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MR of Intracranial Epidermoid Tumors: Correlation of In Vivo Imaging with In Vitro ^{13}C Spectroscopy

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We analyzed the MR findings of five patients with benign intracranial epithelial tumors, commonly called epidermoids. The neoplasms were categorized into two groups on the basis of T1-weighted MR signal intensity (relative to brain): high-signal-intensity masses (short T1) and low-signal-intensity masses (long T1). Surgical specimens were obtained and analyzed by means of ^{13}C MR spectroscopy. Epidermoids with short T1 values (white epidermoids) had a high lipid content comprising mixed triglycerides containing unsaturated fatty acid residues. Epidermoids with long T1 values (black epidermoids) exhibited a much reduced lipid content with no triglycerides or fatty acids. There was evidence of trace amounts of cholesterol in the black epidermoids.

Our data indicate that epidermoids are a heterogeneous group of neoplasms that behave differently with T1-weighted MR imaging and ^{13}C MR spectroscopy. The combination of MR imaging and spectroscopy holds the potential of further elucidating the nature of epidermoids as well as of other forms of neoplasms.

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Epidermoids (epidermoidoma, congenital or primary cholesteatoma, pearly tumor) are slow-growing, extraaxial lesions that are thought to arise from epithelial inclusions formed at the time of closure of the neural tube between the third and fifth week of fetal life [1–4]. Intracranially, epidermoids are most common in the cerebellopontine angle and parasellar areas. They may also be seen within the calvarium or skull base (intraosseous) and, rarely, are found intraaxially, within the cerebral hemispheres or ventricular system [5, 6]. Histopathologically, epidermoids are known to have a component of stratified squamous epithelium with variable degrees of keratinization. The squamous epithelium rests on an outer layer of connective tissue, which may be moderately vascular [7]. Epidermoids may be solid or cystic [6, 8] and are thought to contain high concentrations of both lipid and cholesterol [6, 9–12]. The outer surface of the neoplasm frequently exhibits an irregular, nodular texture with frondlike projections and a shiny mother-of-pearl appearance. Calcification may be present [4, 9, 13].

Classical imaging methods—such as plain films, polytomography, and, more recently, CT—may demonstrate sharply marginated lytic bone lesions or bone erosion with scalloped, sclerotic borders. On CT, the classical appearance of an epidermoid is that of a low-density mass with Hounsfield units approximating that of water or even fat. There may be associated calcification, and, rarely, contrast enhancement. Reports are present in the literature, however, that document occasional epidermoids exhibiting hyperdensity prior to contrast administration [14, 15] as well as cases of such tumors with contrast enhancement [16].

Several authors [9, 17–19] have documented the MR imaging characteristics of epidermoids. Most commonly, these lesions have been noted to exhibit prolonged T1 and T2 values with T1-weighted images demonstrating a CSF-intensity mass. However, additional cases have been noted in which these lesions have demonstrated shortened T1 and prolonged T2 values with high signal intensity on T1-

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weighted images [20, 21]. This suggests the presence of mobile protons in a lipid-type substance.

The purpose of this study was to analyze a group of intracranial epidermoids with MR and to correlate the imaging characteristics with the results of in vitro ^{13}C MR spectroscopy on the excised operative specimens. It was hoped that such a correlative study would lead to a better understanding of the nature and origins of these neoplasms and particularly of their lipid components. Furthermore, such an approach in the future might allow both MR imaging and in vivo spectroscopy to more accurately define and histologically characterize various forms of neoplasms.

