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MR Appearance of Gray and White Matter at the Cervicomedullary Region

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To study the appearance of gray and white matter in the cervicomedullary region, six fresh cadavers were imaged with a 1.5-T MR scanner and then sectioned with a cryomicrotome. The pyramidal tracts, fasciculus cuneatus and gracilis, inferior olivary nuclei, supraspinal nuclei, spinal trigeminal nuclei, and medial lemnisci were identified by MR in the cervicomedullary region.

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This study analyzes in detail the intrinsic anatomy of the cervicomedullary spinal cord. While correlative radiographic anatomic studies of this region have been reported [1–7], identification of the gray and white matter structures in this region by MR has not been analyzed systematically. Previous studies have shown that gray and white matter have different contrast relationships in the spinal cord than in the brain [8].

Materials and Methods

Six cadavers, ages 44 to 77 years old, were selected on the basis of freshness of the tissues and presumed absence of pathology in the cervicomedullary region. MR was performed with a 1.5-T imager* and a 5-in. surface coil† placed posterior to the neck. Spin-echo (SE) images were obtained in axial and sagittal projections with short TR, 800/20 (TR/TE), and long TR, 2500/20, 40, 60, 80 (TR/TES), two excitations, 3-mm slice thickness, contiguous (i.e., interleaved) slices, 256 × 256 matrix, and 16- or 20-cm field of view. The cadavers were frozen after the MR study. The upper cervical spine and posterior fossa were removed from the cadaver by means of an electric bandsaw, and the specimen was placed on a heavy-duty sledge cryomicrotome‡ [9]. Axial anatomic sections were obtained and photographed at 1.5-mm intervals. On the serial axial cryomicrotome sections, five levels were defined in the cervicomedullary region to illustrate the major anatomic structures: level 1, upper medulla; level 2, mid-medulla; level 3, lower medulla; level 4, cervicomedullary junction; and level 5, upper cervical cord (at C1) (see Fig. 1). The photographs were then compared with the correlative MR images. Anatomic and MR images were selected to illustrate this paper. In some cases, gradient reversal echoes (GRIL), 750/10, were obtained with a 16-cm field of view, two excitations, 256 × 256 matrix, and a flip angle of 30°.

Results

Level 1

The upper medulla had a multilobulated contour. Prominent landmarks at this level were the inferior olivary nuclei, pyramids, and the restiform bodies (Fig. 2). The restiform bodies in the posterolateral medulla, the pyramidal tracts in the anterior medulla, and the sensory fibers (medial lemniscus) immediately behind the pyramidal tracts were evident as white matter structures in anatomic section. The

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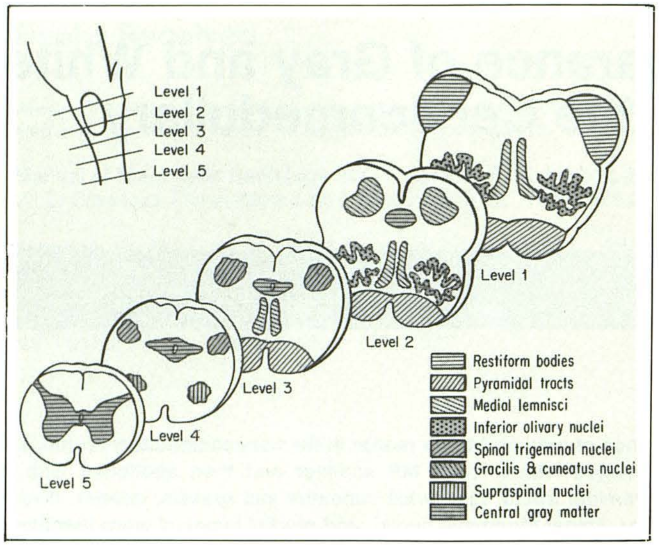
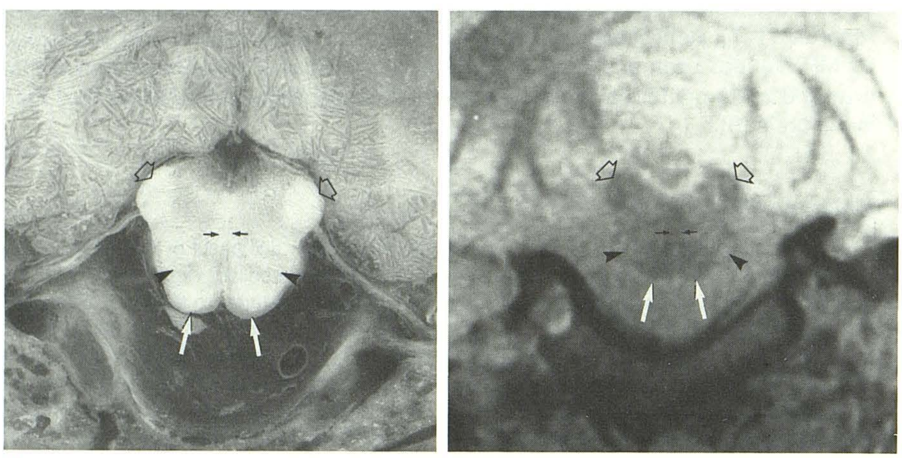


