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Abnormal diffusion-weighted MRI in medulloblastoma: does it reflect small cell histology?

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Abstract A 12-year-old boy presented with the classic CT and MRI findings of medulloblastoma and the unusual finding of increased signal on diffusion MRI. The small-cell histology of medulloblastoma may account for the increased signal seen on diffusion MRI. Diffusion MRI with echoplanar technique may be useful in evaluation of these tumors and metastatic disease.

Introduction

Medulloblastomas are malignant neoplasms composed of undifferentiated, small, round cells with high nuclear-to-cytoplasmic ratio. These tumors account for 30–40 % of posterior fossa tumors in children. We present a case of medulloblastoma with increased signal intensity on diffusion-weighted echoplanar MRI. We theorize that the densely cellular nature of medulloblastoma and the high nuclear-to-cytoplasmic ratio of this tumor restrict diffusion of water, causing increased signal on diffusion-weighted MRI.

Case report

A 12-year-old boy presented with a history of intermittent headache, vomiting, and dizziness of 3 weeks' duration. Physical examination was significant for tremor and ataxia, but was otherwise unremarkable.

Nonenhanced, axial head CT revealed a hyperdense midline posterior fossa mass with cystic components and mild obstructive hydrocephalus (Fig. 1). MRI also demonstrated a cystic mass with a solid component exhibiting isointensity to gray matter on T1- and T2-weighted images and marked contrast enhancement with associated vasogenic edema (Fig. 2 a–c).

Pulsed gradient spin echo (PGSE) diffusion-weighted images (DWI) were obtained on a 1.5 T Siemens Magnetom Vision utilizing echoplanar technique (TR 0.8 ms; TE 123 ms; b value 1100; flip < 90; 5-mm slice thickness; 1 NEX; 128 × 128 matrix). These images demonstrated increased signal intensity in the solid, enhancing portion of the tumor (Fig. 2 d).

The patient underwent craniotomy with excision of the posterior fossa mass and third ventriculostomy for hydrocephalus. Histologically, the tumor consisted of small, round-to-oval cells arranged in solid sheets. Individual cell necrosis and high mitotic activity were observed. These histological features are consistent with a diagnosis of medulloblastoma (Fig. 3). CSF cytology was negative at the time of surgery.

Discussion

There is increasing utilization of diffusion-weighted imaging, particularly in the setting of cerebral ischemia, to identify potentially salvageable tissue and to differentiate acute from chronic infarction.

Diffusion is a process whereby water molecules spontaneously move along random pathways, so-called Brownian motion. Diffusion-weighted MRI is a unique tissue contrast based on this process. For water protons diffusing within a tissue matrix, an observed apparent rate and direction of diffusion will reflect the molecular and macromolecular barriers that the proton "sees" during its translational path length. The diffusion technique

