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MR Imaging of Brainstem Tumors

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Eighteen patients aged 4–72 years old with brainstem tumors were studied using a 0.5 T magnetic resonance (MR) imager and a third- or fourth-generation computed tomographic (CT) scanner. MR imaging showed the brainstem to be enlarged on sagittal views in all cases; exophytic growth was seen in eight. Alterations of signal intensities were shown in most cases on spin-echo sequences using 30 and 90 msec echo times and inversion recovery techniques. It was not possible to distinguish primary from metastatic tumors. The configurations and margins of the areas with abnormal signal did not appear to correlate with the clinical behavior of the tumors. CT was able to recognize brainstem tumor in only 13 of 16 cases. In the two cases of metastases, plain CT scans were normal, but enhancement was seen after administration of contrast material in one. It appears that MR imaging is sensitive in detecting tumor enlargement and abnormal signals and is superior to CT in evaluating brainstem tumors.

Differentiation of intrinsic from extrinsic tumors of the brainstem is extremely important in the management of patients with posterior fossa symptoms: extraaxial tumors may be surgically removed, whereas intrinsic tumors usually require radiotherapy [1–6]. Brainstem gliomas constitute 25% of all posterior fossa tumors in childhood [1–3, 7, 8], but occur also less commonly in adults [4, 5]. They originate usually in the pons and spread to the midbrain and medulla. Surgical intervention on tumors that cause diffuse enlargement of the brainstem may lead to complications, but the morbidity of biopsy of exophytic lesions is acceptable [2, 7–11]. Precise delineation of brainstem tumors is important in planning radiotherapy. The locations and histologic characteristics of these tumors determine the prognosis [12, 13].

Although computed tomography (CT) has been reported to be sensitive in the diagnosis of brainstem tumors in children [14–16], it is less accurate in adults and older children, in whom artifacts from the petrous bone are more pronounced. Arteriography may reveal tumor vascularity, but CT after administration of intrathecal water-soluble contrast material is often required for detailed evaluation for treatment [17]. Because of the ease of performance and the lack of bony artifacts magnetic resonance (MR) imaging promises to be superior to CT in the diagnosis of brainstem tumors [18–22]. Scanning sequences that highlight differences in proton relaxation may also be useful in determining the histologic nature of these tumors.

Subjects and Methods

We studied 18 patients with intrinsic brainstem tumors. Sixteen had primary brainstem gliomas (including three who had been treated by radiotherapy) and two had metastases. The clinical presentations were consistent with such diagnoses in all but one patient whose symptoms suggested an extrinsic lesion. The patients were 4–72 years old. CT was performed on third- or fourth-generation scanners using 5 mm axial sections, without and with single doses of intravenous contrast material (42 g I) in all cases and with intrathecal metrizamide

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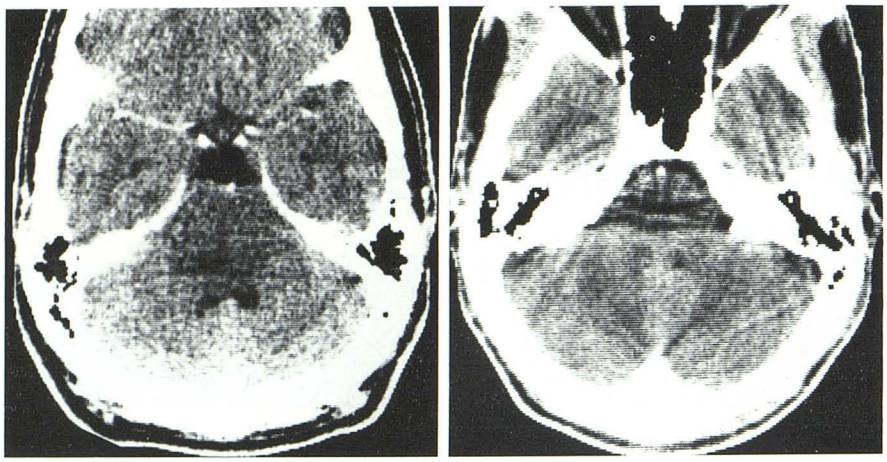


Fig. 1.—Contrast-enhanced CT scans. **A**, Slight compression of floor of fourth ventricle and basal cisterns. Brainstem has slightly decreased attenuation. **B**, Probable compression of fourth ventricle.