Fig. 1.—Diagram showing five levels through medulla and superior cervical spinal cord. Level 1, upper medulla; level 2, mid-medulla; level 3, lower medulla; level 4, cervicomedullary junction; level 5, upper cervical cord.

olivary nuclei appeared brownish red. Central gray matter, occupying the region posterior to the medial lemnisci was not conspicuous on the cryomicrotome sections. In short TR images the pyramidal tracts, the medial lemniscus, and the restiform bodies appeared to have a slightly lower signal intensity than the inferior olivary nuclei.

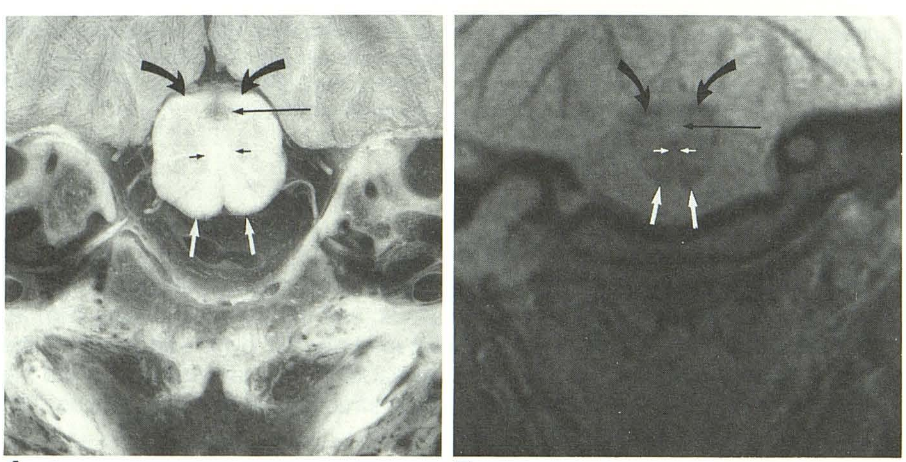
Level 2

At this level the medulla had an oval contour and a prominent median fissure. The structures that were recognized in the anatomic sections were the nucleus gracilis and cuneatus, central gray matter, medial lemniscus, and pyramids (Fig. 3). The pyramidal tracts at level 2 had sufficiently low signal intensity in the short TR images that they could be distinguished. The decussation of the medial lemnisci and medial longitudinal fasciculus immediately dorsal to the pyramidal tract also had low signal intensity. The nucleus gracilis and nucleus cuneatus, interspersed in white matter tracts, were not distinguished in MR. The central gray matter that is immediately ventral to the nucleus gracilis and cuneatus was identified as a region of higher signal intensity.



A B

Fig. 2.—Anatomic and MR sections at level 1. Cryomicrotomic section (*A*), SE 800/20 MR image (*B*). The pyramidal tract (*white arrows*), medial lemniscus (*small black arrows*), inferior olivary nuclei (*arrowheads*), and restiform body (*open arrows*) are seen.



