Emir. J. Food Agric. 2011. 23 (4): 375-380
http://ejfa.info/

Short Communication

Magnetic resonance image and cross sectional anatomy of the normal brain of goat (*Capra hircus*)

A. Kassab*

Department of Aridland Agriculture, Faculty of Food and Agriculture, Alain 17555, United Arab Emirates University, United Arab Emirates

Abstract: Among ruminant animals, there are few studies on the brain of the goat (*Capra hircus*). Our study demonstrates the first series of magnetic resonance (MR) imaging-based anatomically labeled sectioned images of the brain of the goat. T2-weighted dorsal MR images were acquired with a 1.5-T Philips NT scanner with slice spacing of 4 mm thickness. Frozen cross-sectional slices of goat brain were photographed and compared with the MR images. The cerebral hemispheres, hippocampus, thalamus, hypothalamus, cerebellum, pons, myelencephalon and other major features of the brain are clearly defined in the images. These MR images provide an excellent soft tissue contrast and anatomic details of the brain of the goat. MR imaging provides a mean for consistent evaluation of the goat brain structures that could be useful for evaluation of diseases that affect the brain region.

Key words: Anatomy, brain, goat, magnetic resonance image

تصوير بالرنين المغناطيسي والقطاع العرضي التشريحي على دماغ الماعز

أحمد كساب*

قسم الأراضي القاحلة- كلية الأغذية والزراعة- جامعة الإمارات العربية المتحدة

ملخص: هناك القليل من الدراسات التشريحية على دماغ الماعز من بين جميع الحيوانات المجترة. شملت هذه الدراسة على عمل قطاعات متتابعة بموجات الرنين المغناطيسي وكذلك عمل قطاعات تشريحية على دماغ الماعز. تم تصوير دماغ الماعز بجهاز الرنين المغناطيسي على سمك ومسافة 4 مم وتم مقارنتها بصور قطاعات عرضية تشريحية للدماغ والتي تم تجميدها. أظهرت الصور جميع الأجزاء المختلفة للدماغ بداية من نصفي الكره المخي ومنطقة المهاد وتحت المهاد والمخيخ وجذع المخ كما ظهرت باقي أجزاء المخ المختلفة بوضوح. أوضحت النتائج أن تصوير الدماغ بالرنين المغناطيسي أعطى تفاصيل كاملة ودقيقه لتشريح الدماغ في الماعز. لذلك فان الرنين المغناطيسي يعتبر من الوسائل القيمة التي من الممكن أن تستخدم لتقييم أمراض الدماغ في الماعز.

*Corresponding Author, *Email*: a.kassab@uaeu.ac.ae, kassab_aa@yahoo.com
Received 05 February 2011; Revised 05 April 2011; Accepted 08 April 2011

Introduction

Magnetic resonance imaging (MRI) has known a diagnostic tool in human medicine since 1980s (Hawkes et al., 1980; Doyle et al., 1981). Furthermore, this instrument has proved to be valuable in the study of anatomy (Goncalves-Ferreira et al., 2001) and pathology (Arnold and Matthews, 2002) of the central nervous system due its superior soft-tissue contrast.

MRI can differentiate the structures of the large brains as in African elephants (Hakeem et al., 2005) and dwarf sperm whale (Marino et al., 2003) where traditional methods of sectioning, staining, mounting and microscopic examinations are not practical. Several reports in animals have been published (Kraft et al., 1989; Karkkainen et al., 1991; Hudson et al., 1995 and Chaffin et al., 1997). Few studies on the heads of ruminant animals exist specially in camels (Arencibia et al., 2005) and buffaloes (Kassab, 2007) have information on the neuroanatomy of the goat based on MRI.

The first labeled sequential description of the goat brain based on MRI within the head of the goat has been described. We are able to produce a series of slices in which the detailed brain structures can be observed with little or no distortion caused by physically sectioning of the brain. Therefore MRI has become a valuable method for examining goat brains.

