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MR Imaging of the Optic Nerve and Sheath: Correcting the Chemical Shift Misregistration Effect

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The interface between soft-tissue structures and adipose tissue may be obscured by the chemical shift misregistration effect on MR images. In the orbit, this effect occurs at the edges at the optic nerve, even on high-resolution local coil images. In both phantom and clinical studies with a 1.5 T local coil imaging system, it was found that the chemical shift misregistration effect can be minimized by positioning the patient so that the optic nerve is parallel to the frequency encoding gradient. Alternatively, the effect can be corrected by using a computer program to combine "lipid" and "water" proton images. The sensitivity of MR for optic nerve lesions should be improved by these technical modifications.

The purpose of this report is to demonstrate the chemical shift misregistration effect on magnetic resonance (MR) images of the orbit and to present two methods of dealing with this effect. The chemical shift misregistration effect occurs because water and lipid protons have slightly different resonant frequencies. As a result, low- and high-intensity linear bands appear at the edges of soft-tissue structures adjacent to adipose tissue in the direction of the frequency encoding gradient. For this study, this gradient is in the direction of the horizontal axis for axial images. (The frequency encoding gradient gives positional information by virtue of differences in frequency. The phase encoding gradient, which is perpendicular to the frequency encoding gradient, gives positional information by virtue of differences in phase.)

The first method to correct the chemical shift misregistration effect consists of orienting the long axis of the optic nerve parallel to the direction of the frequency encoding gradient. The second method involves obtaining "water" and "lipid" images using the method of Dixon et al. [1–3] and then combining these images via a computer program [4].

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Materials and Methods

MR studies were performed with a GE 1.5 T research MR system using local coils to receive the MR signal and a body coil to transmit the radiofrequency (RF) waves. Local coils were either circular (about 13 cm diameter) or visor-shaped. Technical factors included a 14 cm field of view (FOV), 3 or 5 mm slice thickness, two or four excitations, 128 × 256 or 256 × 256 matrices, short (300–800 msec) and long (2000 msec) repetition times (TRs), echo time (TE) values varying from 20 to 100 msec, and conventional and modified spin-echo (SE) pulse sequences.

In the conventional SE technique, water (W) and fat (F) components are parallel, that is, W + F. Dixon's method involves the use of a modified SE sequence in which the echo formed by the 180° pulse is offset in time from the echo formed by the frequency encoding gradient [1–3]. (The offset for the 180° pulse is equal to $\frac{1}{4}\Delta f$, where Δf is the frequency shift in Hertz. In this system, the frequency shift equals 227 H, which gives an offset of 1.1 msec.) This results in a magnetization vector in which water and fat components are antiparallel, that is,

W − F. Via a computer program, W − F was added to and subtracted from W + F to give water and fat images, respectively. The fat image was then spatially shifted by an amount equal to the chemical shift and then added to the water image to obtain a compensated image [4]. (The bandwidth for these studies was 32 kH. For a matrix with 256 pixels along the frequency encoding direction, the frequency change per pixel is 32,000/256 = 125 H/pixel. The chemical shift of 227 H then corresponds to 1.8 pixels, which equals 1.1 mm for a 16 cm FOV.)

