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Imaging White Matter Tracts and Nuclei of the Hypothalamus: An MR–Anatomic Comparative Study

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PURPOSE: To evaluate the MR appearance of the hypothalamus and its associated white matter tracts. **METHODS:** Coronal and sagittal spin-echo images were obtained in cadaver brains. Gross and histologic sections were made of the cadaver brains. The size, shape, signal intensity, course, and pattern of structures in the hypothalamic region were identified in MR images by comparison with the anatomic sections. **RESULTS:** The mamillary bodies, paraventricular zone of hypothalamic nuclei, postcommissural fornix, mamillothalamic fasciculus, and anterior commissure were identified on the MR images. **CONCLUSION:** This study suggests that, with MR imaging of sufficiently high resolution, some of the tracts and nuclei in the hypothalamus may be identified.

Index terms: Brain, anatomy; Brain, magnetic resonance; Hypothalamus; White matter

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The borders of the normal hypothalamus have been demonstrated with magnetic resonance (MR) (1). The MR appearance of the individual hypothalamic nuclei and white matter tracts associated with the hypothalamus have not been described. We studied the MR appearance of white matter tracts and nuclei in the hypothalamus by comparing high-resolution MR imaging with anatomic sections.

Materials and Methods

Three routine autopsy cases without neurologic disease and without significant postmortem neuropathologic change were selected for this study. Brains were harvested via craniotomy and fixed in 10% buffered formalin solution for 3 weeks. In two specimens, cylinders of brain tissue 10 cm in height and 2 cm in diameter (with the long axis in an anteroposterior direction) containing the hypothalamus were harvested with a specially designed plug cutter attached to an electric drill. The third cylinder was harvested in a similar orientation by means of gross dissection. These cylinders were introduced into 30-cc polypropylene containers with 10% buffered formalin solution to fill the remaining volume and sealed.

The cylinders were imaged in a 1.5-T Signa imager (General Electric Medical Systems, Milwaukee, Wis) with a

2.5-cm-diameter solenoid coil. Spin-echo images were obtained in coronal planes with the following imaging parameters: 1000/54/2 or 2000/80/2 (repetition time/echo time/excitations), 256 × 256 matrix, 1-mm section thickness, 2- or 3-cm field of view, and 0 skip. Sagittal planes were selected with reference to the coronal images, and sagittal images were obtained with the same parameters.

Subsequently, the three specimens were embedded in paraffin and sectioned in sagittal planes with a microtome in 6- μ m thicknesses at selected variable intervals. Coronal sections were obtained at the level of the mamillary bodies in three other routine autopsy cases. The sections were stained with hematoxylin and eosin and luxol fast blue and photographed with a 35-mm camera and macro lens.

White matter tracts in the hypothalamus were identified in anatomic sections as fiber bundles staining darkly with luxol fast blue stain and compared with structures visible on the exactly correlated MR images. The tract originating in the mamillary bodies and terminating in the thalamus, with a posterior and supralateral course, was defined as the mamillothalamic fasciculus (2). The fiber bundle terminating in the mamillary bodies, with a superior course around the anterior perimeter of the third ventricle, was defined as the fornix (2). The tract lateral to the thalamus was defined as the internal capsule or capsulopeduncular transition (1). In MR images, the signal intensity, course, and pattern of structures corresponding to the mamillothalamic fasciculus and fornix were identified. Nuclei in the hypothalamus were identified by the diminished intensity of staining in relation to white matter tracts.

Results

In MR images, signal intensity was highest in cellular regions of the hypothalamus and lowest in white matter tracts. Low signal intensity was demonstrated by both the fornix and mamillothalamic fasciculus. The paraventricular zone of