Materials and Methods

Specimen

In the present study, six heads of adult goats (*Capra hircus*) of different ages (2-3 years) and sexes (two females and four males) were used. Goats were slaughtered in the slaughter house and the heads were sectioned at the level of atlantoaxial joint. Immediately, cooled and imaged within 12 hours to minimize post-mortem changes.

Magnetic Resonance Imaging and sectioning of the head

Contiguous T2-weighted dorsal MR images were acquired with a 1.5-T Philips NT scanner. Imaging protocol parameters were: repetition time (TR) = 4757 ms, echo time (TE) = 120 ms, matrix = 245-256 pixels, Field of view = 160mm, 4mm slice thickness with 4 mm interslice spacing. The head was scanned with the ventral side down in the human head coil.

After MRI, three heads were frozen to -20°C for 24-48 hours, and then sectioned using an electric band saw (Arencibia et al., 2005). One head was sectioned longitudinally and the other two heads were sectioned transversely. All sections were cleaned, photographed and kept for the future studies.

Anatomical labeling and nomenclature

All identifiable anatomical structures of the goat brain were labeled in the axial and sagittal plane images. The MR images were compared with the gross anatomical sections (Hillmann, 1975; Smuts and Bezuidenhout, 1987; Schaller, 1992; Arencibia et al., 2005).

Results

General morphology

The results of the present study consisted of one macroscopic image of midsagittal section, 11 dorsal MR images and 9 gross cross sections through the head of goat. This is a descriptive study of normal brain anatomy in the goat using MRI. Figure 1 shows the midsagittal section of the goat head with the clinically relevant anatomic structures.

Figure 2 (a-k) displays a dorsal-to-ventral sequence of originally acquired 4.0-mm-thick dorsal MR brain sections at 4 mm intervals. The dorsal images were oriented so that the right side of the head is to the viewer's left and the dorsal at the top. The figures include also inset images of goat brain showing the approximate orientation of each transverse section. Figure 3 (a-i) displays a rostral-to-caudal sequence of 4 mm thick transverse brain sections at 4 mm intervals.

The T2-weighted MR images provided excellent anatomical views of the anatomy of the brain and associate structures. The cerebrospinal fluid within the subarachnoid spaces and inside the ventricles had high signal intensity and appeared bright white. The other brain structures had intermediate signal intensity and appeared dark.