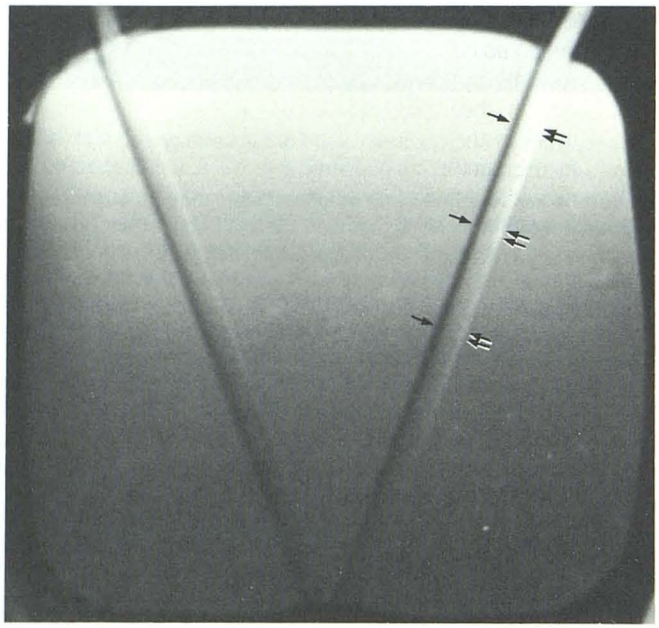


Fig. 1.—Phantom consisting of vegetable oil and glass tubes that simulate optic nerves and contain copper sulfate solution. Each tube in phantom has margins obscured by artifactual black (*single arrows*) and white (*double arrows*) bands that represent chemical shift misregistration effect in direction of frequency encoding gradient. (SE 800/20, 128 × 256 matrix, 5 mm slice thickness.)

The phantom consisted of two glass tubes (internal diameter of 4 mm) containing 0.0025 *M* $CuSO_4$ that were fixed in a V configuration (to simulate the optic nerves) within a plastic container of vegetable oil. On a local coil, the phantom was studied upright (with conventional and modified SE sequences) and turned obliquely so that one glass tube was parallel to the table top (with a conventional SE sequence) (figs. 1–4).

As with the phantom, six normal volunteers were studied supine or turned obliquely so that the optic nerve of interest was nearly parallel to the top of the scanner table [5] (figs. 5–8). Local coils were positioned on a brace to be as close as possible to the eyes of the volunteers when supine, or positioned on the table top when the volunteers were placed in the oblique position. Also studied in the oblique position was a patient with an optic nerve glioma [6] (fig. 9).

Results

With the frequency encoding gradient along the horizontal axis, MR images of the phantom demonstrate the chemical shift misregistration effect as a black band on one side of each tube and a white band not as well seen on the other side (fig. 1). The effect is independent of TE and TR (fig. 2). By repositioning the phantom such that one tube is parallel to the frequency encoding gradient, the artifactual black band does not obscure the margins of the tube (fig. 3). The artifact still appears by the tube, which is obliquely oriented with respect to the frequency encoding gradient. The chemical shift effect by the phantom also can be corrected by using Dixon's technique and a computer program to exactly superimpose fat and water images [1–4]. The walls of the glass tubes are more clearly shown in the resulting compensated image (fig. 4).

On MR images of the orbit when the patient is supine on the scanner table, the chemical shift effect appears as black bands on the same side of the optic nerves and rectus muscles (fig. 5). White bands on the other side are more difficult to see as compared with the high signal intensity of

