# Improved MR Imaging of the Orbit at 1.5 T with Surface Coils

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# Improved MR Imaging of the Orbit at 1.5 T with Surface Coils

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**A method for obtaining localized high-resolution magnetic resonance (MR) images of the eye and orbit is demonstrated. The method uses modified surface receiver coils placed immediately adjacent to the anatomy to detect the MR signal. Surface coils provide enhanced sensitivity for imaging voxels close to the surface of the body while limiting the received patient-generated noise. The resulting improvement in signal-to-noise ratio allows for a reduction in the imaging voxel size to about 0.5 × 0.5 × 5 mm in scan times of 3.4–5 min. At this level of resolution, anatomic detail in the orbital region previously unobservable in MR images is seen.**

The orbit provides a useful test region to explore the possibilities of high-resolution magnetic resonance (MR) imaging. Many important structures in the region are small and have not been well resolved with standard imaging techniques. The intense signal from the orbital fat has been found to exacerbate partial-volume phenomena when thick slices are imaged. Efforts to enhance the spatial resolution of the MR image by decreasing pixel size and slice thickness have been limited by the available signal-to-noise (S/N) ratio. Although longer scan times can partially compensate for the degradation in S/N that necessarily accompanies reduced pixel size, this is particularly undesirable in imaging the orbit, as it is difficult at best for patients to hold the eyes still for extended periods. These problems have been recognized and addressed recently [1]. Some authors have suggested on the basis of initial studies that MR offers no advantage at this time over computed tomography (CT) in the investigation of the orbital region [1, 2]. Other reports [3, 4] compare the quality of MR images of the orbit with that available from early CT images of the region. Given the imaging pixel sizes of 1.5 × 1.5 mm [3] and the slice thicknesses of 7 mm [3] and 10 mm [4] used in these studies, this is certainly not an unreasonable comparison.

We have explored surface coil methods of improving S/N ratios in images of localized anatomic regions. The purpose is to demonstrate the feasibility of smaller pixel sizes and to support the concept that increased spatial resolution is possible and will enhance the diagnostic potential of MR imaging. We present initial results in the application of this technique to the orbit.

## Subjects and Methods

The details of our 1.5-T MR imaging system have been described elsewhere [5, 6]. For routine imaging of the head and body, cylindrical coils with diameters of about 26.5 and 51 cm, respectively, serve to both transmit the radiofrequency excitation field and receive the MR signal. These coils provide relatively uniform excitation throughout the imaging plane and through proper electrical design and construction offer adequate sensitivity in many applications. It has been our experience at 1.5 T that the S/N obtained through the use of coils of this type is capable of sustaining imaging pixel sizes of about 1 × 1 mm and slice thicknesses

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of 4 mm. Further reduction in pixel sizes must be supported by significantly enhanced sensitivity in the imaging region.

Although it is possible to use a single surface coil as both transmitter and receiver elements [7], we have found it advantageous to use separate coils for these functions. The transmitter either is of the typical cylindrical design, capable of accepting the whole body, or consists of a large-diameter surface coil. The use of transmitter coils of this type preserves the relative uniformity of excitation found in the routine imaging experiment [8]. The receiver is a smaller-diameter surface coil placed immediately adjacent to the region of interest. It may be either rigidly mounted adjacent to the region of interest or placed directly on the patient and designed so that its shape conforms to the surface anatomy of the region to be imaged. Typical diameters in the present study for these modified receiver coils are 10–14 cm. The optimum S/N ratio seems to result from the use of a surface receiver coil with a radius about equal to the depth of the pixels of greatest interest (fig. 1).