A B

Fig. 3.—Anatomic and MR sections at level 2. Cryomicrotomic secion (*A*), SE 800/20 MR image (*B*). The pyramidal tracts (*large white arrows*), medial lemniscus (*small arrows*), nucleus gracilis and cuneatus (*curved arrows*), and central gray matter (*long thin arrows*) are seen. Anterolateral to medial lemniscus are the inferior olivary nuclei.

Level 3

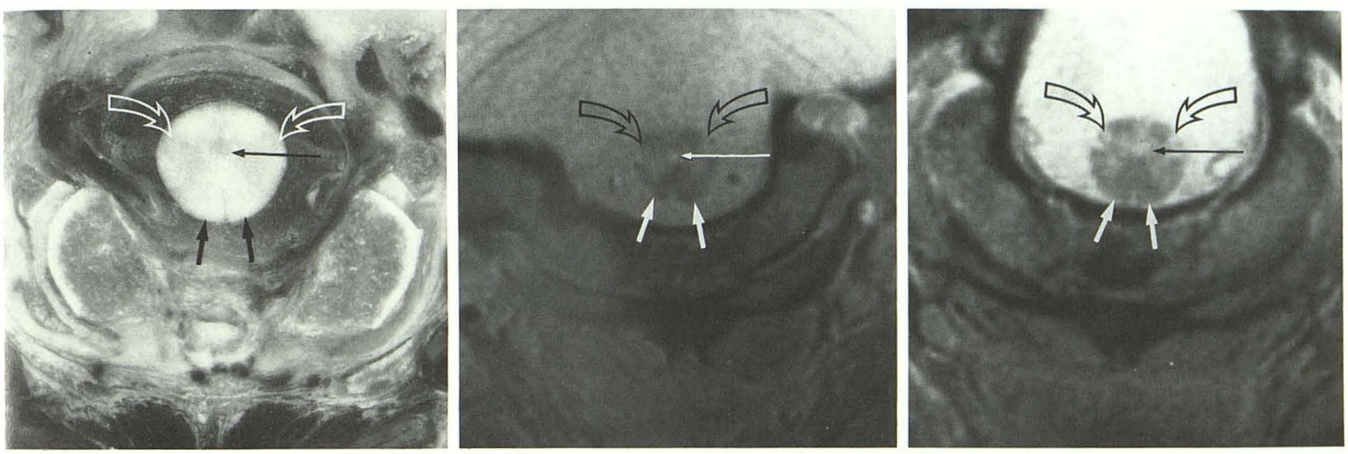
At the level of the lower medulla, the pyramidal tract decussation in the anterior brainstem was the most prominent landmark in the anatomic sections (Fig. 4). The spinal trigeminal nuclei on the posterolateral aspect of the brainstem could also be distinguished on gross inspection of the axial anatomic sections. In short TR, or long TR with short TE, images at this level the trigeminal nuclei and the central gray matter were distinguished as regions of brighter signal intensity; the pyramidal tracts, as regions of lower signal intensity.

Level 4

The spinal trigeminal and supraspinal nuclei and decussation of the pyramidal tracts were evident in the anatomic sections at the level of the cervicomedullary junction (Fig. 5). The spinal trigeminal nuclei, located posterolaterally and peripherally in the cord, appeared as high signal intensity areas on short TR, or long TR with short TE, images. The central gray matter near the middle of the cord was seen as a triangular-shaped region of high signal intensity. The supraspinal nuclei in the anterolateral cord were detectable as regions of higher signal intensity. The pyramidal tracts at this level were distinguished as a region of lower signal intensity than the rest of the cord.