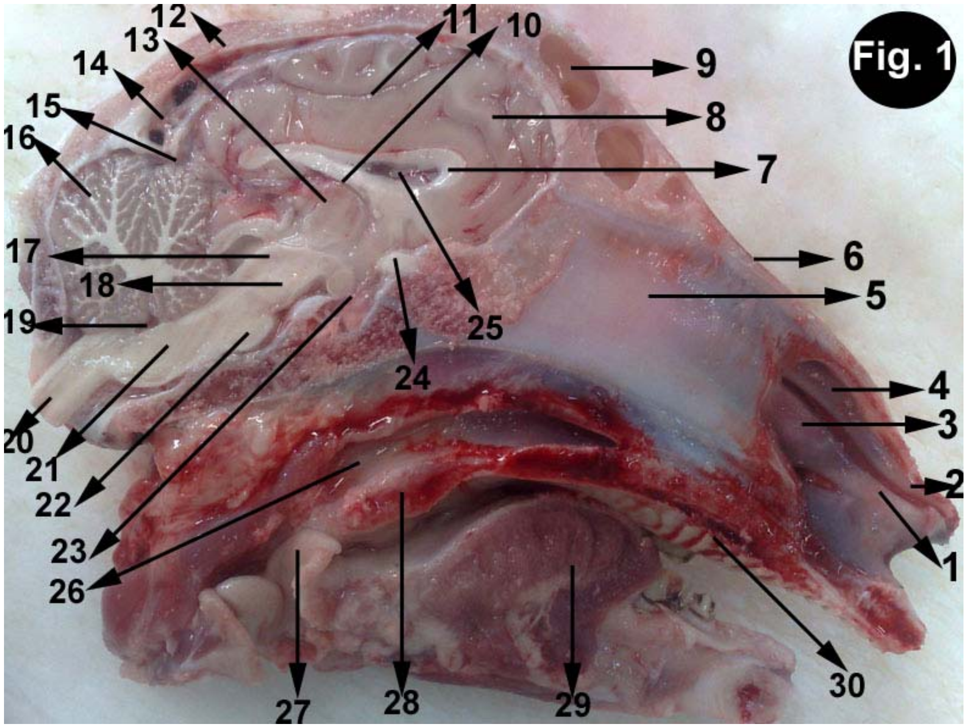

Figure 1. Macroscopic image of a Midsagittal section of normal goat brain. Rostral is to the right and dorsal is to the top of the image.

1, alar fold; 2, straight fold; 3, ventral nasal concha; 4, dorsal nasal concha; 5, nasal septum; 6, nasal bone; 7, corpus callosum; 8, cerebrum; 9, frontal sinus; 10, fornix; 11, Gyrus cinguli (Cingulate gyrus); 12, parietal bone; 13, thalamus and interthalamic adhesion; 14, dorsal sagittal sinus; 15, tentorium cerebella; 16, cerebellum; 17, Tegmentum of mesencephalon; 18, cerebral peduncle; 19, Fourth ventricle; 20, spinal cord; 21, Medulla oblongata; 22, pons; 23, Pituitary gland; 24, optic nerve; 25, lateral ventricle; 26, nasopharynx; 27, epiglottis; 28, soft palate; 29, tongue; 30, hard palate.

The cerebral hemispheres were narrow in the rostral part and become wider in their caudal part, as shown in the coronal slices (Figure 2). The basal ganglia structures such as the caudate nucleus can be easily visualized in Fig 3c. The internal capsule was wide and clear (Figure 2 a-h and Figure 3a-h), and carry the descending motor fibers. The hippocampus is small and in the ventral position in Figure 3e. The thalamus and hypothalamus were seen (Figure 2 g, h). The corpus callosum is thin with respect to the size of the cerebral hemispheres when compared to the human brain.

The cerebral peduncle is large and lies on the ventral surface of the midbrain (Figure 2).

Discussion

Knowledge of normal transverse anatomy of the brain of goat is essential to the evaluation of MRI. The present MR images allow for the visualization of the characteristic features of the goat brain.

The corpus callosum is relatively small structure in the goat brain with respect to the size of the cerebral hemispheres. This is in agreement with the earlier findings by Tarpley and Ridgway (1994) and Nieto et al. (1976) for cetaceans and humans and this is in contrast to the elephant brain that has an unusually large corpus callosum (Hakeem et al., 2005).

The present results show that the goat brain has small hippocampus which is found exclusively in the ventral position, similar to that observed in buffaloes (kassab, 2007). This is in contrast to the hippocampus of the elephant brain which is large and extends dorsally (Hakeem et al., 2005).

Understanding of normal brain anatomy of the goat using MRI is necessary for the diagnosis of the central nervous system diseases (Dennis, 1995).