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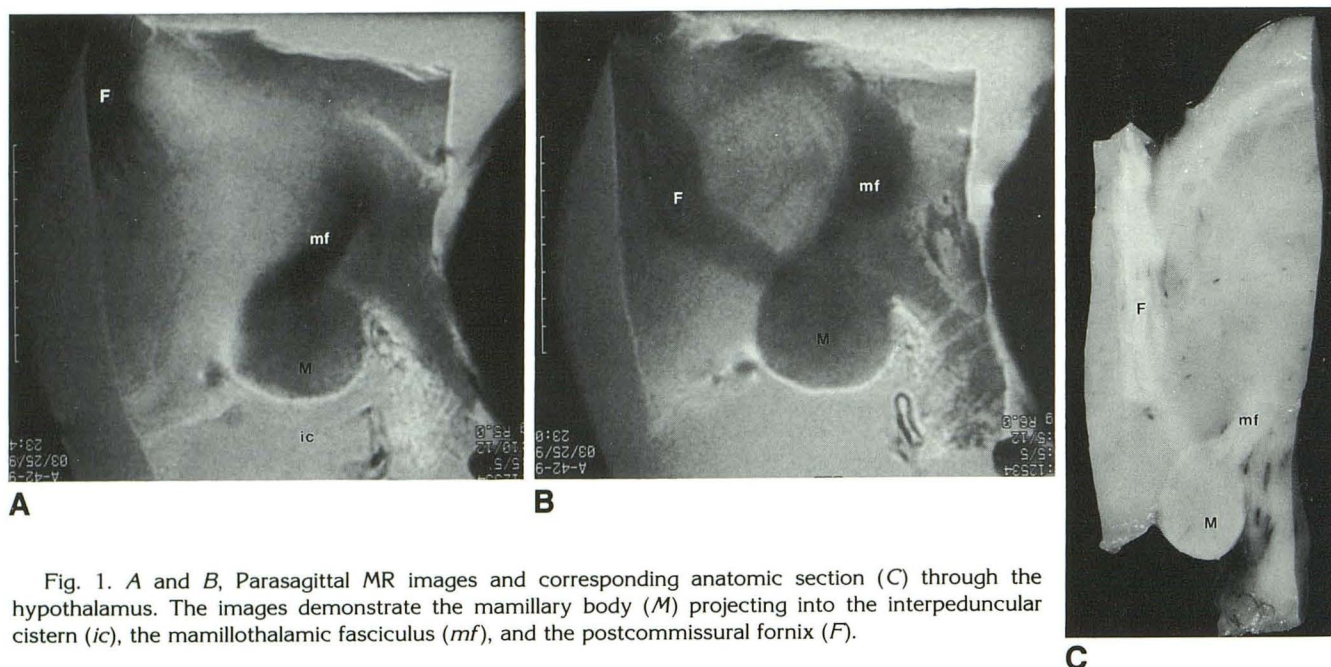


Fig. 1. *A* and *B*, Parasagittal MR images and corresponding anatomic section (*C*) through the hypothalamus. The images demonstrate the mamillary body (*M*) projecting into the interpeduncular cistern (*ic*), the mamillothalamic fasciculus (*mf*), and the postcommissural fornix (*F*).

hypothalamic nuclei demonstrated a thin region of much higher intensity signal. The mamillary bodies produced a signal intermediate in intensity between the white matter tracts and hypothalamic nuclei.

In sagittal MR images the hypothalamus, mamillary bodies, fornix, mamillothalamic fasciculus, and anterior commissure are recognized. The section just off the midline (Fig 1A) depicts the mamillothalamic fasciculus as a homogeneous, low-signal-intensity white matter tract with a posterosuperior course around the perimeter of the third ventricle to the thalamus. The postcommissural fornix appears as an inhomogeneous white matter tract composed of discrete bands of low-intensity signal interspersed with high-intensity signal structure. The mamillary bodies appear in this image as sharply defined spheroid structures of intermediate signal intensity protruding into the interpeduncular cistern. The hypothalamus is evident anterior to the mamillary bodies as a region of homogeneous, higher signal intensity.

The next lateral contiguous section (Fig 1B) best depicts the course of both the mamillothalamic fasciculus and the postcommissural fornix. A comparison of the two sharply defined white matter tracts demonstrates that the postcommissural fornix possesses greater signal intensity and heterogeneity than the mamillothalamic fasciculus. The mamillary bodies appear with interme-

