Anatomic Relationship of the Oculomotor Nuclear Complex and Medial Longitudinal Fasciculus in the Midbrain

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PURPOSE: To compare the MR characteristics of the oculomotor nucleus with its appearance on anatomic images. **METHODS:** Specimens of cadaveric brains were imaged in a 3.0-T MR imager equipped with a 3.0-cm solenoid coil. The specimens were sectioned, stained, and examined histologically. On anatomic sections, the oculomotor nuclei, medial longitudinal fasciculus, red nuclei, and oculomotor nerve were identified. The MR images were then compared with the anatomic sections. **RESULTS:** The oculomotor nuclei, medial longitudinal fasciculus, red nuclei, and oculomotor nerve could be identified on MR images by their size, shape, signal intensity, and location. **CONCLUSION:** MR images show the anatomic relationship of the oculomotor nerve complex, medial longitudinal fasciculus, and related structures in the brain stem.

Index terms: Brain, anatomy; Brain, stem; Mesencephalon; Nerves, oculomotor (III)

AJNR Am J Neuroradiol 18:111–113, January 1997

Magnetic resonance (MR) imaging is routinely performed in patients with third nerve palsies and suspected midbrain lesions. The purpose of this study was to compare the MR characteristics of the oculomotor nuclei and anatomically related structures in the brain stem with their appearance on anatomic images.

Materials and Methods

Brains from routine autopsy studies of five subjects without neurologic disease were fixed in 10% buffered formalin solution for 3 weeks. A 4 × 2.5 × 2.5-cm specimen (with the long axis parallel to the brain stem) was harvested from each brain by means of gross dissection. The specimen was cut to the shape of a cylinder and sealed in 45-cm^3 polypropylene containers with sufficient 10% buffered formalin solution to exclude air.

The specimens in the containers were imaged in a Biospec (Bruker, Karlsruhe, Germany) 3.0 T/60-cm imager equipped with a 3-cm-diameter solenoid coil. Spin-echo axial interleaved images of the specimens were acquired with imaging parameters of 1000/30/4 (repetition time/echo time/excitations), a 256 × 256 matrix, a 1-mm section thickness, a 3-cm field of view, and a 1-mm gap. Acquisition time was 17 minutes for a series of 11 images.

Two of the specimens were embedded in paraffin and sectioned with a microtome in 6-μm thicknesses at selected intervals. The sections were stained with hematoxylin-eosin and Luxol fast blue and photographed with a 35-mm camera and macrolens. The histologic sections were compared with the corresponding MR images from the same specimen.

White matter tracts in the midbrain were identified on the anatomic sections as fiber bundles staining darkly with Luxol fast blue. Nuclei in the midbrain were identified by the diminished intensity of staining in relation to white matter tracts. The tract interconnecting the abducens nucleus and the oculomotor nuclear complex with a superior course anterior to the fourth ventricle and sylvian aqueduct was identified as the medial longitudinal fasciculus.

Results

On the MR images (1000/30), the signal intensity in the white matter tracts was low compared with that in more cellular regions. Low signal intensity was apparent in the medial longitudinal fasciculus, oculomotor nerve, and medial lemniscus. The midbrain reticular formation, superior colliculus, and oculomotor nuclear complex were of intermediate signal in-

Received May 1, 1996; accepted after revision July 23.

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AJNR 18:111–113, Jan 1997 0195-6108/97/1801–0111

Fig 1. MR image through the midbrain shows the course of the occulomotor nerve fibers (*arrows*) through the red nuclei to the point where they exit the ventral midbrain between the cerebral peduncles (*CP*).

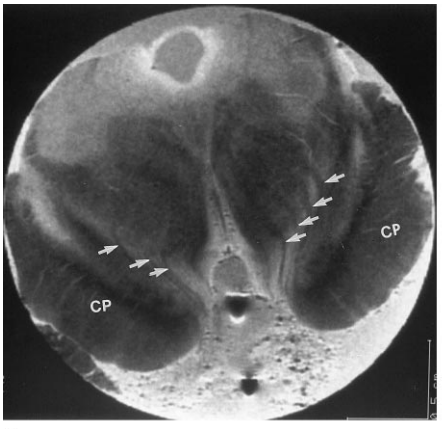

Fig 2. MR image through the midbrain 1 mm inferior to Figure 1 shows the dorsal tegmental decussation of the medial longitudinal fasciculus (*arrow*).

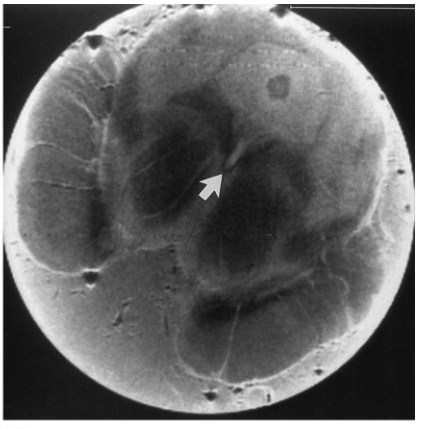

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Fig 3. MR image through the midbrain 1 mm inferior to Figure 2 at the level of the superior colliculus. The oculomotor-nuclear complex (*white arrows*), medial longitudinal fasciculus (*arrowheads*), cerebral aqueduct (*black arrows*), red nucleus (*RN*), and cerebral peduncle (*CP*) are labeled.