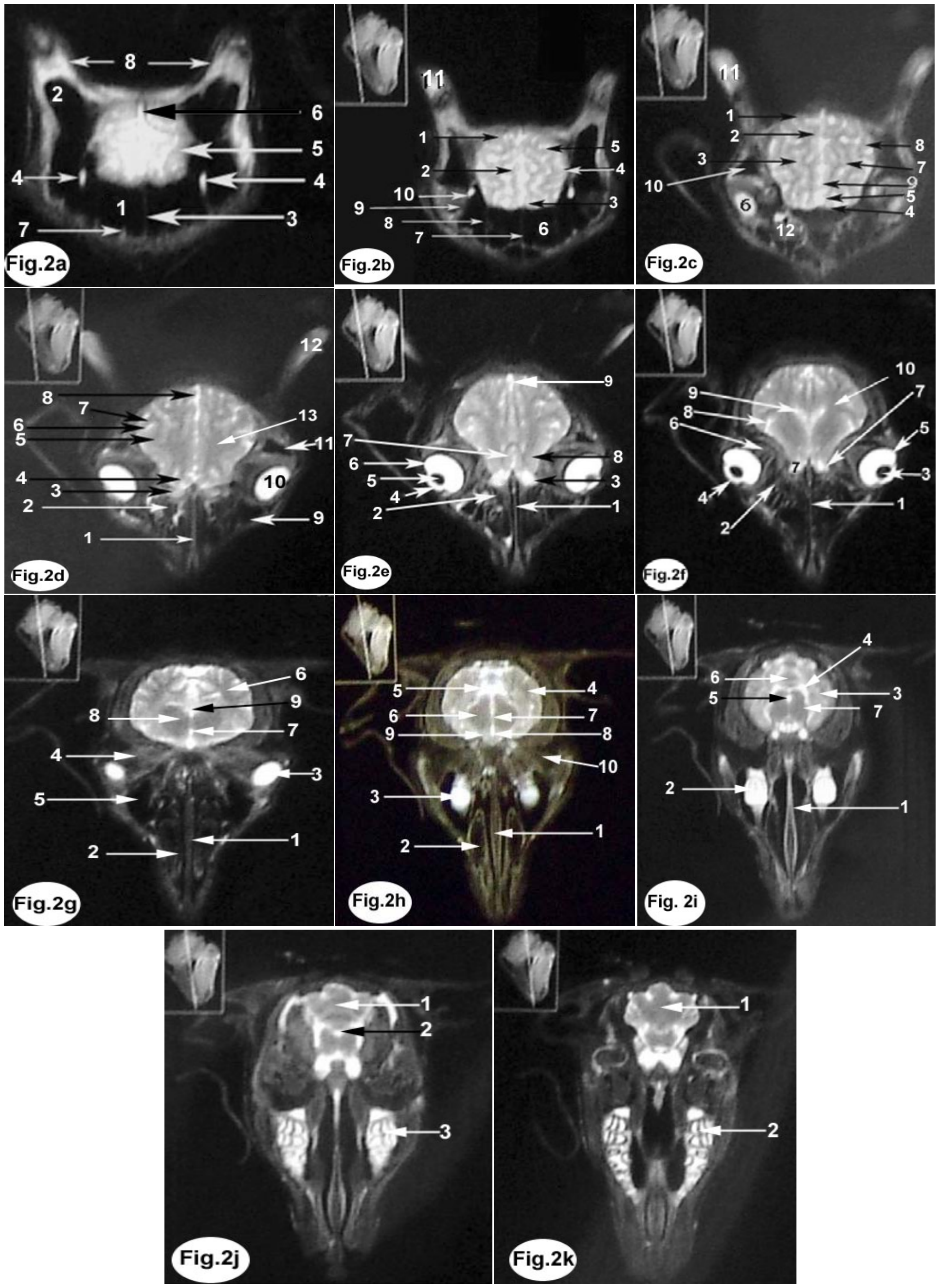

Figure 2. (a-k) Dorsal-to-ventral sequence of anatomically labeled T2-weighted dorsal MR images through the whole goat brain.

