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MR Imaging of Metastatic GI Adenocarcinoma in Brain

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Purpose: To investigate an observed preferential T2-shortening effect seen in patients with intracerebral metastases from adenocarcinoma of the GI tract. **Methods:** Ten patients with intracerebral metastases from adenocarcinoma of the GI tract were evaluated with MR imaging with CT and histopathologic correlation. **Results:** Nine of 10 patients demonstrated intracranial masses with decreased signal intensity on T2-weighted images. T1-weighted images showed decreased or isointense signal in all cases. Special histologic staining was performed in four of 10 cases, all of which were positive for increased protein (mucin) with no evidence of blood products or calcium. **Conclusion:** We propose that the observed preferential T2-shortening effect is secondary to slowing of rotational and translational proton motion caused by increased protein concentration in the form of mucin.

Index terms: Neoplasms, GI tract, metastasis; Brain neoplasms, magnetic resonance

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Intracerebral metastases have been found in 11%–24% of autopsied cancer patients. The most common primary tumors to metastasize to brain are those of lung and breast, and malignant melanoma. Tumors of the GI and GU systems represent the fourth most common primary cause of brain metastases (1–3). In contrast to the usual prolongation of T1 and T2 relaxation times, which nonhemorrhagic metastases demonstrate, we observed preferential T2 shortening in metastatic adenocarcinoma to the brain by magnetic resonance (MR) imaging. Therefore, we undertook a retrospective study of the MR appearance of metastatic adenocarcinoma of the GI tract with two purposes: 1) to determine if the observed T2 shortening effect was a consistent finding for metastatic adenocarcinoma of the GI tract, and 2) to review histopathology from brain biopsies in an attempt to explain this signal behavior.

Patients and Methods

A retrospective study of patients with pathologically confirmed adenocarcinoma of the GI tract and masses in the brain by MR imaging was undertaken. Our patient population consisted of 10 patients (four men, six women) with an age range of 48 to 89 years (mean 66). Eight of 10 patients were imaged on a 0.6 T unit (General Electric Medical Systems, Milwaukee, WI); one patient on a 1.0 T unit (Siemens Medical Systems, Erlangen, Germany); and one patient on a 1.5 T unit (General Electric).

A standard spin-echo pulse sequence was used to obtain T1-weighted, 500–600/15–32/2–4 and T2-weighted, 2000–2500/22–32, 80–120/1–2 (TR/TE/excitations) images in the sagittal, axial, and coronal planes. Enhanced T1-weighted images were obtained on five patients using gadolinium-DTPA (0.1 mmol/kg). A 192 × 256 or 256 × 256 matrix was used to obtain images of 5–10 mm slice thickness. Field of view was 23–24 cm. Pre- and postcontrast computed tomography (CT) images were obtained on five patients. Slice thickness was 10 mm. All imaging studies were reviewed by two neuroradiologists (J.C.E., J.S.R.). MR and CT imaging was performed between September 1985 and July 1990.

Special histopathologic correlation was available on four of 10 patients. In addition to routine hematoxylineosin staining, special stains for blood products, iron, and calcium were obtained. These included Prussian blue, mucicarmine, and Alcian blue stains.

Results

Sixteen intracerebral masses were found by MR in 10 patients. Six patients had single masses