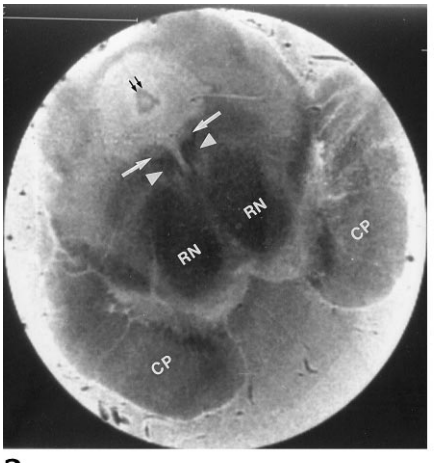
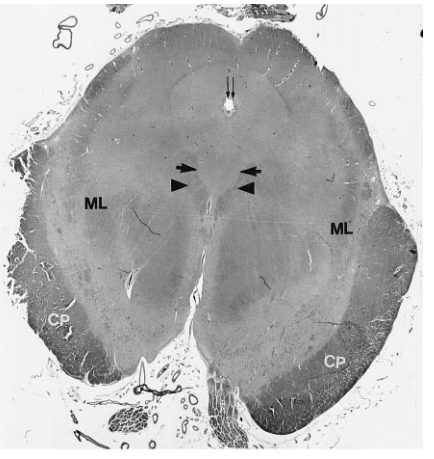


Fig 4. Anatomic section through the midbrain corresponding to Figure 3. The oculomotor nuclear complex (*single arrows*), medial longitudinal fasciculus (*arrowheads*), medial lemniscus (*ML*), cerebral peduncles (*CP*), and cerebral aqueduct (*double arrows*) are labeled.



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tensity. High signal intensity was seen in the periaqueductal gray matter.

On axial MR sections through the midbrain at the level of the third nerve, the ventral fascicles of the oculomotor nerve appeared as discrete serpigenous bands of low signal intensity passing through or medial to the red nuclei and exiting the midbrain between the cerebral peduncles (Fig 1). On MR images 1 mm caudad to the oculomotor nerve fibers, the medial longitudinal fasciculus passed ventromedially between the red nuclei and merged at the midline to form the dorsal tegmental decussation of the medial longitudinal fasciculus (Fig 2). Axial MR images 1 mm farther caudad, at the level of the superior colliculi, showed the oculomotor nuclear complex, the medial longitudinal fasciculus, and the oculomotor nerve (Fig 3). The oculomotor nuclei appeared on MR images as paired ovoid regions of homogeneous, intermediate intensity signal 1 mm in diameter immediately ventral to the periaqueductal gray matter. The nuclei contrasted with the sharply defined low signal intensity of the medial longitudinal fasciculus ventral to them. Branches of the medial longitudinal fasciculus appeared to wrap around the oculomotor nuclei. The relationship between the oculomotor nuclei and the medial longitudinal fasciculus was shown in a corresponding anatomic section (Fig 4).

Discussion

In this study as in others (1, 2), low signal intensity characterizes white matter tracts and higher signal intensity characterizes the nuclei. On MR images, we identified oculomotor nerve fibers in the brain stem, oculomotor nuclei, and adjacent medial longitudinal fasciculus. These landmarks can be used to identify the location of brain stem lesions.

Our observations may not be directly extrap-

olated to clinical imaging because experimental imaging parameters different from prevalent clinical imaging techniques were used to optimize resolution. Resolution in our MR images was increased by a small field of view and high field strength. With our imaging techniques at 3.0 T, the signal-to-noise ratio exceeds that at 1.5 T by a factor of 1.4. Obtaining similar results at 1.5 T would require longer acquisition times (3). Harvesting of tissue was performed to minimize anatomic distortion. Fixation changes signal intensity, possibly the contrast, and possibly the size of anatomic structures (4–6). The absence of motion artifacts from head movement, brain pulsations, and flow of blood and cerebrospinal fluid also undoubtedly improved our resolution. The correlation of MR images of 1-mm section thickness with 6-μm-thick anatomic sections necessarily would be imperfect.

Because of the close anatomic relationships between the oculomotor nuclear complex, medial longitudinal fasciculus, red nuclei, oculomotor nerve, and cerebral peduncles, brain stem lesions rarely produce isolated third nerve palsies. The neurologic deficits that accompany gaze palsies associated with brain stem lesions include contralateral paresis (Weber syndrome), produced by a lesion of the cerebral peduncle and the oculomotor nerve tracts; contalateral involuntary movements (Benedikt syndrome), produced by a lesion of the red nucleus involving the oculomotor nerve tracts (7, 8), ataxia (Claude syndrome), produced by a lesion of the superior cerebellar peduncle and the third nerve; and intranuclear opthalmoplegia, produced when the lesion involves the medial longitudinal fasciculus and oculomotor nuclei (9).

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