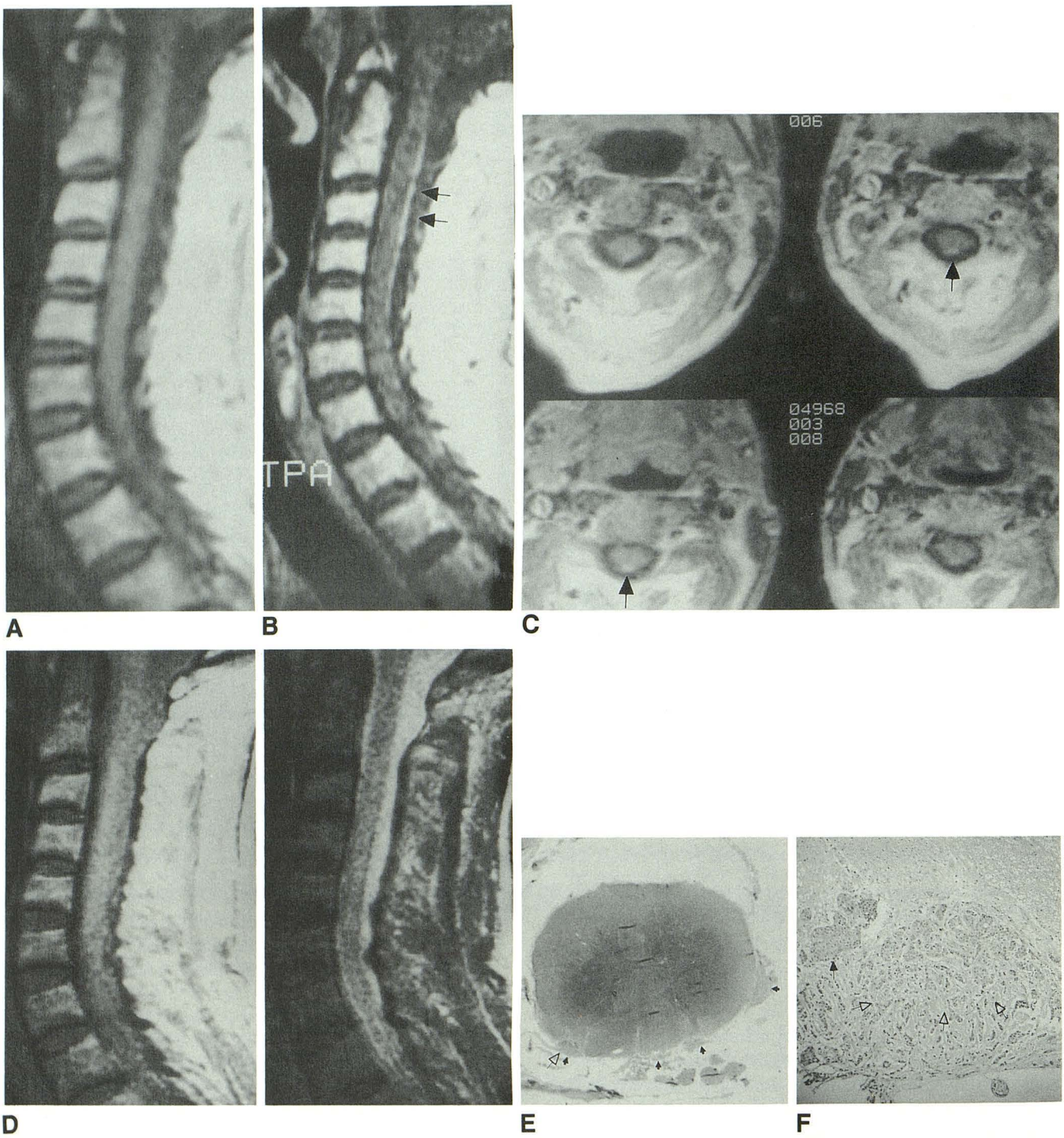


Fig. 4.—Case 5: 72-year-old woman with breast cancer treated 17 years prior to admission.

*A*, Precontrast sagittal T1-weighted (400/20) image of cervical spine is normal.

*B*, Sagittal gadopentetate-dimeglumine–enhanced T1-weighted (400/20) image of cervical spine shows a thin linear streak of enhancement along dorsal surface of cord (*arrows*).

*C*, Axial gadopentetate-dimeglumine–enhanced T1-weighted (800/20) images confirm the abnormal enhancement along dorsal surface of cervical cord (*arrows*).

*D*, Precontrast sagittal intermediate and T2-weighted (2000/30,80) images show no evidence of cord or pial abnormality.

*E*, Cross section of cervical spine with low-power magnification shows increased thickness of pial lining (*solid arrows*) due to metastatic infiltration. An area of cord invasion by tumor cells is magnified in part *F* (*open arrow*).