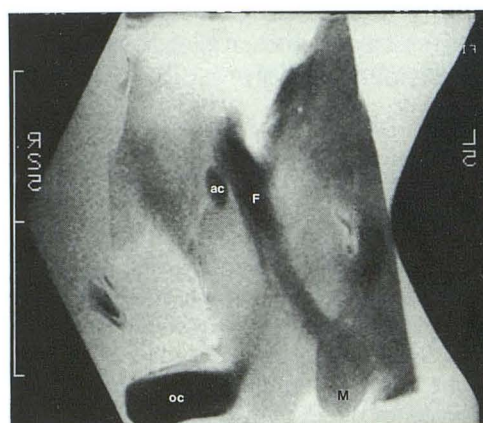
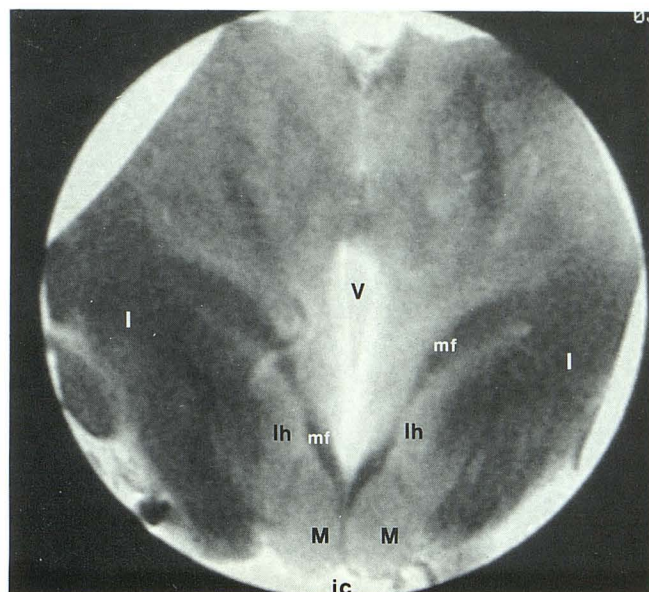


Fig. 2. Parasagittal MR image with a 3-cm field of view in a different specimen illustrating the relationship of the anterior commissure (*ac*) and optic chiasm (*oc*) to the postcommissural fornix (*F*) and mamillary body (*M*).

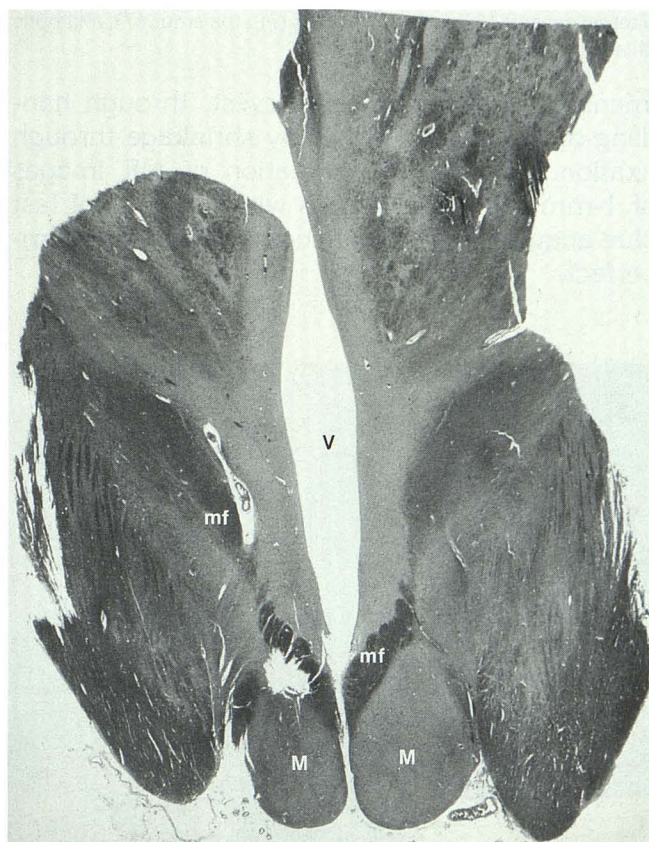
diate signal intensity. The tracts and nuclei are identified by referring to the corresponding anatomic section (Fig 1C).

The anterior commissure appears in the 3-cm field of view sagittal images as an ovoid, low-signal-intensity structure anteroinferior to the body of the fornix (Fig 2). In the 2-cm field of view images the region of the anterior commissure was not included. The postcommissural fornix is demonstrated as a curving, low-intensity tract posterior to the anterior commissure.