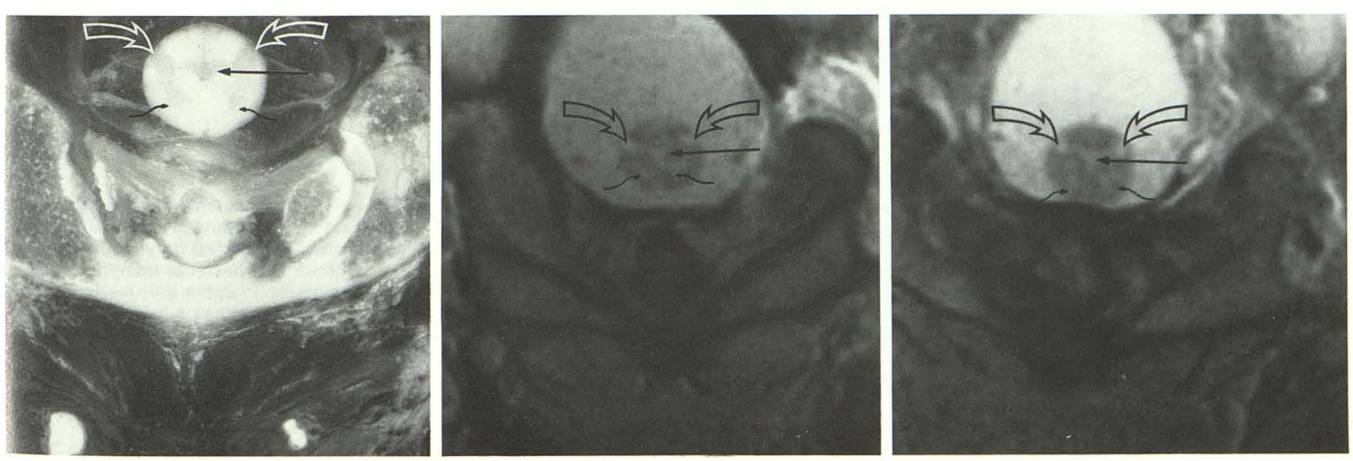
Level 5

In the upper cervical cord, the butterfly-shaped central gray matter of the cord was the most conspicuous landmark in the anatomic sections (Fig. 6). In the short TR, and long TR with short TE, images the central gray matter had a higher signal intensity than the adjacent white matter (i.e., the fasciculus gracilis and cuneatus located posterior to it). The other white matter tracts (pyramidal, rubrospinal, lateral cortical spinal, and lateral tegmentospinal) also had a lower signal intensity than the gray matter. These individual tracts, however, could



A B C

Fig. 4.—Anatomic and MR sections at level 3. Cryomicrotomic section (*A*), SE 800/20 MR image (*B*), SE 2500/20 MR image (*C*). Pyramidal tracts (*short straight arrows*), spinal trigeminal nuclei (*open curved arrows*), and central gray matter (*long thin arrows*) are landmarks at this level.



A B C

Fig. 5.—Anatomic and MR sections at level 4. Cryomicrotomic section (*A*), SE 800/20 MR image (*B*), SE 2000/20 MR image (*C*). Supraspinal nuclei (*wavy arrows*), spinal trigeminal nuclei (*open arrows*), and central gray matter (*long thin arrows*) are identified.