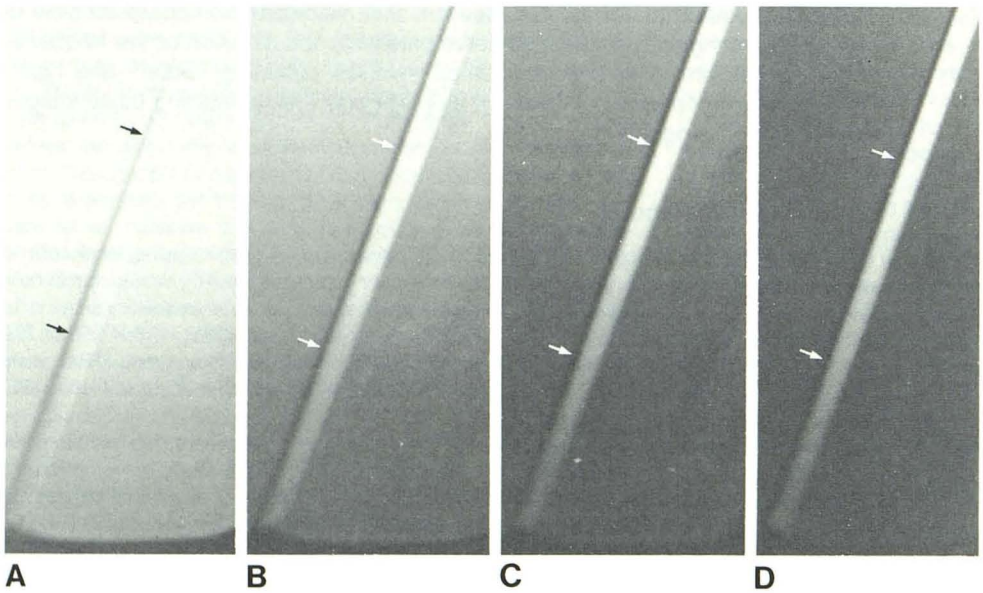


Fig. 2.—Artifactual black bands (*arrows*) are at same side of each tube when imaged with long TR (2000 msec) and TE values of 25 (**A**), 50 (**B**), 75 (**C**), and 100 (**D**) msec. (128 × 256 matrix, 5 mm slice thickness.)

fat. The reason that the black band is on one side of structures in figures 1–4 and on the other side in figure 5 is that the gradients were in the opposite direction when the latter image was obtained.

On axial MR images in which an optic nerve is nearly parallel to the frequency encoding gradient or in which a computer-generated compensated image is obtained, symmetric low-intensity bands on both sides of the nerve probably represent subarachnoid cerebrospinal fluid (CSF) and optic nerve sheath (figs. 6 and 7). These bands appear prominent in an example of an optic nerve glioma (fig. 9). On coronal computer-generated compensated images, low-intensity rings surrounding the optic nerves probably represent CSF and sheath (fig. 8).

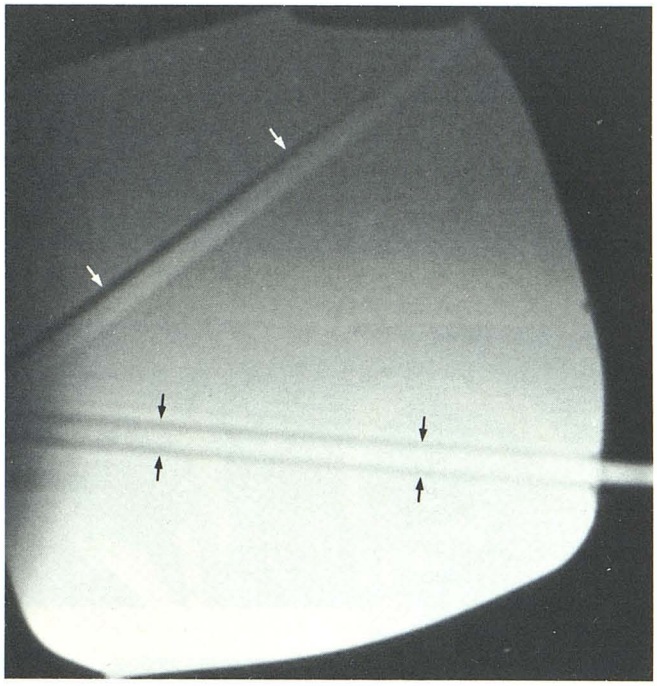


Fig. 3.—With phantom repositioned, artifactual black band (*white arrows*) obscures margin of tube obliquely oriented with respect to frequency encoding gradient but not margins (*black arrows*) of tube parallel to gradient. (SE 800/20, 128 × 256 matrix, 5 mm slice thickness.)

Discussion

Fat and water protons, due to their different chemical environments, have different resonant frequencies, a phenomenon known as chemical shift. The chemical shift effect is the basis for MR spectroscopy. In MR imaging the resonant frequency in the presence of a gradient gives positional information in the direction of the frequency encoding gradient. The chemical shift in frequency is interpreted by the computer as a change in position that results in artifactual black and white bands by the edges of orbital soft-tissue structures in the direction of the frequency encoding gradient. The chemical shift misregistration effect also is observed elsewhere in the body (e.g., the junction of perirenal fat and renal parenchyma) [7].