Coronal MR images and anatomic sections best depict the medial to lateral orientation of the



A



B

Fig. 3. A, Coronal MR image and B, corresponding anatomic section through the hypothalamus. The images illustrate the mamillothalamic fasciculus (*mf*) at the mamillary bodies (*M*), the internal capsule (*I*), the lateral hypothalamic nuclei (*lh*), the third ventricle (*V*), and the interpeduncular cistern (*ic*). The irregular void in the anatomic section represents a sectioning artifact.

mamillothalamic fasciculus, fornix, and internal capsule with respect to the third ventricle, mamillary bodies, and one another (Figs 3A and 3B). The third ventricle, sharply differentiated from the hypothalamus on each side, appears as a homogeneous midline area of moderately high signal intensity. The mamillary bodies, which protrude into the interpeduncular cistern, are evident as homogeneous, spheroid structures of intermediate signal intensity. The internal capsule, seen lateral to the mamillary bodies, is demonstrated as a low-intensity signal structure interspersed with high-intensity bands. The mamillothalamic fasciculus, originating at the supra-medial aspect of the mamillary bodies, shows low-intensity signal with marked contrast to surrounding tissue. The lateral hypothalamic nuclei appear as an area of intermediate signal intensity.

The next contiguous anterior section (Fig 4A) illustrates the postcommissural fornix, paraventricular zone of hypothalamic nuclei, and tuber cinereum. The termination of the postcommissural fornix at the mamillary bodies is evident as a low-intensity-signal region. The paraventricular zone of hypothalamic nuclei, flanking the third ventricle, is included within a thin region of high-intensity signal. The tuber cinereum, seen projecting into the interpeduncular cistern, appears with high-intensity signal in this section.

In the next anterior contiguous section (Fig 4B), in the plane of the foramen of Monro, the postcommissural fornix is located along the lateral margins of the third ventricle and appears as a band with low signal intensity and sharp borders. The internal capsule has a lower intensity signal than either the thalamus, which borders it medially, or the lenticular nucleus, which borders its lateral margin. Lateral to the hypothalamus, the optic tracts and anterior cerebral arteries are prominent low-signal-intensity landmarks. An anatomic section corresponds to the images depicted in Figures 4A and 4B (Fig 4C).

The most anterior of the contiguous sections (Fig 5) demonstrates the internal capsule, thalamus, lenticular nucleus, anterior commissure, and precommissural fornix. The internal capsule defines the borders of the lenticular nucleus and thalamus, which are superior and lateral to the hypothalamus and of intermediate-intensity signal. The anterior commissure, a landmark near the anterior border of the hypothalamus, appears

as a well-delineated low-intensity structure. The precommissural fornix appears with low-intensity signal superior to the anterior commissure.

Discussion

Loes and colleagues (1) described the boundaries and anatomy of the hypothalamus with standard spin-echo pulse sequences but did not describe the appearance of individual hypothalamic nuclei or white matter tracts on MR. Others described a focus of high signal intensity in the hypothalamus with infundibular disease (3). This study compares anatomic specimens and high-resolution MR images of the hypothalamic region.

Our observations may not be directly extrapolated to clinical imaging, because experimental imaging parameters different from prevalent clinical imaging techniques were used to optimize resolution. The descriptions presented herein are based on the MR appearance of cadaveric fixed tissue. Consequently, our observations may not correlate precisely with the MR appearance of structures in the hypothalamic region *in vivo*. All possible anatomic structures and variations may not have been identified within the samples studied because of technical inadequacies and normal anatomic variation. Anatomic distortion may have been introduced into our spec-

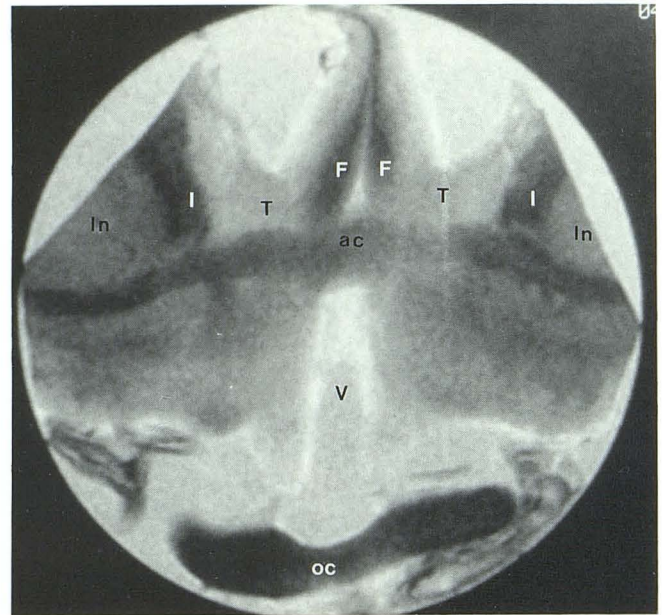


Fig. 5. Coronal MR image anterior to those in Figure 4 illustrating the precommissural fornix (F), anterior commissure (ac), internal capsule (I), lenticular nucleus (In), thalamus (T), and optic chiasm (oc).

imens by the method of harvest, through handling of the specimens, or by shrinkage through fixation. Finally, the correlation of MR images of 1-mm section thickness with 6- μ m luxol fast blue anatomic sections necessarily would be imperfect.