Figure 2a. 1- Sinus frontales, 2- extension of frontal sinus into corneal process, 3- Septum sinuum frontalium, 4- N. opticus, 5- Hemicepherium cerebri, 6-Sinus sagittalis dorsalis 7- Laminae intrasinuales, 8- Processus Cornualis ossis frontalis. Figure 2b. 1- Gyrus occipitalis, 2- Gyrus marginalis, 3- Gyrus precruceatus, 4- Gyrus ectosylvius caudalis, 5- Gyrus ectomarginalis medius, 6- Sinus frontales, 7- Septum sinuum frontalium, 8- Laminae intrasinuales, 9- Musculi oculi, 10- N. opticus, 11- Cornu. Figure 2c. 1- Gyrus occipitalis, 2- Gyrus marginalis, 3- Gyrus ectomarginalis medius, 4- Gyrus proreus, 5- Gyrus precruceatus, 6- Bulbus oculi, 7- Pars lateralis of gyrus ectomarginalis, 8- Gyrus ectosylvius caudalis, 9- Gyrus postcruciatus, 10- Sinus frontales, 11- Cornu, 12- Conchae ethmoidales. Figure 2d. 1- Lamina perpendicularis ossis, 2- labyrinthus ethmoidalis, 3- Bulbus olfactorius, 4- Gyrus proreus, 5- Gyrus obliquus rostralis, 6- sulcus obliquus, 7- Gyrus obliquus caudalis, 8- Fissura longitudinalis cerebri (Cerebral longitudinal fissure), 9- sinus maxillaris, 10- Bulbus oculi, 11- Sinus frontales, 12- Cornu, 13- Capsula interna (internal capsule). Figure 2e. 1- Lamina perpendicularis ossis, 2- labyrinthus ethmoidalis, 3- Bulbus olfactorius, 4- Bulbus oculi (Camera anterior bulbi), 5- Lens, 6- Bulbus oculi, Camera posterior bulbi, 7- Gyrus geniculi, 8- Gyrus proreus, 9- Fissura longitudinalis cerebri (Cerebral longitudinal fissure). Figure 2f. 1- Lamina perpendicularis ossis, 2- labyrinthus ethmoidalis, 3- Lens, 4- Bulbus oculi, Camera anterior bulbi, 5- Bulbus oculi, Camera posterior bulbi, 6- Musculi oculi, 7- Bulbus olfactorius, 8- Fissura sylvia, 9-Ventriculus lateralis, 10- Capsula interna (internal capsule). Figure 2g. 1- Lamina perpendicularis ossis, 2- concha nasales, 3- Bulbus oculi, 4- Musculi oculi, 5- sinus maxillaris, 6- Capsula interna (internal capsule), 7- Ventriculus tertius (Third ventricle), 8- Thalamus, 9- Lateral ventricle. Figure 2h. 1- Lamina perpendicularis ossis, 2- concha nasales, 3- dental alveoli, 4- Cerebral hemisphere, 5- Lateral ventricle, 6- Tegmentum mesencephali (Mesencephalic tegmentum), 7- Ventriculus tertius (Third ventricle), 8- Aqueductus mesencephali (Mesencephalic aqueduct), 9-.Hypothalamus, 10- Musculi oculi. Figure 2i. 1- Lamina perpendicularis ossis, 2- dental alveoli, 3- Cerebral hemisphere, 4-Lateral ventricle 5- Aqueductus mesencephali (Mesencephalic aqueduct), 6- Vermis 7- Tegmentum mesencephali (Mesencephalic tegmentum). Figure 2j. 1- Cerebellum, 2- Fourth ventricle, 3- dental alveoli. Figure 2k. 1- Cerebellum, 2- dental alveoli.