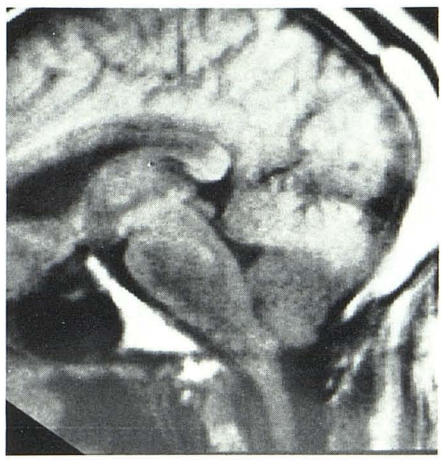


Fig. 2.—Sagittal SE 500/30 image. Generalized enlargement of entire brainstem.

in three. Pathologic proof was obtained by biopsy in four cases and by autopsy in one. One case represented extension of tumor from the thalamus to the brainstem.

MR imaging was performed with a Technicare 0.5 T imaging system. Sagittal views were obtained in all patients and axial views in 14 (by anisotropic volume, single- or multiple-slice techniques). The other three patients were too ill to tolerate these additional sections. A spin echo (SE) sequence was used with 30 msec echo delay (TE) and repetition time (TR) of 500 msec in all sagittal and axial sections. In 14 patients appropriate sagittal and axial sections using SE sequences with longer TEs (60, 90, and 120 msec) and TRs (1000–1500 msec) were performed also. Inversion-recovery (IR) sequences using inversion times (TIs) of 450 msec and TRs of 1500 msec were performed in 10 patients. In single sections, 192 gradient steps were used; 128 or 192 steps were selected for the anisotropic volume imaging. The signals were averaged twice. Multiple sections and anisotropic volume images were 8 mm thick and contiguous. Single sections were 10 mm thick. Scanning times varied from 3.3 to 9.9 min for single and multiple slices and 10 to 37 minutes for anisotropic volume imaging.

All CT scans and MR images were reviewed independently without clinical data. Several criteria were used to evaluate MR images. Enlargement was evaluated in both sagittal and axial planes. On the sagittal views the midbrain was considered enlarged when there was posterior displacement of the aqueduct, and the pons and medulla were enlarged when there was posterior bulging of the floor of the fourth ventricle. In the axial planes asymmetry of the brainstem was always abnormal, as was posterior compression of the fourth ventricle and basal subarachnoid space by an enlarged brainstem. Exophytic growths were seen in both sagittal and axial planes as localized expansions, usually irregular. Increased *signal* appeared as white and decreased signal as black on all imaging sequences. The margins of the abnormal signal were judged as well or poorly defined by subjective observation. CT scans were evaluated on the basis of the size of the basal cisterns, size and position of the fourth ventricle, and attenuation before and after intravenous contrast enhancement.

Results

Brainstem Gliomas

CT scans were abnormal in 10, equivocal in three, and normal in three cases. Eight cases showed evidence of brainstem enlargement causing compression and displacement of the fourth ventricle and basal cisterns, three were normal, two were probably normal (fig. 1), and two were impossible to evaluate because of artifacts. The attenuation of the brainstem on CT was decreased in five, increased due to calcium in two, and normal in the other cases. Contrast enhancement was present in only two cases.

Sagittal MR images showed enlargement of the brainstem on SE images with 30 msec TEs in all cases: the enlargement involved the entire brainstem in three, the midbrain and pons in six, the pons and medulla in five, and the medulla alone in two (fig. 2). There was evidence of exophytic growth posteriorly into the fourth ventricle in four, anteriorly into the pontine cistern in three, (fig. 3), and laterally in one case. Decreased signal was shown on SE images with 30 msec TEs and on IR sequences in six cases (figs. 4 and 5). The signals were increased on SE images with 60–120 msec TEs in seven cases. The abnormal signals were well demarcated in six cases, poorly defined in six, and involved the entire brainstem in one (fig. 6). The increased signal intensity surrounded an area of calcification in one case (fig. 7). The signal intensity did not alter with different imaging techniques in four cases.