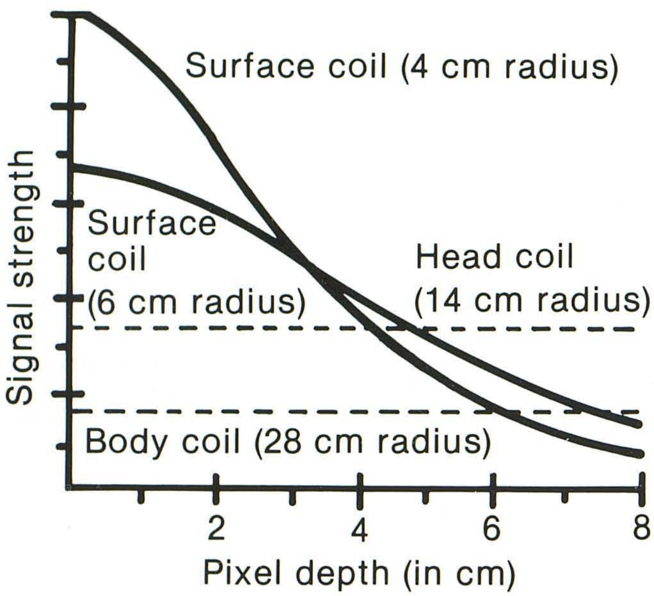


Fig. 1.—Relative coil sensitivities for pixels at various depths are compared for circular surface coils of 4 and 6 cm radii and conventional cylindrical head and body coils of 14 and 28 cm radii. Reader is cautioned that this is plot of signal strength (not of signal-to-noise ratio) vs. pixel depth. Spatially localized sensitivity of surface coil results in reduction in received patient generated noise. Thus, significant signal-to-noise advantage is obtained through use of surface receiver coils.

Given this coil arrangement, the S/N ratio at 1.5 T is sufficient to allow gradient strength to be increased such that pixel size is reduced to about 0.5 × 0.5 mm. The imaging slice thicknesses are 3–5 mm. Transverse, coronal, and sagittal images of the orbit were obtained on healthy volunteers in scan times for a single slice of 3.4–5.1 min. While all of the images reported here were recorded using our spin-warp spin-echo imaging method and a partial saturation pulse sequence [9], the surface coil technique places no constraints on what sequences may be used.

No local anesthesia was used to immobilize the eyes during the imaging sequences. The subjects were asked only to keep the eyes open and to fix their gaze on a spot inside the bore of the magnet during data acquisition.

## Results

Excellent resolution of a number of normal anatomic structures of the orbit is apparent in images made with the surface coil technique. The bright signal from the orbital fat serves to outline structures lying within it, such as the optic nerve and the extraocular muscles. An axial slice through one eye (fig. 2) clearly shows the contracted lateral rectus and the relaxed medial rectus that accompany the volunteer's rightward gaze. The lens, vitreous chamber, sclera, and structures in the nasal cavity are readily seen. Additional structure is apparent in the


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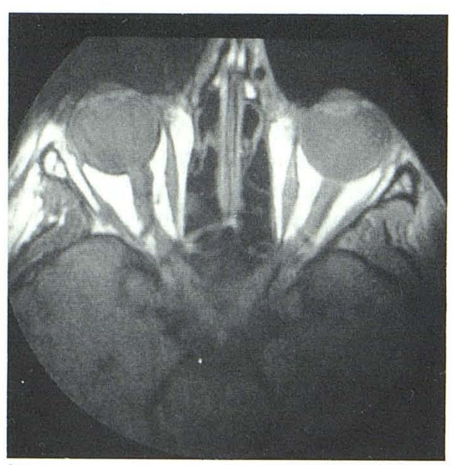
3

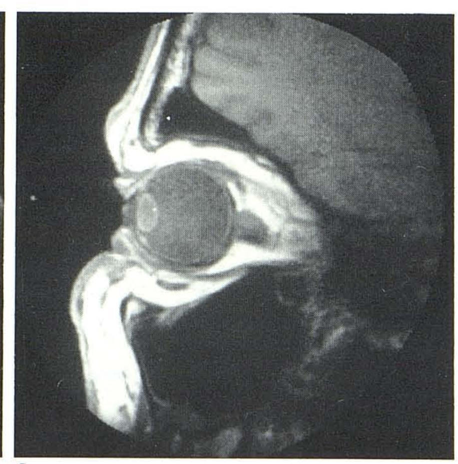
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Fig. 2.—Axial section through one eye of normal volunteer acquired using 13-cm-diam, rigidly mounted surface coil as receiver. Slice thickness is 5 mm; image consists of 256 × 256, 0.56 × 0.56 mm pixels. TR = 0.5 sec; number of signal averages is two; total scan time is 256 sec.