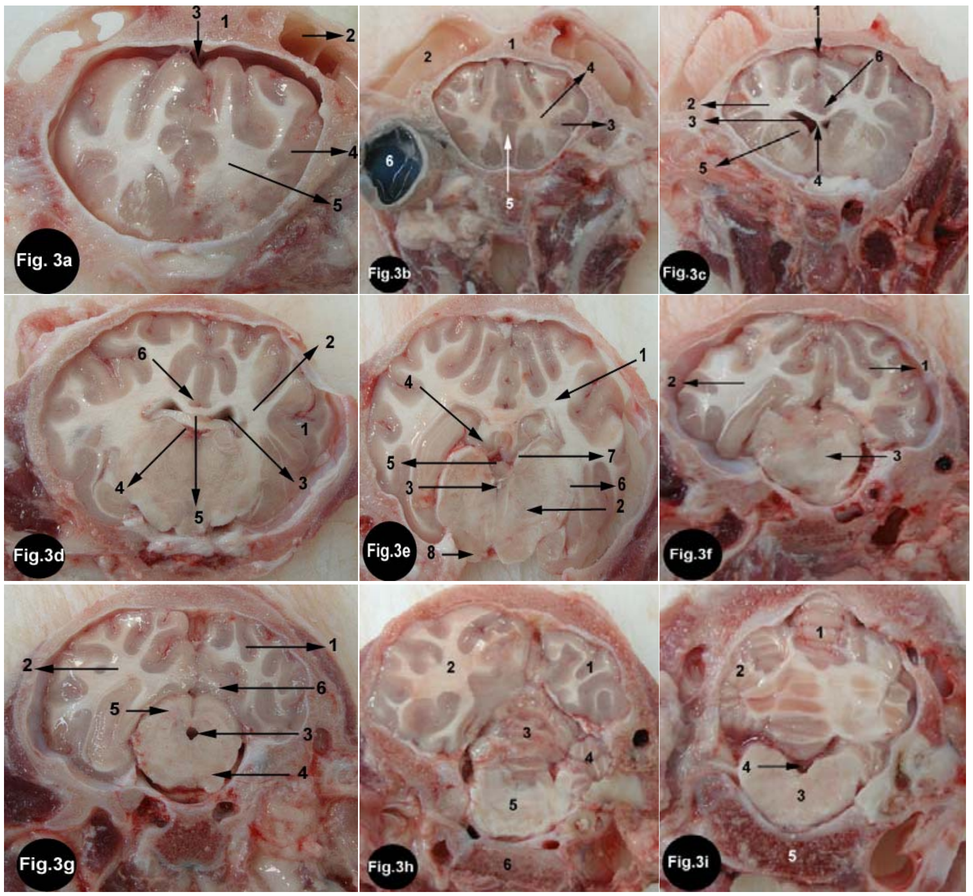

Figure 3. (a-i) Rostral-to-caudal sequence of anatomically transverse macroscopic images through the whole goat brain.

Figure 3a. 1, Frontal bone; 2, Frontal sinus; 3, Sinus sagittalis dorsalis; 4, Cerebral hemisphere; 5, Capsula interna (Internal capsule). Figure 3b. 1, Frontal bone; 2, Frontal sinus; 3, Cerebral hemisphere; 4, Capsula interna (Internal capsule); 5, Fissura longitudinalis cerebri (Cerebral longitudinal fissure); 6, Eyeball. Figure 3c. 1, Sinus sagittalis dorsalis (Dorsal sagittal sinus); 2, Capsula interna (Internal capsule); 3, Ventriculus lateralis (Lateral ventricle); 4, Septum pellucidum; 5, Nucleus caudatus (Caudate nucleus); 6, Corpus callosum. Figure 3d. 1, Cerebral hemisphere; 2, Capsula interna (Internal capsule); 3, Ventriculus lateralis (Lateral ventricle); 4, Nucleus caudatus (Caudate nucleus); 5, Septum pellucidum; 6, Corpus callosum. Figure 3e. 1- Capsula interna (internal capsule), 2- Tegmentum mesencephali (Mesencephalic tegmentum); 3- Ventriculus tertius (Third ventricle), 4- Hippocampus; 5- Pineal gland; 6- Corpus geniculatum laterale (Lateral geniculate body); 7, Corpus geniculatum mediale (Medial geniculate body); 8- Crus cerebri. Figure 3f. 1, Cerebral hemisphere; 2, Capsula interna (internal capsule); 3, Tegmentum mesencephali (Mesencephalic tegmentum). Figure 3g. 1, Cerebral hemisphere; 2, Capsula interna (internal capsule); 3, Aqueductus mesencephali (Mesencephalic aqueduct); 4, Tegmentum mesencephali (Mesencephalic tegmentum); 5, Tectum mesencephali-colliculus rostralis; 6, Hippocampus. Figure 3h. 1, Cerebral hemisphere; 2, Capsula interna (internal capsule); 3, Vermis; 4, Cerebellar hemisphere; 5, Medulla oblongata; 6, Occipital bone. Figure 3i. 1, Vermis; 4, Cerebellar hemisphere; 3, Medulla oblongata; 4, Fourth ventricle; 5, Occipital bone.