*F*, High-power magnification shows pial infiltration by metastatic adenocarcinoma of the breast (*open arrows*) as well as focal invasion of cervical cord (*solid arrow*).

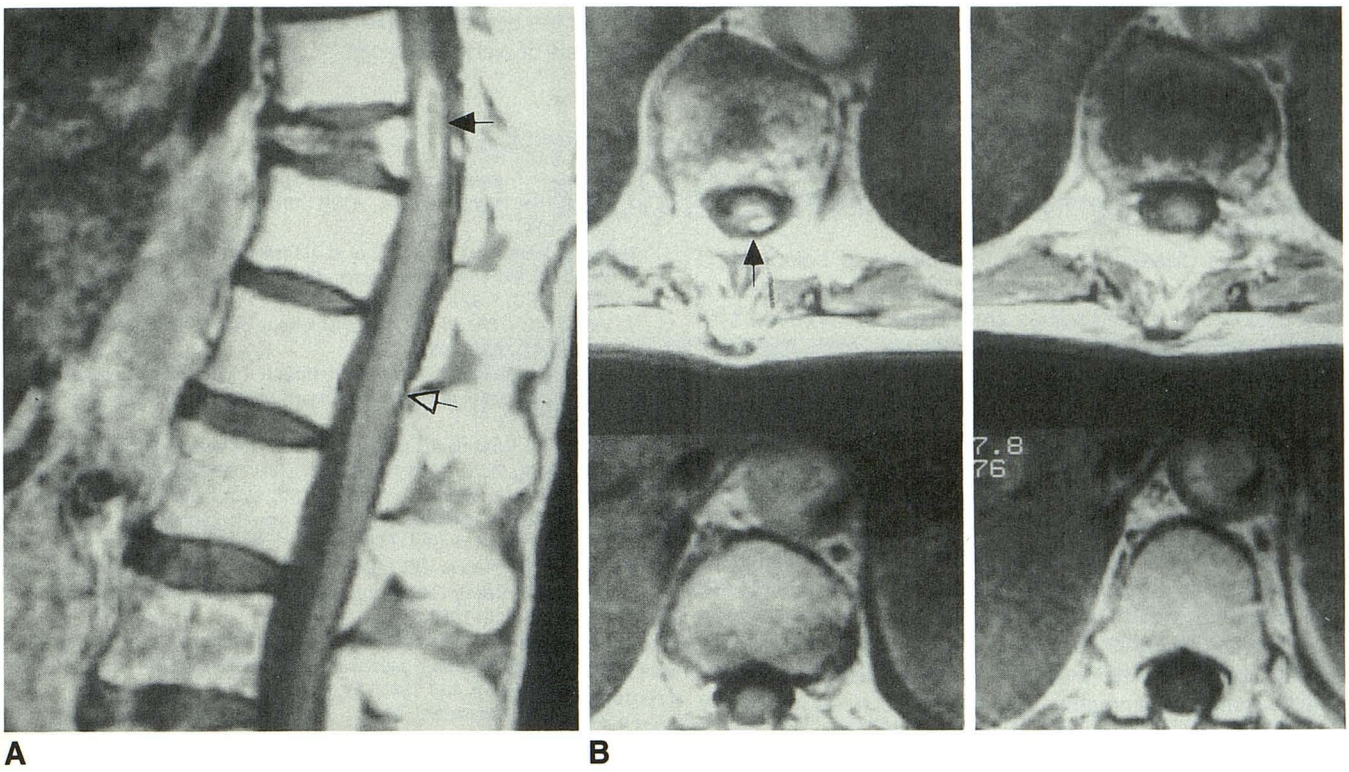


Fig. 5.—Case 4: 62-year-old woman with metastatic breast cancer.
*A*, Sagittal gadopentetate-dimeglumine–enhanced T1-weighted (500/20) image of lumbar spine shows both a thick (*closed arrow*) and thin (*open arrow*) rim of abnormal enhancement. Note the radiation change with increased fatty marrow and collapsed T11 vertebral body and vertebral metastases involving L3–L5.
*B*, Axial gadopentetate-dimeglumine–enhanced T1-weighted images confirm the circumferential thick rim of enhancement (*arrow*).