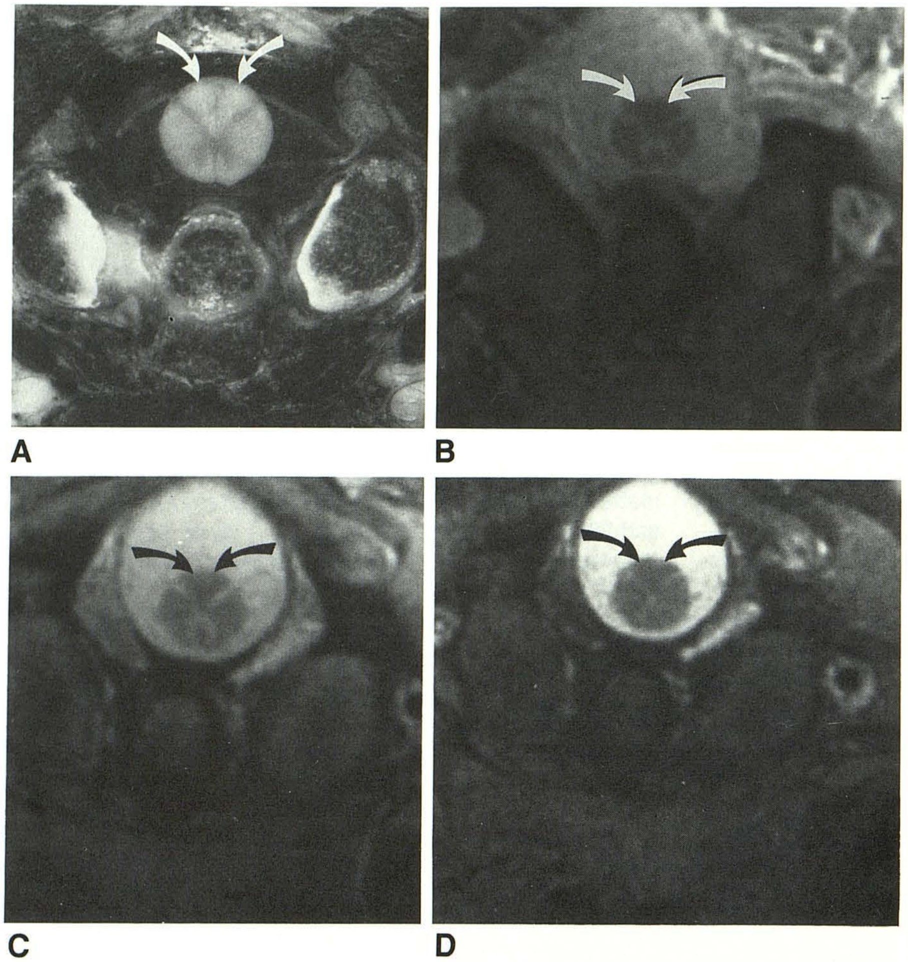


Fig. 6.—Anatomic and MR sections at level 5. Cryomicrotomic section (*A*), SE 800/20 MR image (*B*), SE 2500/20 MR image (*C*), SE 2500/80 MR image (*D*). The fasciculus gracilis and cuneatus (*curved arrows*) are identified at this level. The butterfly-shaped central gray matter has a higher signal intensity than white matter in the three MR images.

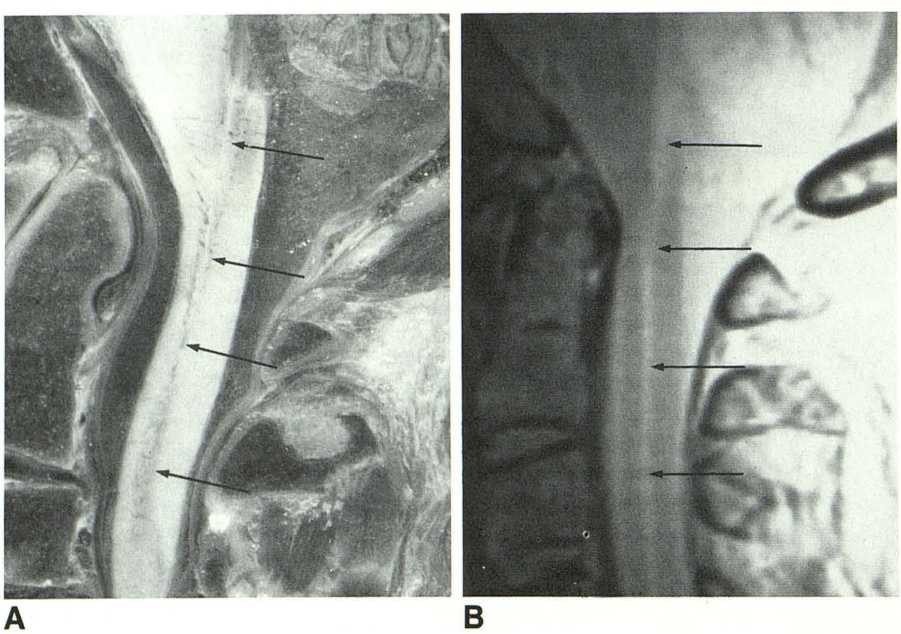


Fig. 7.—Sagittal anatomic section (*A*) and corresponding SE (2500/80) MR image (*B*) illustrate the relationship of central gray matter (*arrows*) to the anterior and posterior margins of spinal cord and medulla. In *B*, the gray matter of medullary and spinal cord has a bright signal intensity while cerebellar white matter has a lower signal intensity than adjacent gray matter. Note the seeming discontinuity in gray matter at level of decussation (posterior to the dens).

not be differentiated from one another. In long TR and TE images, gray matter had more signal intensity than white matter.