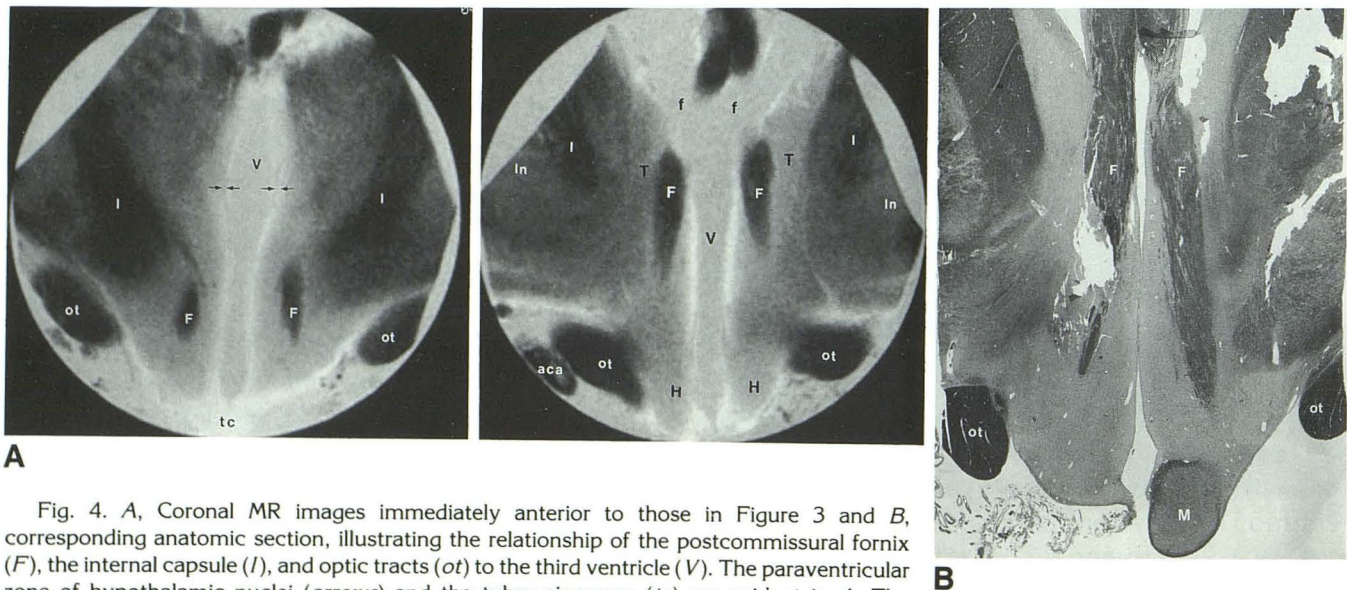


Fig. 4. A, Coronal MR images immediately anterior to those in Figure 3 and B, corresponding anatomic section, illustrating the relationship of the postcommissural fornix (F), the internal capsule (I), and optic tracts (ot) to the third ventricle (V). The paraventricular zone of hypothalamic nuclei (arrows) and the tuber cinereum (tc) are evident in A. The thalamus (T), hypothalamus (H), lenticular nucleus (In), anterior cerebral artery (aca), and foramen of Monro (f) are evident in B. The irregular voids in the anatomic section represent sectioning artifacts.

Although the effects of formalin on contrast in cerebral tissues has not, to our knowledge, been systematically studied, the relative contrast between gray and white matter in our experimental images resembles that in clinical images. This suggests that the anatomic detail in our study could be obtained clinically with the use of appropriate fields of view and surface coils to achieve suitable signal-to-noise ratios. Consequently, high-resolution MR imaging could be implemented to evaluate intrinsic hypothalamic

anatomy and pathology, and possibly to investigate sexual dimorphism in the hypothalamus (4).

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