MR imaging made a definite diagnosis of brainstem tumor in all 16 cases, compared with CT, which was unequivocally abnormal in only 13 cases. Intravenous contrast enhancement was not essential for detecting brainstem tumors: the two cases showing enhancement were definitely abnormal before enhancement (fig. 7).

Metastases

Plain CT scans were normal in both cases; one enhanced after administration of intravenous contrast material. On MR images, the brainstem was smoothly enlarged in one, but irregular and asymmetric in the other case. Both cases showed altered signal intensities within the lesion. The primary tumors were of the lung and breast.

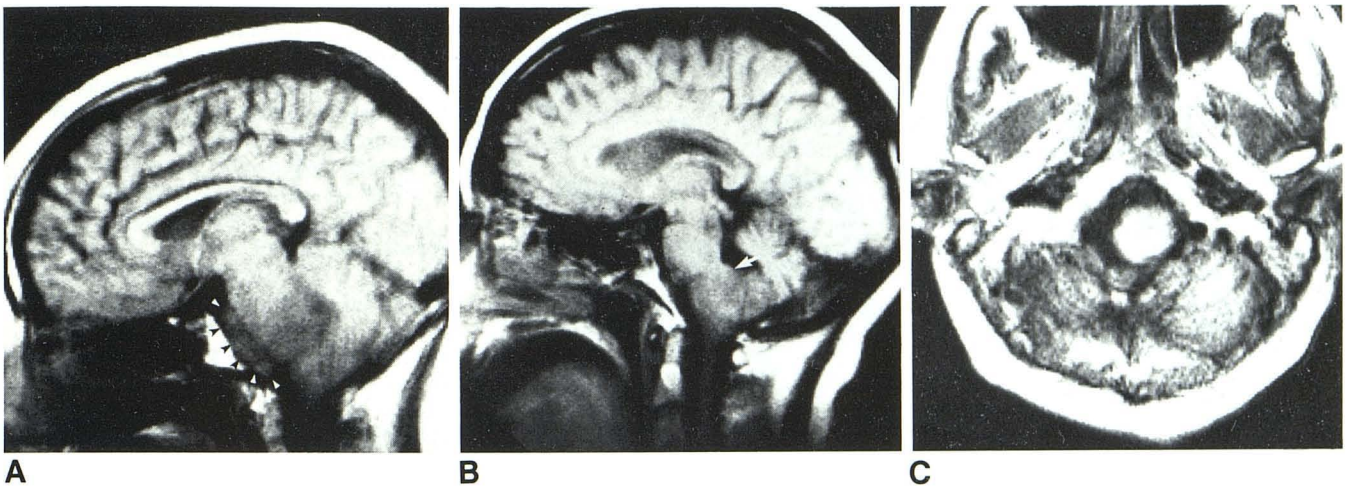
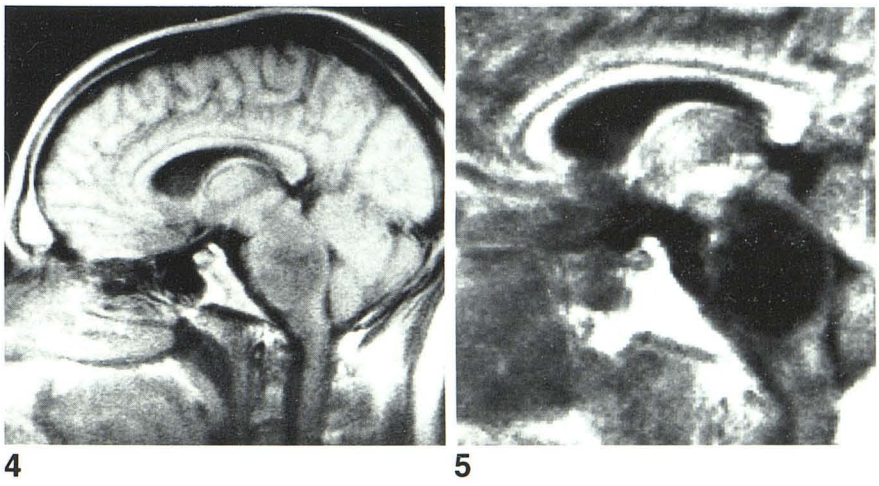


Fig. 3.—Sagittal SE 500/30 images. Exophytic growth extending anteriorly into pontine cistern (**A**, *arrowheads*) and posteriorly into fourth ventricle (**B**, *arrow*). **C**, Axial view. Asymmetric enlargement of medulla.