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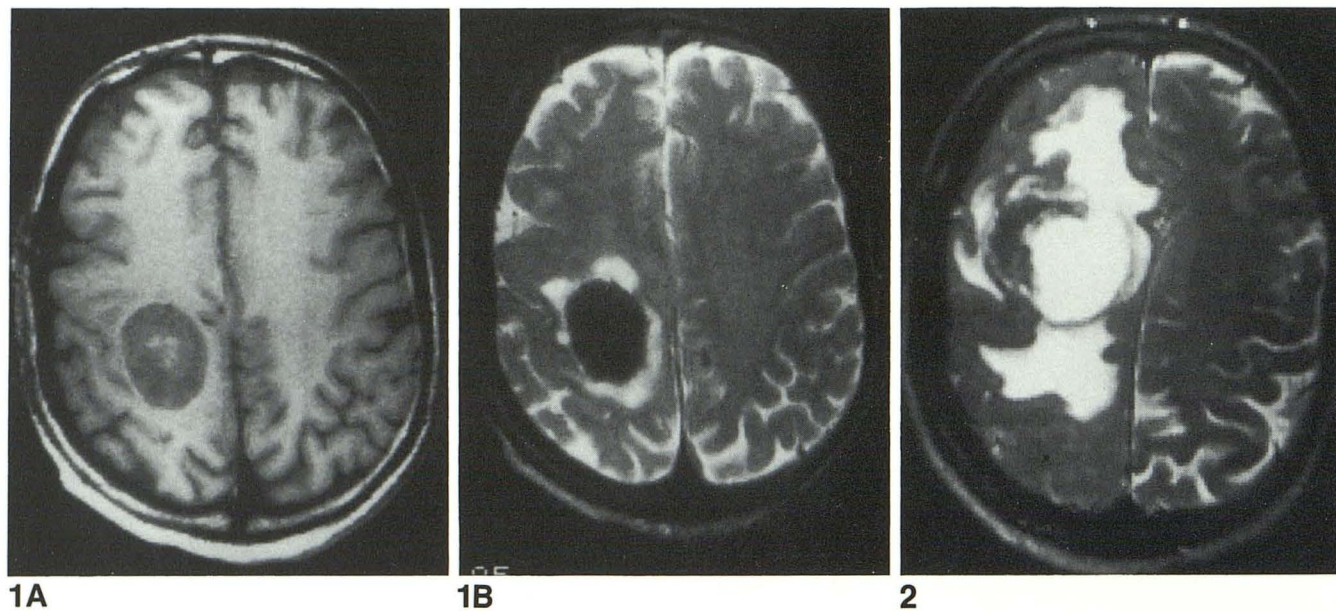


Fig. 1. A, Axial T1W (500/32) MR image demonstrates a large metastatic lesion in the right parietal lobe with both isointense and decreased signal.

B, T2W (2000/120) MR image shows homogeneously decreased signal within the mass and a small area of surrounding edema.

Fig. 2. Axial T2W (2000/120) MR image of a large right frontoparietal metastasis shows mixed signal characteristics with areas of decreased and increased signal intensity, surrounding edema, and midline shift.

and four patients had multiple masses. Eleven of the 16 masses were located in the cerebrum, four in the cerebellum, and one in the brain stem. On T2-weighted images, 12 of 16 masses demonstrated areas of decreased signal. Eleven of the 12 had mixed signal characteristics with nine demonstrating areas of decreased and isointense signal and two demonstrating areas of both decreased and increased signal (Figs. 1 and 2). Three masses demonstrated purely increased signal on T2-weighted images and one mass had isointense signal. On T1-weighted images, all lesions demonstrated decreased or isointense signal. In patients having postcontrast studies, five of five masses demonstrated enhancement (Tables 1 and 2).

CT correlation was available on five patients. With the exception of one mass, all lesions demonstrated areas of decreased attenuation on non-contrast imaging with enhancement after contrast administration. The lesion that did not enhance was one of the masses that also demonstrated increased signal on T2-weighted images.

Histopathologic comparison with brain biopsy specimens was available on four patients. All specimens demonstrated findings compatible with metastatic adenocarcinoma of the GI tract. In all specimens, stains were positive for increased protein concentration, with no evidence of iron products or calcium.

Discussion

Intracerebral metastases represent approximately 20% of all brain tumors with an incidence in the general population of 2.8 to 11/100,000. Approximately 20% of autopsies in cancer patients demonstrate intracerebral metastases. Fifteen to 30% of metastases are clinically silent. Metastatic lesions to brain from GI primaries represent 5% of the total of intracerebral metastatic lesions (1-3).