Subjects and Methods

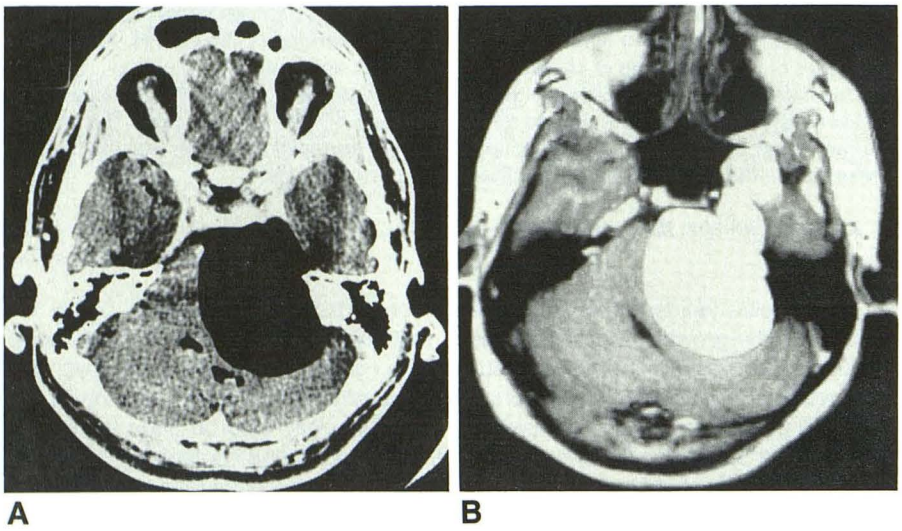
Five patients with proved benign intracranial, extraaxial epidermoids were studied with clinical MR imaging. The excised surgical specimens were subjected to in vitro ^{13}C MR spectroscopy. Additionally, all five patients had routine CT examinations during the course of their preoperative evaluation.

MR imaging

All patients were imaged at 0.5 T on a Siemens Magnetom unit. T1-weighted images were obtained with routine spin-echo pulse sequences with short TEs (16–35) and short TRs (300–500). Spin-density- and T2-weighted images were also obtained, but were less characteristic. T1 values for both types of tumors were determined on an IBM PC-10 instrument.

^{13}C MR Spectroscopy

All ^{13}C MR spectra were run on a wide-bore FT-NMR spectrometer (Bruker AM 400, Bruker A.G., Karlsruhe, W. Germany) operating at 100.61 MHz with proton decoupling. Spectra were accumulated in 16K data points with a spectral width of 22 kHz and a recycle time of 2 sec. Equivalent amounts (1.0 g) of fresh, postsurgical tumor specimens were used for spectral analysis. The tissues themselves were investigated in 10-mm NMR tubes, without sample spinning. A concentric capillary containing D_2O served as the external lock in the case of the tissue determinations. The tissue FIDs (free induction decay) were processed with a line-broadening factor of 10 Hz and automatic baseline correction. In addition, 1.0 g of each neoplasm was subjected to extraction with 10 ml of a chloroform-methanol mixture (5:1), filtered and evaporated. The dried residue in each case



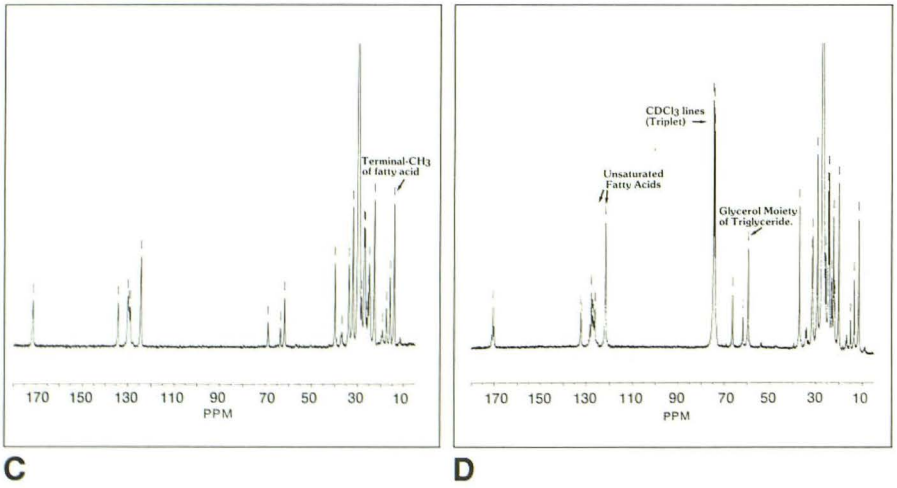


Fig. 1.—*A*, Axial CT scan of white epidermoid shows a large, well-defined extraaxial mass centered in left cerebellopontine angle. The neoplasm is associated with negative (fatty) Hounsfield units.