To correct the chemical shift effect, a computer-generated compensated image can be used. With this technique, the acquisition of fat and water images doubles the scanning time. However, the compensated image has twice the signal to noise ratio of either the fat or H_2O images. An alternative method is to position the head so that the optic nerve of interest is parallel to the frequency encoding gradient. The limitation of this method is that comparison of the optic nerves would be difficult.

Technical modifications that diminish the chemical shift artifact should improve demonstration of the optic nerves with MR. On corrected images, low-intensity bands detected on each side of normal optic nerves can be interpreted confidently as a combination of CSF and optic nerve sheath (figs.

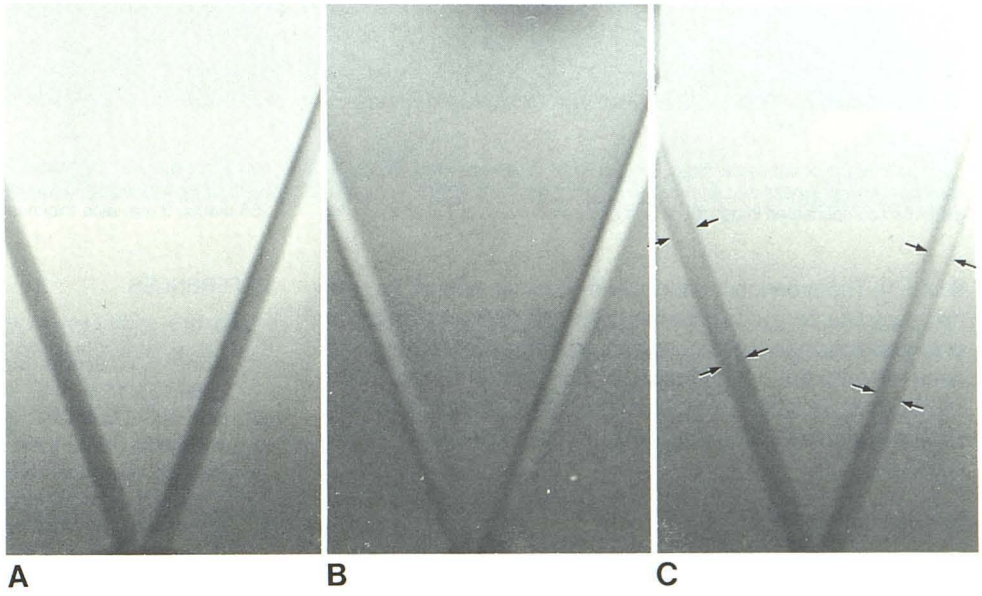
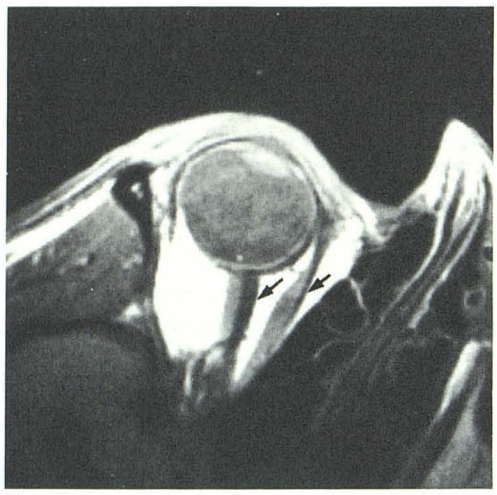


Fig. 4.—Walls (*arrows*) of glass tubes are more clearly shown in computer-compensated image (**C**) than in lipid (**A**) and water (**B**) images of phantom. (**A** and **B**: SE 800/20, 128 × 256 matrix, 5 mm slice thickness.)