Discussion

Although imaging in cadavers differs significantly from imaging in patients, gray and white matter in the cervicomedullary region in our MR images resembled that in clinical studies. Although tissue signal intensity may change after death [10], no obvious differences between the cadaver and clinical images were seen except for the higher signal intensity of CSF in some cadavers, most likely due to blood and absence of pulsations in the CSF. Image quality in our studies probably exceeds that in clinical imaging owing to the lack of motion of the spinal cord and CSF and the use of longer acquisition times. In the future, higher quality MR images may be obtained when better fast-scanning techniques are developed.

Gray and white matter structures of the cervicomedullary region could be distinguished in one or more of the pulse sequences used. In short TR SE images, the gray matter had higher signal intensity than white matter. In long TR and long TE SE images, there also is higher signal intensity detected from the gray matter compared with the white matter fiber tracts.

The anatomic landmarks of the cervicomedullary region that can be distinguished with MR are the central gray matter, trigeminal nucleus, supraspinal nucleus, posterior columns (fasciculus gracilis and cuneatus), pyramidal tracts, and the motor and sensory decussations. The most prominent landmark, the central gray matter, occupies a different position in the brainstem than in the upper spinal cord. In the medulla the central gray matter is situated posteriorly near the obex.

In sagittal images (Fig. 7), the anatomic relationships of the central gray matter are clearly shown. It is near the dorsal surface of the brainstem in the medulla, near the center of the cord at the cervicomedullary junction, and near the ventral surface of the cord in the cervical spinal cord. Distortion of the normal anatomic landmarks may be expected in processes such as atrophy of the posterior column or destruction of central gray matter.

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REFERENCES

1. Smoker WRK, Keyes WD, Dunn VD, Menezes AH. MRI versus conventional radiologic examinations in the evaluation of the craniovertebral and cervicomedullary junction. *RadioGraphics* **1986**;6:953–994
2. Han JS, Benson JE, Yoon YS. Magnetic resonance imaging in the spinal column and craniovertebral junction. *Radiol Clin North Am* **1984**;22:805–827
3. Han JS, Bonstelle CT, Kaufman B, et al. Magnetic resonance imaging in the evaluation of the brainstem. *Radiology* **1984**;150:705–712
4. Flannigan BD, Bradley WG, Mazziotta JC, et al. Magnetic resonance imaging of the brainstem: normal structure and basic functional anatomy. *Radiology* **1985**;154:375–383
5. Norman D, Mills CM, Brant-Zawadzki M, Yeates A, Crooks LE, Kaufman L. Magnetic resonance imaging of the spinal cord and canal: potentials and limitations. *AJR* **1983**;141:1147–1152
6. Watson C. *Basic human neuroanatomy: an introductory atlas.* Boston: Little, Brown, **1977**;106–119
7. Schnitzlein HN, Murtagh FR. *Imaging anatomy of the head and spine: a photographic color atlas of MRI, CT, gross and microscopic anatomy in axial, coronal and sagittal planes.* Baltimore: Urban and Schwarzenberg, **1985**
8. Czervionke L, Daniels DL, Ho P, et al. The MR appearance of gray and white matter in the cervical spinal cord. *AJNR* **1988**;9:557–562
9. Rauschning W, Bergstrom K, Pech P. Correlative craniospinal anatomy studies by computed tomography and cryomicrotomy. *J Comput Assist Tomogr* **1983**;7:9–13
10. Pech P, Bergstrom K, Rauschning W, Haughton V. Attenution values, volume changes, and artifacts in tissue due to freezing. *Acta Radiol* **1987**;28:1–4