Fig. 4.—Sagittal SE 500/30 image. Poorly defined area of decreased signal intensity.

Fig. 5.—Sagittal IR 1500/450 image. Well demarcated area of increased signal intensity in pons and medulla.



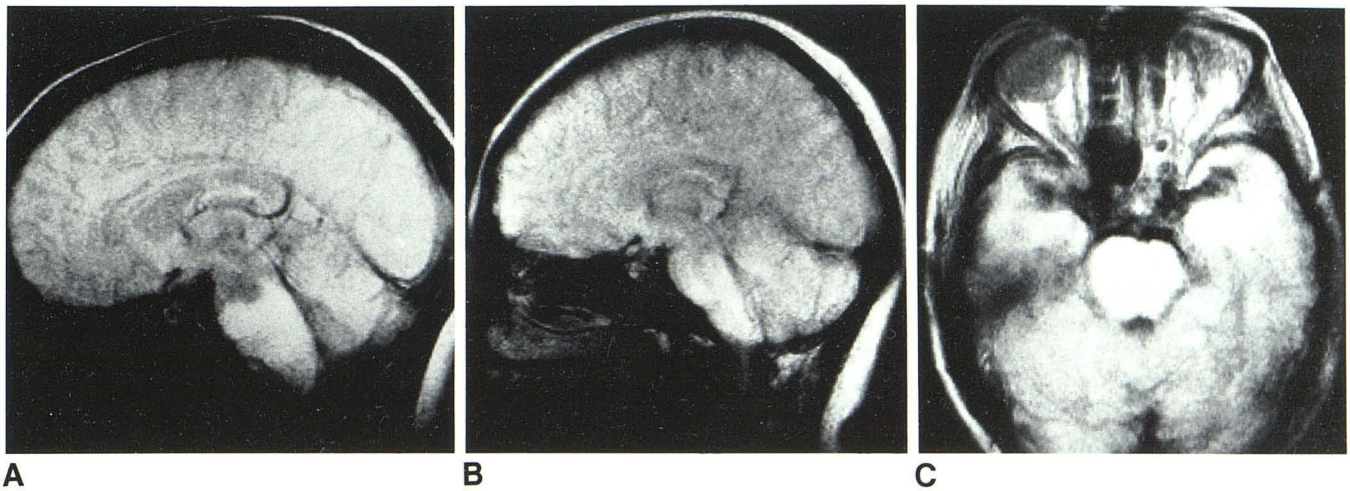


Fig. 6.—Sagittal SE 1500/90 images. Well demarcated (**A**) and poorly defined (**B**) areas of increased signal intensity. **C**, Axial SE 1500/120 image. Slight but definite increased signal intensity in entire midbrain, which is slightly enlarged.