***B*, Axial T1-weighted MR image of white epidermoid shows a large, hyperintense, cerebellopontine angle mass, with extension into middle fossa and cavernous sinus. The mass is hyperintense owing to a short T1 of approximately 500 msec.**

***C* and *D*, ^{13}C MR spectra of white epidermoid (*C*) and chloroform-methanol extract of white epidermoid (*D*). Intense resonances are seen at 61.9 ppm and 70.0 ppm from the C-1, C-3, and C-2 carbons of the glycerol moiety. There is a relatively strong carbonyl resonance at 171.8 ppm as well as several strong signals at 115–135 ppm, indicating olefinic residues.**

was dissolved in 0.4 ml $CHCl_3$ for the spectral determinations in 5-mm NMR tubes. The spectrum of the white epidermoids was referenced by assigning the chemical shift value of 14.1 ppm to the highest frequency signal due to the terminal methyl groups of the fatty acid residues within the triglycerides. The spectrum of the black tumors was referenced by assigning the chemical shift value of 130 ppm to the broad olefinic resonance.

Results

White epidermoids (found in three patients) were characterized surgically as being cystic with dense, adherent capsules and on CT as having lucent, nonenhancing mass effect with negative (fatty) Hounsfield numbers (Fig. 1A). On MR imaging (Fig. 1B), they had bright signal due to short T1 values (≈ 500). These epidermoids had a very high lipid content and the ^{13}C MR spectra exhibited an excellent signal/noise ratio even after only 500 scans (Figs. 1C and 1D). The predominant lipid component seems to be mixed triglycerides on the basis of the intense resonances at 61.9 ppm and 70.0 ppm (peak intensity ratio 2:1) for the C-1, C-3, and C-2 carbons of the glycerol moiety, respectively, as well as the relatively strong carbonyl resonance at 171.8 ppm. The chemical shift of the carbonyl resonance also precludes the presence of free fatty acids in this tumor. The region at 115–135 ppm for olefinic carbon resonances showed several strong signals (Figs. 1C and 1D), the chemical shifts of which indicate the presence of polyunsaturated fatty acid residues in the mixed triglyceride [22] present within the tumor. There was no evidence in the ^{13}C MR spectra of the white tumor and its $CHCl_3$-MeOH extract for the presence of cholesterol or its derivatives.

The black epidermoids (found in two patients) were found at surgery to be the classical type Pearly tumor with a solid consistency and with nodular and frondlike glistening excrescences. CT in these patients demonstrated a water-density mass indistinguishable from the density of CSF (Fig. 2A). They were hypointense on T1-weighted images (Fig. 2B) with long T1 values (≈ 1100). These epidermoids exhibited a much lower lipid content than the white epidermoids, and an ac-