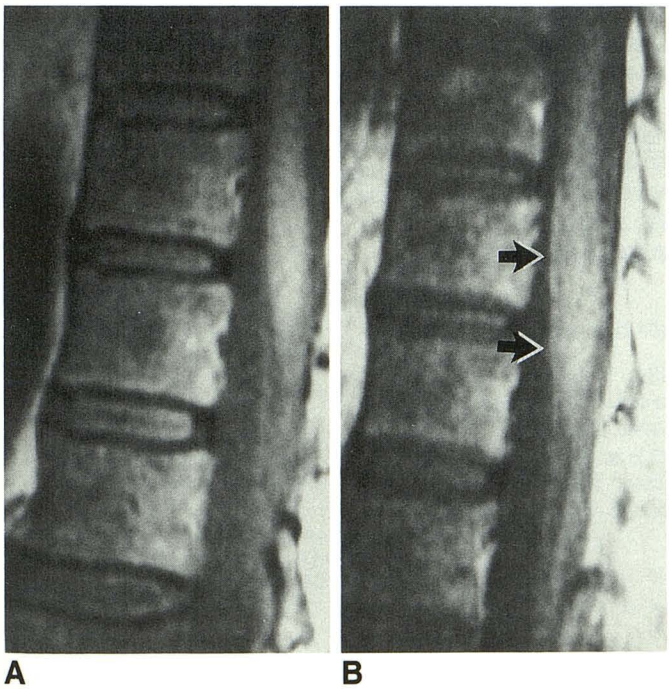


Fig. 6.—Normal patient.
*A*, Sagittal precontrast T1-weighted image of conus.
*B*, Sagittal postcontrast T1-weighted image shows minimal enhancement along anterior surface of conus (*arrows*).

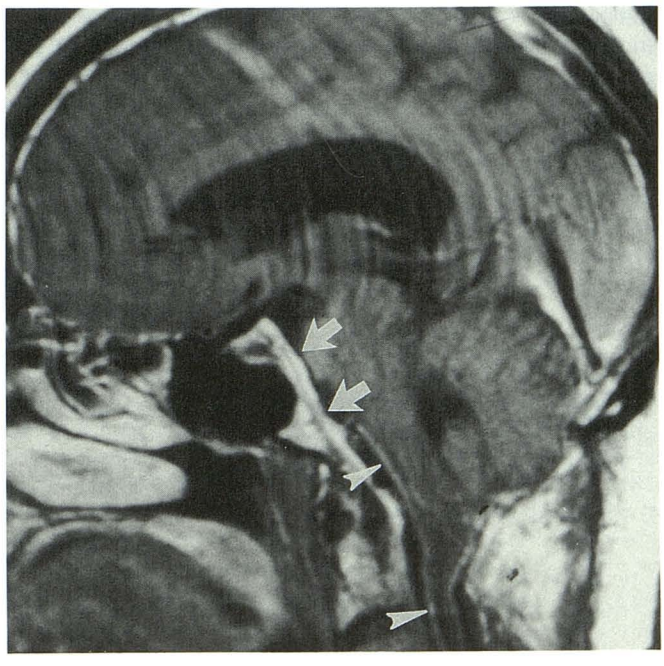

Fig. 7.—Chronic meningeal fibrosis caused by shunting for Arnold Chiari I complicated by syrinx. Sagittal postcontrast T1-weighted (750/20) image of brain and upper cervical cord shows both dural enhancement along clivus (*arrows*) and pial enhancement along surface of midbrain and upper cervical cord (*arrowheads*).

plaints. Since this is not an autopsy study, we cannot comment on the sensitivity or false-negative rate of contrast-enhanced MR in the detection of spinal cord pial metastases. However, one of the two patients who had a postmortem examination (case 5) demonstrated diffuse involvement of the pial lining of the cord, while contrast-enhanced MR performed 2 months earlier showed only abnormal cervical pial enhancement.

Metastatic disease to the leptomeninges is being found increasingly as a complication of systemic cancer. There is speculation that these findings are a result of improved systemic therapy for certain malignancies [11, 13]. The most common primary malignancies reported include breast carcinoma, small-cell and non–small-cell lung carcinoma, malignant melanoma, gastrointestinal carcinomas, and lymphoma [10, 12, 14]. Up to 50% of patients with acute lymphoblastic leukemia may develop this complication, and a similar phenomenon has been observed in the myelogenous leukemias [11]. Malignancies in our series included breast carcinoma, chronic lymphocytic leukemia, large-cell lymphoma, lung adenocarcinoma, melanoma, and prostate carcinoma.

Abnormal pial enhancement on MR is not unique to metastatic disease. We have observed similar findings with both infectious and inflammatory conditions, such as meningeal fibrosis caused by chronic shunting (Fig. 7). Pial involvement by spinal sarcoidosis has also been described recently [15]. Clinical correlation and CSF analysis including cytology are necessary to make a specific diagnosis. In our series, five of seven patients were treated for leptomeningeal spread of malignancy with either intrathecal methotrexate or radiation. One patient underwent experimental chemotherapy. A longer period of follow-up and a larger series of patients with this complication of malignancy are necessary to determine the impact of our observation of pial enhancement and of the subsequent therapy.

In conclusion, metastatic disease to the pial lining of the spinal cord may present as a focal or diffuse rim of increased signal along the surface of the cord on contrast-enhanced T1-weighted MR images. Metastatic screening studies performed without the use of gadopentetate dimeglumine may miss the diagnosis of pial metastases.

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