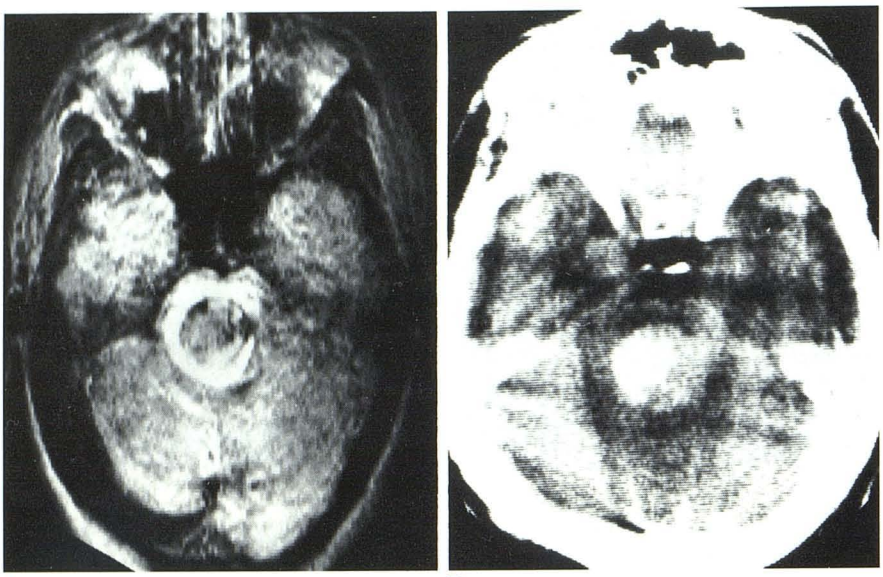


Fig. 7.—**A**, Axial SE 1000/90 image. Central region of normal signal surrounded by rim of increased signal. **B**, Nonenhanced CT scan. Center contains calcification.

Discussion

Tumor Diagnosis

The precise locations and extent of brainstem enlargement are uniformly demonstrated in all cases. The accuracy of these findings is so striking that we stopped performing metrizamide CT scanning after detailed comparison with MR images in three patients. The anatomic displacements are shown optimally on SE sequences with 30 msec TEs, 500 msec TRs and 192 gradient steps. Increasing the number of gradient steps beyond this results in unacceptable noise levels and consequent loss of anatomic detail. The most useful view is the midline sagittal section, which shows either a smooth swelling of the brainstem (fig. 2) or localized exophytic enlargement extending posteriorly into the fourth ventricle or anteriorly into the basal cisterns (fig. 3). The axial view is used for demonstrating whether the enlargement is symmetric.

Relaxation Characteristics

Apart from merely enlarging the brainstem, intrinsic tumors cause changes in T1 and T2 relaxation times [23, 24]. However, tissue contrast is a complex function of T1, T2 hydrogen density, flow, TR, TE, and TI [25]. The signal intensity in the SE sequence using a single TE is not an absolute indicator of these factors. In view of the variable appearances of brainstem tumors demonstrated in our study, it is essential to perform SE sequences with differing TEs. In addition, IR pulse sequences may provide additional data.

It is difficult to directly compare altered CT attenuation and contrast enhancement with abnormal signal on MR images, as the methods used for detecting these changes are different. The higher incidence of MR signal changes tends to suggest that this method is more sensitive than CT in detecting abnormalities. It was hoped initially that tumors with well defined borders on MR images would be less aggressive than those with poorly defined margins (figs. 4–6). Unfortunately the clinical behavior cannot be predicted by these criteria. It is noteworthy that the three cases previously treated by radiotherapy show changes in the size of the brainstem but show normal signal by all imaging techniques. The neurologic abnormalities are static in these cases, suggesting remission of tumor growth. It is probable that signal changes may be used to monitor progress of therapy.

In many cases the regions immediately adjacent to the tumor masses show marked increase in signal intensity on the long SE sequences. This may be caused by tumor infiltration and/or edema. The visual appearances do not allow differentiation between these two abnormalities.

Differential Diagnosis

Since there is such a variation in signal intensities of histologically similar lesions, it is not possible to predict the exact pathology of brainstem tumors. The two cases of presumed brainstem metastasis show alteration of signal intensities in some sequences similar to those seen within primary tumors. MR imaging is very useful in differentiating hemorrhage from calcification, as both cause high attenuation on CT scans [26, 27]. Calcium has no signal on MR imaging, whereas hemorrhage gives rise to increased signal in all sequences because of its short T1 and long T2 relaxation. In our case the combination of calcification (low signal) and tumor (high signal) probably accounts for the resultant normal intensity in the center of the lesion. Although calcification within brainstem gliomas is uncommon on CT scans [14, 15], increased signal surrounding such a region is suggestive evidence of tumor infiltration.

Patients with encephalitis occasionally have symptoms mimicking brainstem tumors, which are difficult to clarify on CT scans. It is not clear whether MR imaging can differentiate these entities by virtue of signal intensity characteristics.

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