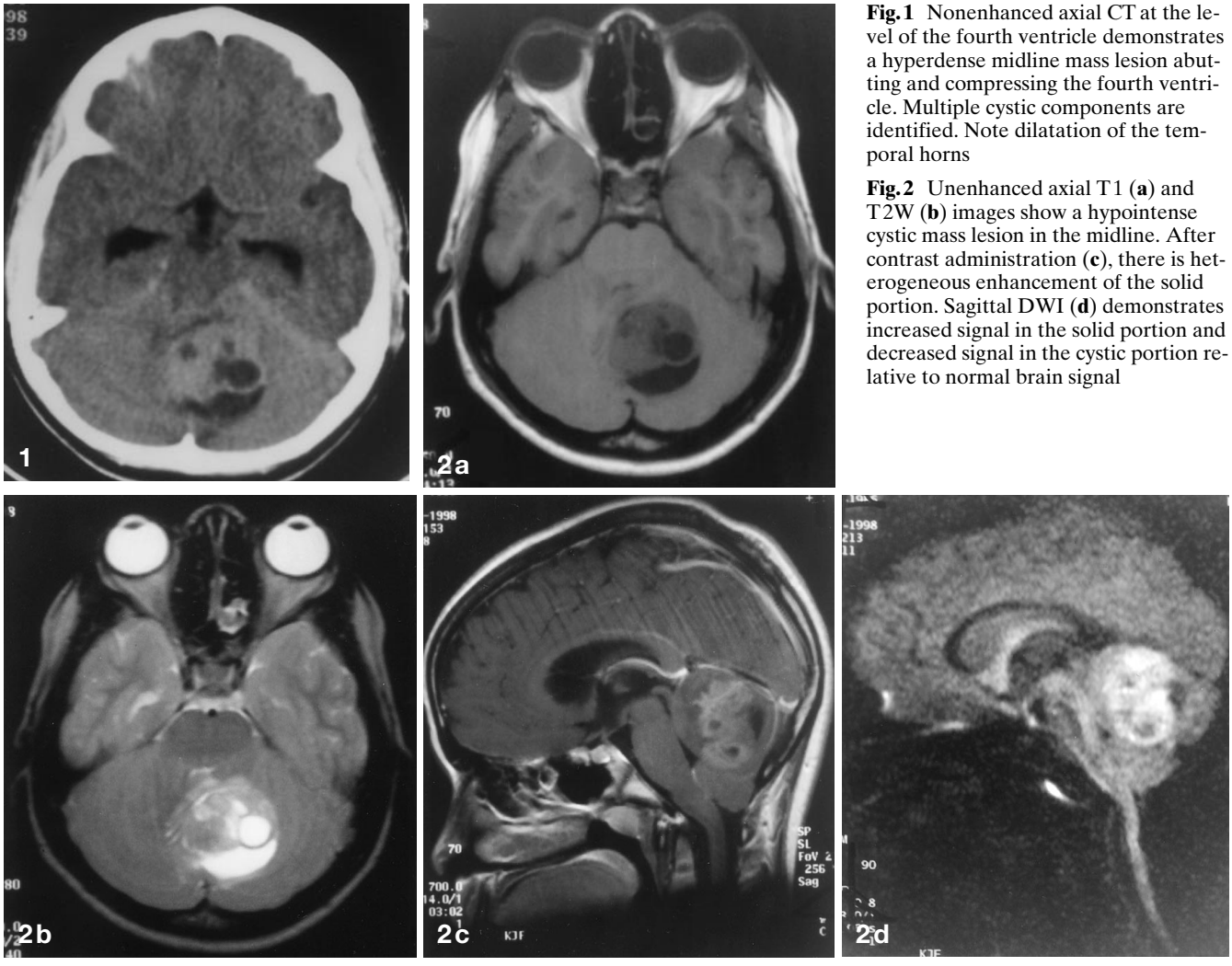

Fig. 1 Nonenhanced axial CT at the level of the fourth ventricle demonstrates a hyperdense midline mass lesion abutting and compressing the fourth ventricle. Multiple cystic components are identified. Note dilatation of the temporal horns

Fig. 2 Unenhanced axial T1 (**a**) and T2W (**b**) images show a hypointense cystic mass lesion in the midline. After contrast administration (**c**), there is heterogeneous enhancement of the solid portion. Sagittal DWI (**d**) demonstrates increased signal in the solid portion and decreased signal in the cystic portion relative to normal brain signal

uses a pair of strong magnetic gradient pulses to dephase and subsequently rephase protons. Protons experiencing slow or hindered diffusion will largely rephase (fewer spins phase-cancel because the spins have not traversed far enough apart to randomize their phases), and this appears as retention of high signal intensity [1]. In tissue, diffusion can be restricted by microviscosity, by interactions with macromolecular substances, or by cellular and compartmental membranes [2]. The features that characterize heavily diffusion-weighted images of the brain are: low signal from the CSF, strong T2-weighting, and selective highlighting of the white-matter tracts as a function of the direction of gradient sensitization [3].