Fig. 3.—Axial section through two eyes acquired using 13.5-cm-diam surface coil receiver. Slice thickness and resolution in plane of image are as in fig. 2. TR = 0.2 sec; number of signal averages is six; total scan time is 308 sec.

Fig. 4.—Sagittal section through one eye acquired using 10-cm-diam, rigidly mounted surface coil receiver. Slice thickness is 4 mm; image consists of 256 × 256, 0.4 × 0.4 mm pixels. TR = 0.4 sec; number of signal averages is two; total scan time is 205 sec. (Reprinted from [10].)

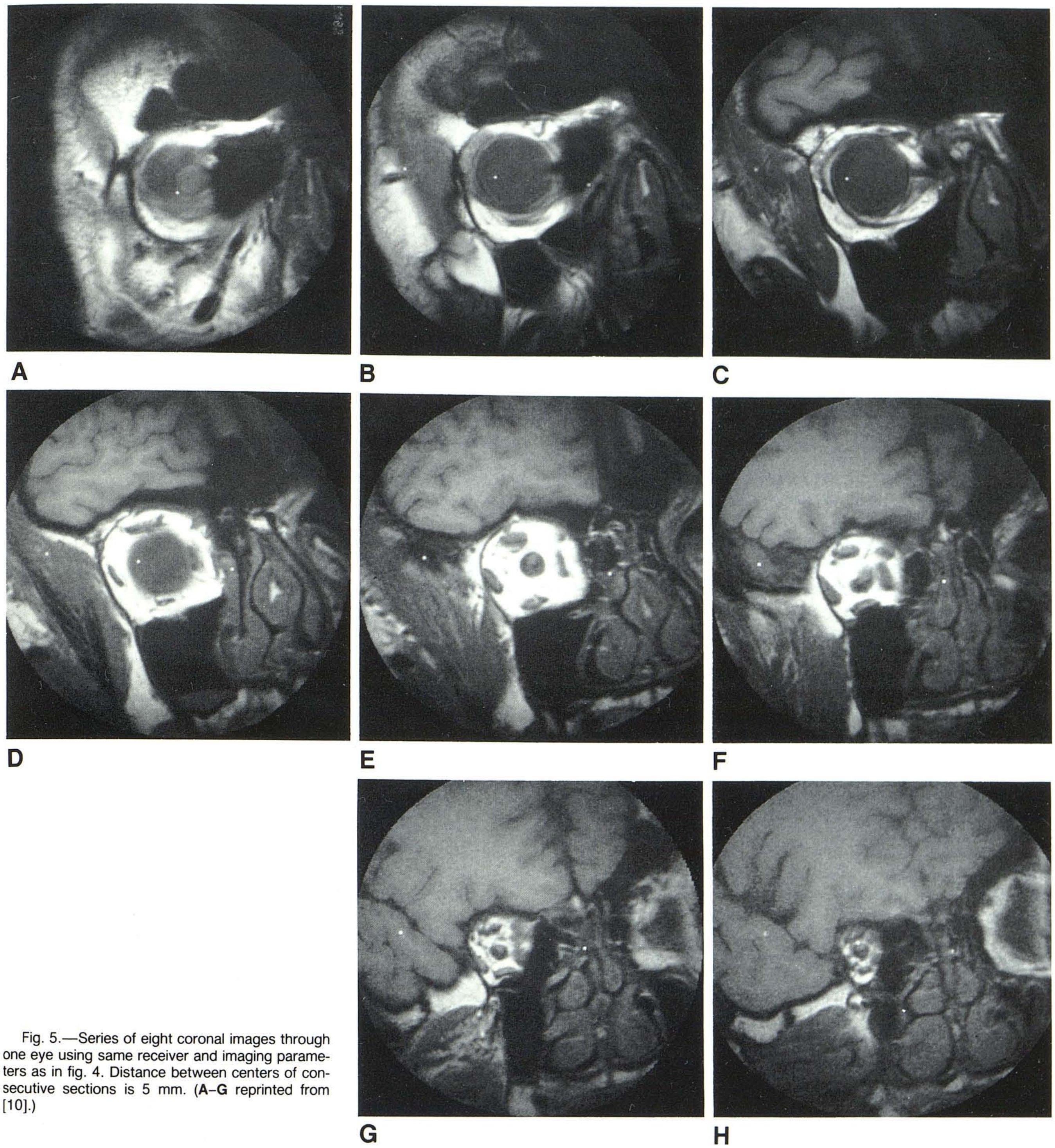


Fig. 5.—Series of eight coronal images through one eye using same receiver and imaging parameters as in fig. 4. Distance between centers of consecutive sections is 5 mm. (**A–G** reprinted from [10].)

axial section through two eyes (fig. 3). In this section, the optic nerves may be followed continuously from the eye to the optic chiasm. This figure also illustrates the principle that, while the noise level is constant throughout the image, the signal strength decreases for pixels remote from the coil.

A sagittal slice through one eye (fig. 4) demonstrates the superior and inferior rectus muscles, the optic nerve, and the superior ophthalmic vein. The ability of the technique to resolve small structures is shown in the appearance in this image of the orbital septum immediately above the globe.

Figure 5 shows a series of eight coronal images through one eye of a normal volunteer. The individual slice thicknesses are 4 mm with their centers 5 mm apart. Considerable detail is apparent throughout the sequence. The lacrimal gland is seen in figure 5B adjacent to the upper left part of the eye. In figure 5C, the infraorbital nerve is observed exiting the lower orbit. Good depiction of the extraocular muscles results in part from contrast created by the strong signal from surrounding fatty tissues. These sections also demonstrate good gray/white matter contrast in the brain.

## Discussion

In recent years, CT has established itself as a valuable diagnostic method in a wide variety of abnormalities of the orbit [11]. The role of CT will certainly continue to be an important one, especially in the diagnosis of disorders involving the bony orbit, calcifications of various kinds, and injury.

