Magnetic resonance imaging of spinal meningiomas and neurinomas

Improvement of imaging by paramagnetic contrast enhancement

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The detection and delineation of spinal tumors by magnetic resonance imaging (MRI) after intravenous administration of gadolinium (Gd)-diethylenetriaminepenta-acetic acid (DTPA) is demonstrated in eight cases of neurinoma or meningioma. The advantages of Gd-DTPA-enhanced MRI over other MRI techniques used in more than 100 cases of spinal cord diseases are described.

KEY WORDS • magnetic resonance imaging • gadolinium-DTPA • spinal cord neoplasm • neurinoma • meningioma

Magnetic resonance imaging (MRI) of the spinal cord offers some advantages compared to standard diagnostic examinations. In comparison to myelography, MRI permits direct visualization of the cord itself, not only of its contours. Because of the high signal intensity of the medullary bone (which contains fat and blood), MRI clearly identifies the vertebral bodies, and there are no limitations of spatial and contrast detail due to artifacts from the adjacent bone, as encountered with computerized tomography (CT). In cases of a spinal mass causing subarachnoid block, myelography carries a 14% to 26% risk of acute worsening. This deterioration has been attributed to so-called “spinal coning” resulting from compartmental pressure differences or may be due to the often highly delicate hemodynamic situation of the tumor-compressed spinal cord. Furthermore, in tumors that completely block the spinal canal, an additional injection at C1–2 may be necessary to demonstrate the upper pole of the tumor.

Until now, the primary spatial resolution of MRI has lagged behind that of CT, but MRI does offer superior soft-tissue contrast sensitivity. The degradation of the spinal cord signal to noise ratio, due to motion and flow artifacts, and the partial volume effects caused by the cord’s comparatively small size make it essential to obtain good differentiation between the normal cord tissue and pathological structures if small lesions are to be recognized. In order to evaluate the diagnostic reliability of nonenhanced and gadolinium (Gd)-diethylenetriaminepenta-acetic acid (DTPA)-enhanced spinal MRI, we studied eight patients with neurinoma or meningioma. The findings on Gd-DTPA-enhanced MRI were compared with those obtained with standard MRI techniques and other conventional neuroradiological procedures.

Clinical Material and Methods

The MRI scans were obtained with a Siemens Magnetom,* a superconducting whole-body imager operating at a static magnetic field of 1.5 Tesla. Technical factors for the whole-body or surface coil images included a spin-echo technique with multislice double echo or single-slice multiecho (up to 16 echoes). The system has a 256 × 256 matrix, and a slice thickness of 5 to 10 mm was obtained. As a rule, the patients were investigated using a standard examination program, including T1-weighted images (pulse relaxation time (TR) 400 msec, echo delay time (TE) 30 msec) and

*Siemens Magnetom manufactured by Siemens AG, Erlangen, West Germany.
Table 1 summarizes the clinical, neuroradiological, and operative findings of eight patients with extramedullary tumors. Most of the patients had progressive transverse spinal cord lesions. One patient with neurinoma at the C-3 vertebral level (Case 5) had palsy of the phrenic nerve. Another patient (Case 6) with neurinoma of the cauda equina presented with a 20-year history of sciatica and 3 months of L5-S1 palsy.

The diagnosis was established by myelography in six patients. In Case 1 myelography showed only a block of contrast medium at the foramen magnum level (Fig. 1). A CT scan after myelography suggested an intramedullary tumor. The MRI studies for this patient are shown in Fig. 2. Computerized tomography was the primary diagnostic modality in one patient with a meningioma at the C5–6 level (Case 3); in that case contrast-enhanced CT revealed an enhancing intraspinal tumor. In two cases of neurinoma (Cases 4 and 5) CT was helpful in the delineation of the extramedullary tumor.
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FIG. 1. Case 1. Ascending myelograms suggesting a block at the foramen magnum/C-1 level. This patient was clinically suspected of having multiple sclerosis. A meningioma at the foramen magnum/C-1 level was found at surgery.

portion of the tumor, but in Case 6 it did not disclose a large, purely intradural neurinoma of the cauda equina. In three patients CT was not performed, and in one it was not done after a diagnostic myelogram.

Nonenhanced MRI (T₁- and T₂-weighted) allowed distinct demarcation of the tumor in three patients (Cases 1, 4, and 8). Only indirect signs of a space-occupying process could be demonstrated in Cases 2 and 3, and the findings did not permit a precise separation of the tumor from the adjacent structures (Figs. 3 and 4). This was mainly due to motion or blood flow artifacts and the poor distinction between the normal and pathological tissues. Most of the small neurinomas and meningiomas showed the same relaxation time as the cord and were therefore difficult to identify, especially if situated in the thoracic region and lateral to the spinal cord. In Cases 2 and 3, flattening of the cord by severe compression simulated an intramedullary lesion when MRI was restricted to one plane. The nonenhanced MRI study in Case 7 failed to show any pathological changes.

After intravenous administration of Gd-DTPA, MRI positively identified the tumor in every case (Figs. 2 to 7). Demarcation of the lesion and its differentiation from the cord and other adjacent structures was far better on Gd-DTPA-enhanced images in all patients except Case 8, where a transitory technical defect of the surface coil was encountered. Greater, faster, and more constant tumor enhancement was found in meningiomas compared with the more variable enhancement behavior of neurinomas. However, a reliable differentiation of the two tumor types on the basis of contrast enhancement alone was not possible. Classical criteria like tumor localization, bone destruction, and extradural/extraspinal extension of the mass had to be taken into consideration for a more specific diagnosis. In each case, however, the upper and lower extent of the tumor could be demonstrated accurately on Gd-DTPA-enhanced images, thus avoiding the necessity for additional myelograms above or below the tumor in cases of complete block (Cases 2 and 6).