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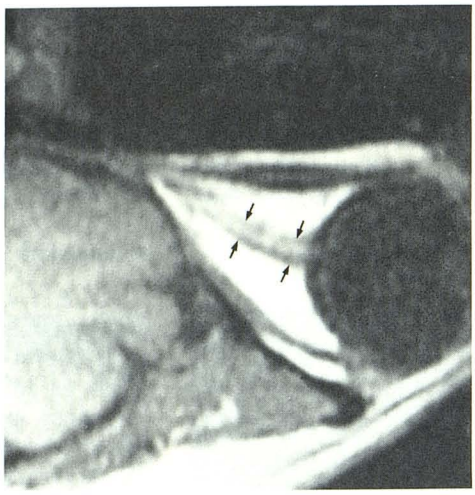

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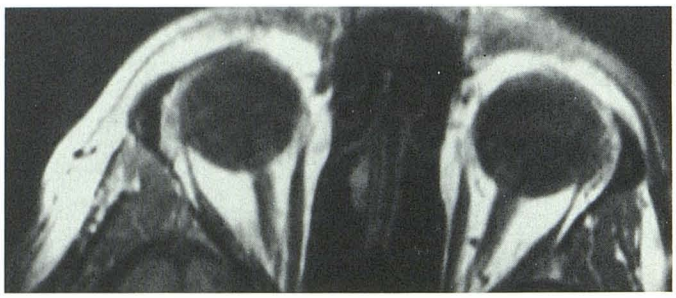
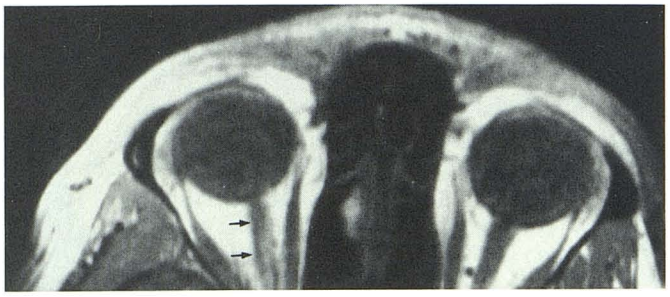
Fig. 5.—Artifactual black band (*arrows*) appears on same side of optic nerve and medial rectus muscle, which have their long axes nearly perpendicular to frequency encoding gradient. (SE 400/20, 256 × 256 matrix, 3 mm slice thickness.) (Reprinted from [5].)

Fig. 6.—MR image of volunteer positioned such that optic nerve is almost parallel to top of scanner table. Low-intensity bands (*arrows*) on both sides of nerve probably represent CSF and optic nerve sheath. (SE 800/20, 128 × 256 matrix, 3 mm slice thickness.) (Image courtesy of Amy Sue Biller, Milwaukee.)



A



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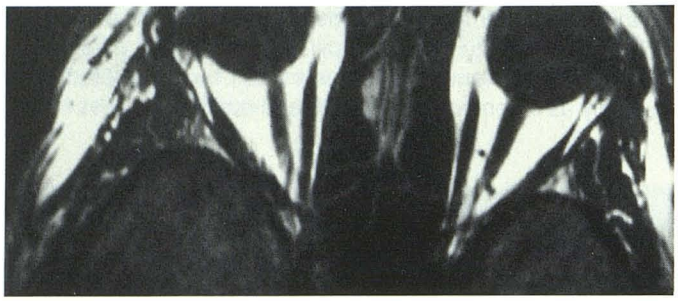
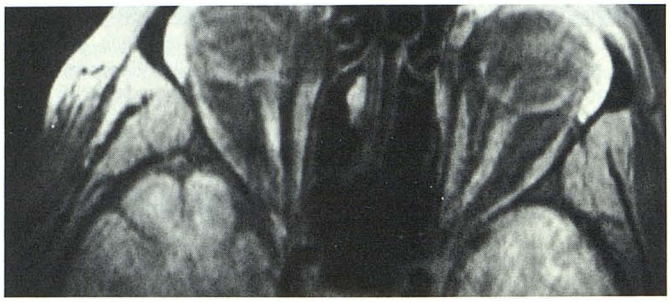