With ischemic failure of the Na-K ATPase pump, there is cytotoxic edema with shift of water from the extracellular to the intracellular space. In addition, there are ion and macromolecular imbalances, denaturation of intracellular structures, and changes in local tissue magnetic susceptibility gradients induced by hemoglobin deoxygenation. The decrease in apparent diffusion and increase in signal seen on DWI represent an ensemble averaging of these factors [4].

MRI diffusion abnormalities are not, however, specific for ischemia/infarction. Recently, there have been reports of increased signal on DWI in brain abscess [5] and in some brain tumors such as lymphoma [6] and glioma [7]. Chang et al. [5] suggest that the finding in brain abscess is due to "high-viscosity." Others note that densely packed, randomly organized tumor cells can inhibit effective motion of water protons and therefore restrict diffusion [8]. Additionally, the strong T2-weighting of this technique provides high sensitivity for lesions with increased signal on T2-weighted images, causing a "shine-through" effect further reducing specificity [2].

We postulate that the dense nature of medulloblastoma restricts extracellular diffusion of water protons and

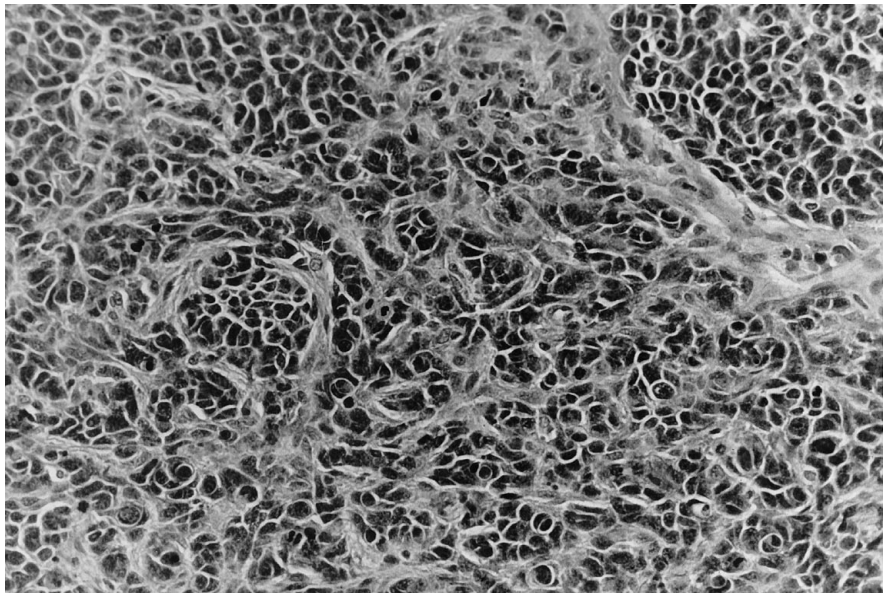

Fig. 3 Histologic specimen at medium power shows small, round, densely packed tumor cells

that the high nuclear-to-cytoplasmic ratio of these tumor cells limits intracellular motion. The combination of these factors leads to a significant reduction in the rate of apparent diffusion and in a marked increase in signal on diffusion echoplanar images. This may account for the similar findings reported in cases of lymphoma and high-grade glioma and the absence of such findings in most brain tumors. As noted above, this mechanism is implicated to explain the CT and T2W MRI characteristics of such tumors and may add diagnostic specificity. Our case demonstrated isointense signal on T2W images, thereby eliminating any contribution from a shine-through effect.

We have found the PGSE DWI echoplanar technique to be very useful in the pediatric population, secondary to short acquisition time (several seconds) that limits susceptibility to motion artifact. If further study validates our theory that this technique is relatively specific for small-cell histology, applications for its use could expand. For example, as protocols are developed to image the spine reliably, DWI could potentially improve speed and accuracy in the evaluation of metastatic medulloblastoma.

In conclusion, we have presented the imaging findings in a surgically proven case of medulloblastoma and have proposed that the small-cell histology of this tumor may explain the diffusion abnormalities seen.

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