Discussion

With MRI, large spinal cord tumors can be identified both by pathological changes and by signal intensity; however, until now small tumors could be missed due to partial volume problems and the lower spatial resolution of MRI compared with CT. The superior soft-
FIG. 4. Magnetic resonance imaging in Case 3, with a meningioma at C5-6 (spin-echo images: TR 400 msec, TE 30 msec). Left Pair: The T1-weighted nonenhanced sagittal (upper) and axial (lower) images fail to distinguish between the tumor and the spinal cord. Right Pair: After administration of Gd-DTPA, the meningioma is highlighted.

FIG. 3. Case 2. Sagittal (left) and para-axial (following the direction of the spinal cord, right). T2-weighted magnetic resonance images showing a neurinoma at T2-4. Upper Pair: Images without contrast agent demonstrating inhomogeneous intraspinal signal intensities without distinct demarcation between the lesion and the spinal cord (spin-echo (SE) images: TR 400 msec, TE 30 msec). Lower Pair: Images after injection of Gd-DTPA clearly showing the extramedullary tumor ventral of the spinal cord (SE images: TR 400 msec, TE 30 msec).

FIG. 5. Magnetic resonance paraxial (left) and axial (right) images enhanced with Gd-DTPA in Case 4, with a neurinoma at T10-12. The extraspinal and intraspinal portions of the dumbbell-shaped tumor are clearly visualized (spin-echo images: TR 400 msec, TE 30 msec).

tissue sensitivity of contrast-enhanced MRI allows very small lesions to be recognized.

In this series of eight patients, conventional spin-echo MRI techniques with T1- and T2-weighted images gave clear delineation of the tumor mass in a reasonable examination time in only three patients, even though the location of the lesion was known prior to MRI in seven cases. The meningioma of the foramen magnum was clearly depicted only by MRI. In this case, Gd-DTPA enhancement provided better visualization of the surgically proven extension of the tumor in a narrow layer following the dura of the clivus.

The differentiation between tumors and normal tissue seen on MRI is usually a result of an increase in tumor T1 and T2. With the spin-echo technique, which at present can be regarded diagnostically as the most useful pulse sequence, heavily T2-weighted imaging with high soft-tissue contrast is the most sensitive MRI technique for detection of intraparenchymal lesions. In the evaluation of spinal cord disease, however, several disadvantages of T2-weighted imaging must be taken into consideration. As the signal intensity of each consecutive echo decreases, the overall signal:noise ratio also decreases and thus increased T2-weighted images become progressively noisier. If this noise is added to artifacts from the heart, blood flow, respiration, and abdominal peristalsis, which are difficult to avoid in spinal cord MRI, the image noise may obliterate the lesion contrast sound (Fig. 7). In addition, due to the long investigation time (up to 20 minutes) involved in the heavily T2-weighted spin-echo technique as well as in the inversion-recovery technique, motion artifacts are more likely.

The third problem with T2-weighted imaging of spinal cord lesions consists in the loss of lesion visibility due to cross-over and boundary effects. Even if there is a clear distinction between the lesion and the spinal cord, the signal intensity curves of the tumor and the adjacent cerebrospinal fluid (CSF) may cross over, resulting in a loss of visibility of small lesions. In addition, the cord-CSF interface results in gray transition zones at these boundaries due to resolution loss and/or partial volume effects.4

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FIG. 6. Magnetic resonance images in Case 5, with a neurinoma at C2-3 (spin-echo images: TR 400 msec, TE 30 msec). Left Pair: Without contrast enhancement neither parasagittal (upper) nor axial (lower) images provide a sufficient demarcation of the extraspinal part of the tumor from the surrounding tissue (arrows). Right Pair: The tumor is clearly delineated on the Gd-DTPA-enhanced images.

Judging from more than 30 cranial and spinal meningiomas that we have investigated to date, the $T_1$ and $T_2$ relaxation times of meningiomas and small neurinomas are in the vicinity of the gray/white matter and spinal cord tissue. Therefore, on $T_2$-weighted images the signal intensities of spinal meningiomas and neurinomas are similar to those of the spinal cord, and in CPGM sequences the signal tends to decay in a manner similar to that of the adjacent spinal cord. The obscuring influence of the boundary effect, especially in intraspinal extramedullary lesions, can only be avoided by imaging techniques that cause the lesion to be the brightest tissue in the image. This may be difficult or impossible in the diagnosis of spinal extramedullary tumors with the aid of alteration of pulse sequences only.

After intravenous injection, the contrast medium Gd-DTPA, a tightly bound chelate between the rare earth element Gd and DTPA, is distributed in the vascular system and excreted through the kidney without any side effects. The Gd-DTPA accumulates in tumors as a result of extravascular leakage, providing a greater degree of enhancement than that seen on CT scans. Due to the large magnetic moment, the relaxation times of the adjacent protons are decreased. When Gd-DTPA was administered in low concentrations of about 0.1 mM/kg of body weight (as in our study), only $T_1$ relaxation times decreased, whereas $T_2$ values remained nearly unchanged. Thus, with fast $T_1$-weighted images, very high signal intensities can be obtained selectively from structures accumulating Gd-DTPA. Based on our experience, fast $T_1$-weighted imaging after application of Gd-DTPA may be an important fast screening technique in intraspinal intramedullary as well as in extramedullary tumors.

References


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