C



D

Fig. 7.—Edge of right optic nerve is obscured by chemical shift misregistration effect in uncompensated axial image (**A**) but to lesser degree in computer-generated compensated image (**B**, *arrows*), obtained by exactly superimposing lipid (**C**) and water (**D**) images. High-intensity signals are produced by orbital fat in **C**, by orbital soft tissue structures in **D**. (**A**, **C**, and **D**: SE 400/20, 128 × 256 matrix, 3 mm slice thickness.)

6 and 7). The prominent dark bands on either side of the optic nerve glioma on a corrected image most likely represent an enlarged optic nerve sheath space or alternatively a thickened nerve sheath, but not chemical shift artifact. In an evaluation of MR in optic nerve or sheath tumors, a greater sensitivity and specificity can be expected if the chemical shift artifact is eliminated.

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REFERENCES

1. Dixon WT. Simple proton spectroscopic imaging. *Radiology* **1984**;153:189–194
2. Lee JKT, Dixon WT, Ling D, Levitt RG, Murphy WA Jr. Fatty infiltration of the liver: demonstration by proton spectroscopic imaging. *Radiology* **1984**;153:195–201
3. Dixon WT. Proton spectroscopic imaging at 0.35 T. In: *Scientific program of the third annual meeting of the Society of Magnetic Resonance in Medicine*. Berkeley, CA: Society of Magnetic Resonance in Medicine, **1984**:193–194