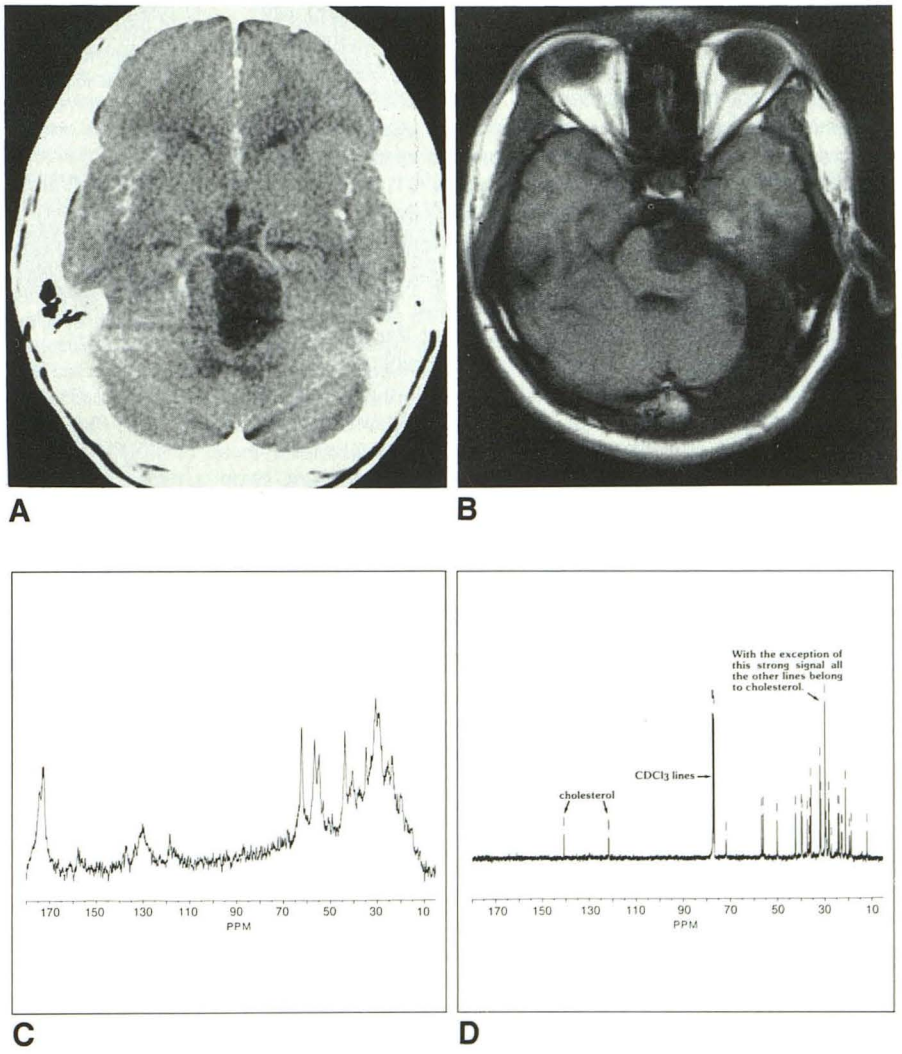


Fig. 2.—*A*, Axial CT scan of black epidermoid shows a relatively well-defined water-density mass in perimesencephalic cistern, which compresses and displaces the brainstem.

***B*, Axial T1-weighted MR image of black epidermoid shows a hypointense, well-defined extraaxial mass indenting and compressing the brainstem. The hypointense epidermoid has relatively long T1 values of approximately 1100 msec.**

***C* and *D*, ^{13}C MR spectra of black epidermoid (*C*) and chloroform-methanol extract of black epidermoid (*D*). The lack of signal at 70.0 ppm for the C-2 of glycerol indicates an absence of triglycerides. Strong resonances are seen in the 40–60 ppm region of chloroform-methanol extract as a result of small amounts of cholesterol.**

ceptable signal/noise ratio in the ^{13}C MR spectrum was achieved only after an overnight run (26,000 scans) (Figs. 2C and 2D). The lack of signal at 70.0 ppm for the C-2 of the glycerol moiety in triglycerides indicated an absence of this lipid in the black tumor. The region from 115 to 135 ppm for olefinic carbons showed only broad, ill-defined resonances at 120 ppm, 130 ppm, and 140 ppm, respectively. However, the region from 40 to 60 ppm exhibited strong resonances, which were absent in the spectrum of the white epidermoid. All the resonances for cholesterol were exhibited in the ^{13}C MR spectrum of the $CHCl_3$-MeOH extract of the black epidermoid only.

Discussion

Benign intracranial epidermoids are a heterogeneous group of neoplasms that not only present a varied appearance on CT studies but also behave quite differently on MR imaging when T1-weighted partial saturation techniques are used. The underlying basis for these differences becomes apparent when ^{13}C MR spectroscopy is used for the analysis of tumor samples. One type of epidermoid tumor is associated with negative Hounsfield numbers on CT and is white (short T1) with T1-weighted MR imaging. This group is cystic and is associated with a high lipid content with mixed triglycerides containing polyunsaturated fatty acids and no cholesterol. The second group of epidermoids consists of the classical pearly tumor with a water-density mass on CT and is black (long T1) on T1-weighted MR imaging. These tumors are solid and have no triglyceride. The presence of cholesterol was not obvious in the ^{13}C MR spectrum of the tissue, though the $CHCl_3$-MeOH extract clearly showed all the signals corresponding to this steroid. While it is true that the differences noted between the black and white epidermoids on the T1-weighted MR scans could theoretically be due to a difference in proton concentration, such a difference would be reflected in the spin-density-weighted MR scans. No such differences were observed, indicating that the proton concentrations in the two tumors are similar. Thus, we feel confident in ascribing the difference to a lipid-dependent decrease in T1.

This study suggests an approach to the characterization of neoplasms based on both MR imaging and spectroscopy. The application of these methods holds the potential of both demonstrating the anatomy of the various forms of neoplasms as well as providing a biochemical analysis of the individual lesions.

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