Typically, on MR imaging, nonhemorrhagic intracerebral metastases demonstrate long T1 and T2 relaxation times. Hemorrhage is not usually found in metastatic GI adenocarcinoma to brain,

TABLE 1: Signal characteristics of metastatic GI adenocarcinoma in brain

	Signal on T1W (N = 16)	Signal on T2W (N = 16)
Decreased		12
Homogeneous	2	1
Mixed	14	11
Isointense/decreased	14	9
Increased/decreased		2
Increased		3
Isointense		1

TABLE 2: Signal characteristics/imaging field strength masses with histopathologic correlation

Case No.	Signal on T1W in Relation to Normal Gray Matter	Signal on T2W in Relation to Normal Gray Matter	Field Strength (Tesla)
1	Decreased	Increased	.6 T
2	Decreased	Mixed	.6 T
		Decreased/Increased	
3	Mixed	Mixed	.6 T
	Decreased/Isointense	Decreased/Isointense	
4	Mixed	Mixed	1.5 T
	Decreased/Isointense	Decreased/Isointense	

although microcalcifications have been reported causing increased attenuation on CT imaging (4, 5). In our study, histologic evaluation revealed no evidence of blood products or calcium. We propose that the explanation for the observed T2-shortening effect (with iso or decreased signal on T1-weighted images) in metastatic adenocarcinoma of the GI tract to brain is related to hydration layer effect.

In 1948, Bloembergen et al found that relaxation characteristics are related to molecular motion (6). In 1977, Edzes and Samulski explained the dependence of tissue relaxation on motional properties of macromolecular constituents using what they call the cross-relaxation mechanism (7, 8). The most important source of shortening of relaxation in tissues at MR frequency is caused by changes in the hydration state of a solid or liquid (9).

The relaxation of most fat-free tissues can be described in terms of three water fractions: bound water, structured water, and bulk water. Bound water represents water molecules directly bonded to a macromolecule. Structured water is water molecules that are motionally perturbed by a macromolecule, but not bonded. Bulk or "free" water is water molecules, the molecular motion of which is determined solely by the interaction characteristics of the water molecule. Hydration water is all water molecules, bound or structured, for which motion is perturbed from bulk water by the presence of a macromolecule. The relaxation rate for the bound water fractions are the most important (9, 10).

In metastatic adenocarcinoma of the GI tract, the glandular cells produce the hydrophilic protein, mucin, which represents the macromolecule. Mucin is a large, complex, conjugated protein that combines with the nonprotein prosthetic group acetylhexosamine to form one of the glycoproteins (11, 12). This macromolecule causes

a change in the state of the bound and structured water in the brain by binding hydrogen protons and perturbing the motion of other hydrogen protons. The increasing size in mass of the macromolecule structure causes anisotropic molecular motion in both hydration water phases. As a result, there is a slowing or decrease in the tumbling rate of hydrogen ions, with subsequent slowing of the translational and rotational proton motion and an increase in field inhomogeneity. Dephasing of protons occurs with loss of coherent resonance. This slowing continues until the molecules have reached a frequency much lower than the Larmor frequency. T1 relaxation is most efficient when the frequency of the molecules is similar to the Larmor frequency. At a lower frequency, T1 relaxation is inefficient causing a long T1 relaxation time. Differences in resonance frequencies in a population of protons, particularly at frequencies below the Larmor frequency, will preferentially shorten T2 relaxation over T1 relaxation (13).

An alternate theory proposed by other authors states that solvent (water) and solute (protein) particles must be considered as two thermodynamic systems. Water molecules randomly wander by thermal-induced diffusion through the intra- and extracellular spaces of tissue. When the two systems interact, the dynamics of the magnetization and relaxation of one system influences and alters the dynamics of the other system (cross-relaxation). This and the intrinsic relaxation of each system is the basis of water proton relaxation rates in tissue and contrast in MR (14, 15).

Three of our cases demonstrated increased signal on T2-weighted images. A possible explanation for this finding would be a lower concentration of mucin within the metastatic lesion and a subsequent greater bulk water state. This would allow for a longer T2 relaxation time.

We feel it is unlikely that the observed preferential T2 shortening is secondary to the paramagnetic effect of a free radical, such as is seen with melanin. This effect is dependent on field strength (16), and eight of 10 of our patients were imaged on a 0.6 T unit.

In conclusion, we observed that metastatic adenocarcinoma of the GI tract to brain commonly demonstrates decreased signal on T2-weighted images. We believe this unusual signal behavior can be explained by the protein concentration of mucin found in adenocarcinoma. The binding of this macromolecular structure to hy-

drogen ions results in slowing of the tumbling rate of the hydrogen ion, loss of coherent resonance, and subsequent preferential T2 shortening.

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