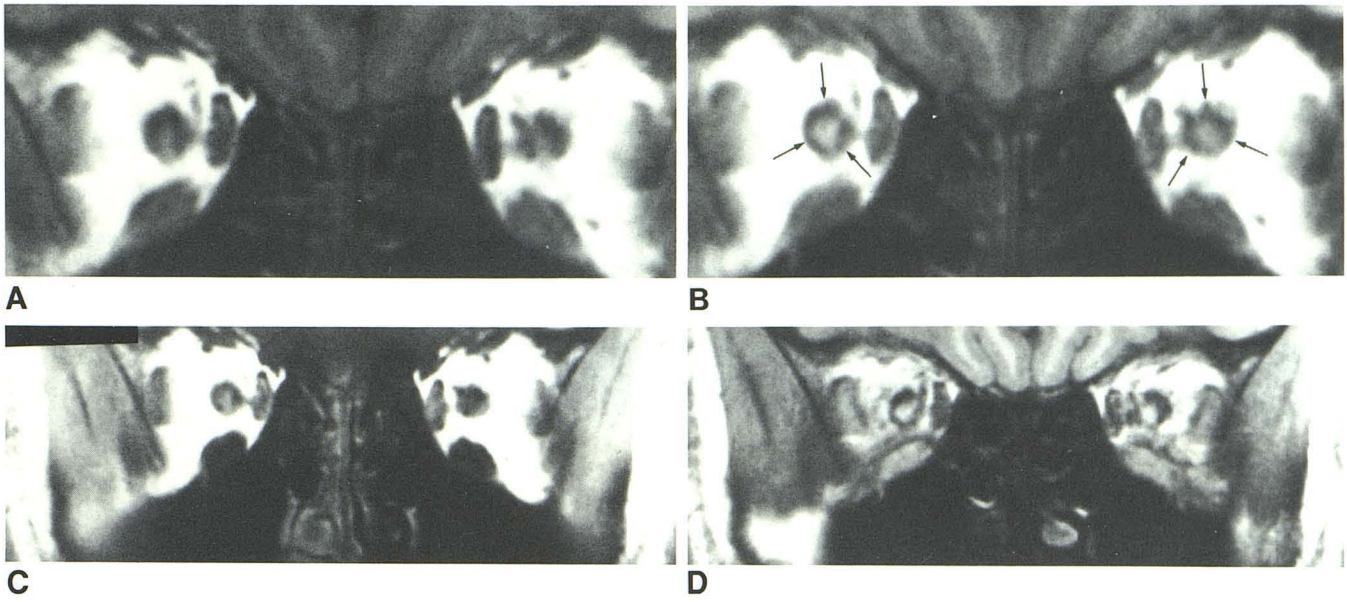

Fig. 8.—**A**, Coronal uncompensated image. Optic nerve sheaths are not easily resolved. **B**, Computer-compensated image obtained by superimposing lipid (**C**) and water (**D**) images. Low-intensity rings (*arrows*) probably represent CSF and nerve sheaths surrounding optic nerves. (**A**, **C**, and **D**: SE 400/20, 256 × 256 matrix, 5 mm slice thickness.)

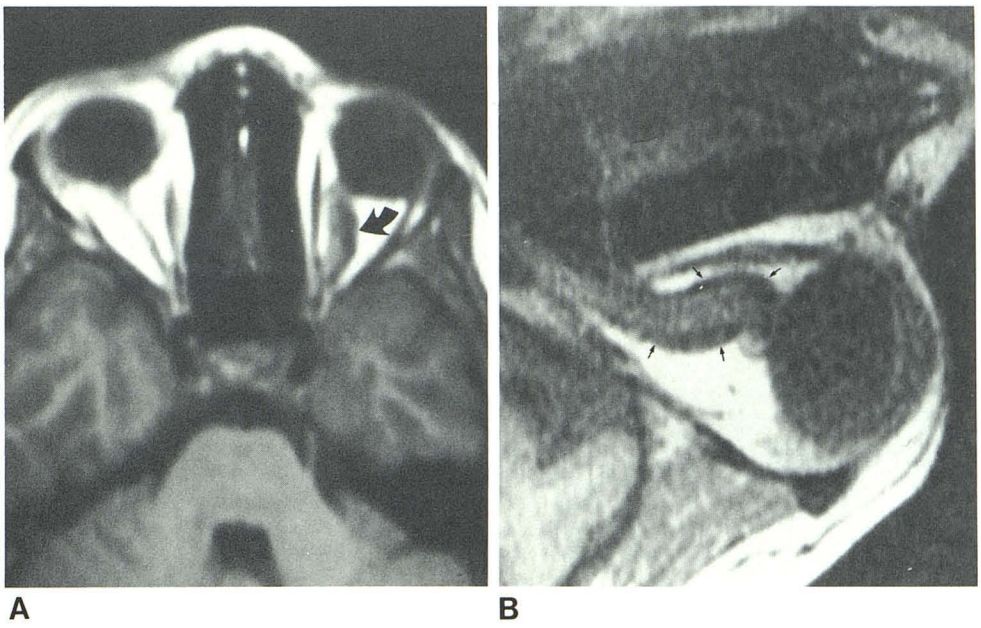

Fig. 9.—9-year-old girl with left-sided optic nerve glioma. **A**, Axial MR image. Dark band (*arrow*) by enlarged left optic nerve probably represents chemical shift effect. **B**, Local coil image with patient repositioned such that abnormal nerve is parallel to *X* axis. Glioma appears as thickened nerve. Prominent low-intensity bands (*arrows*) consistent with CSF and nerve sheath are adjacent to tumor. (**A** reprinted from [6]; **B**: 300/20, 256 × 256 matrix, 3 mm slice thickness.)

4. Wehrli FW. *Magnetic resonance tomorrow—issues and challenges*. Milwaukee: General Electric Medical Systems Group, **1985**
5. Schenck JF. *The surface coil approach*. Milwaukee: General Electric Medical Systems Group, **1984**
6. Daniels DL, Herfkins RH, Gager WE, et al. Magnetic resonance imaging of the optic nerves and chiasm. *Radiology* **1984**;152:79–83
7. Soila KP, Viamonte M Jr, Starewicz PM. Chemical shift misregistration effect in magnetic imaging. *Radiology* **1984**;153:819–820