Although we have just begun to extend surface coil imaging studies to patients with orbital pathology, the initial experience with normal volunteers indicates that this high-resolution approach will enable MR to make significant contributions in this area. The very thin 1.5–2 mm slice thicknesses available with the current generation of CT scanners have not yet been demonstrated in MR. Nonetheless, the 3–5 mm imaging slices demonstrated here compare favorably with those typically used in CT imaging of the orbit [11]. The images in figures 2–5 show that with the application of the high-resolution techniques, MR is superior to CT in the resolution of small anatomic structures in the orbit. The absence of ionizing radiation further contributes to the attractiveness of this new method as a means of diagnosing disorders of the eye and orbit, particularly when thin slices are required.

The use of surface receiver coils improves the S/N ratio in two ways. First, for tissues close to the surface of the body, these coils provide significantly enhanced sensitivity as compared with the standard cylindrical radiofrequency coils (fig. 1). Stated simply, identical sample volumes will produce higher MR signal strength in a surface coil placed in close proximity to that volume. Second, while standard MR coils receive patient-generated noise voltages originating from throughout a relatively large volume, the spatially localized sensitivity of the surface coil ensures that noise is received from a much smaller region. Thus, the volume of tissue outside of the imaging slice that contributes to the received noise is significantly reduced.

Beyond the coil design modifications described here, no further changes in our system were required in order to obtain these images. The method involves no particular discomfort for the patient and requires only that the eyes be held reasonably motionless during the scan time. Our experience with healthy volunteers has been that this is not especially difficult. However, if this requirement is too demanding for a particular patient, imaging times may be shortened with some sacrifice in S/N ratio in the resultant images.

Surface coil imaging is very well suited to the orbit. It is expected that the enhanced S/N ratio obtained and the corresponding improvement in image resolution will prove to be useful in other anatomic regions as well. Initial work in extending the technique to the neck, knee, and breast has produced encouraging results. It seems that careful attention to the factors determining S/N ratio can significantly enhance the diagnostic capabilities of MR.

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