The use of MRI in goat is currently limited because of its expense and availability but with developing technology, it may become more readily available as the equipment become most effective.

Conclusion

MRI provides a mean for consistent evaluation of the goat brain structures useful for evaluation of diseases that affect the brain region.

References

Arencibia, A., M. Rivero, F. Gil, J. A. Ramirez, J. A. Corbera, G. Ramirez and J. M. Vazquez. 2005. Anatomy of the craniocephalic structures of the camel (*Camelus dromedarius* L.) by imaging techniques: A magnetic resonance imaging study. Anat. Histol. Embryol. 34:52-55.

Arnold, D. L. and P. M. Matthews. 2002. MRI in the diagnosis and management of multiple sclerosis. Neurol. 58:23-31.

Chaffin, M. K., M. A. Walker, N. H. Mcarthur, E. E. Perris and N. S. Matthews. 1997. Magnetic resonance imaging of the brain of normal neonatal foals. Vet. Radiol. Ultrasound 38:102-111.

Dennis, R. 1995. Magnetic resonance imaging: an overview of its current use in veterinary medicine. Vet. Internat. 7:50-58.

Dolye, F. H., J. M. Pennock and J. S. Orr. 1981. Imaging of the brain by nuclear magnetic resonance. Lancet 2:53-57.

Goncalves-Ferreira, A. J., M. Herculano-Carvalho, J. P. Melanicia, J. P. Farias and L. Gomes. 2001. Corpus callosum: microsurgical anatomy and MRI. Surg. Radiol. Anat. 23:409-414.

Hakeem, A. Y., P. R. Hof, C. C. Sherwood, R. C. Switzer III, L. E. L. Rasmussen and J. M. Allman. 2005. Brain of the African elephant (*Loxodonta africana*): Neuroanatomy from magnetic resonance images. Anat. Rec. 287:1117-1127.

Hawkes, R. C., G. N. Holland and W. S. Moore. 1980. Nuclear magnetic resonance (NMR) tomography of brain: a preliminary clinical assessment with demonstration of pathology. J. Comput. Assist. Tomog. 4:577-586.

Hillmann, D. J. 1975. Skull. In: Sisson and Grosman's The Anatomy of the Domestic animals, 5th ed. (R. Getty, Ed.). WB Saunders Co, Philadelphia, PA.

Hudson, L. C., L. Cauzinille, J. N. Kornegay and M. B. Tompkins. 1995. Magnetic resonance imaging of the normal feline brain. Vet. Radiol. Ultrasound 36:267-275.

Kassab, A. 2007. Magnetic resonance imaging of the normal brain of buffaloes (*Bos bubalis*). Benha Vet. Med. J. 18:47-61.

Kraft, S. L., P. Gavin, L. R. Wendling and V. K. Reddy. 1989. Canine brain anatomy on magnetic resonance images. Vet. Radiol. Ultrasound 30:147-158.

Karkkainen, M., M. Mero, P. Nummi, and L. Punto. 1991. Low field magnetic resonance imaging of the canine central nervous system. Vet. Radiol. Ultrasound 32:71-74.

Marino, L., K. Sudheimer, D. A. Pabst, W. A. Mclellan and J. I. Johnson. 2003. Magnetic resonance images of the brain of a dwarf sperm whale (*Kogia simus*). J. Anat. 203:57-76.

Nieto, A., D. Nieto and P. Pacheco. 1976. Possible phylogenetical significance of the corpus callosum with special reference to the dolphin brain (*Stenella graffmani*). Acta Anat. 94:397-402.

Schaller, O. 1992. Illustrated Veterinary Anatomical Nomenclature. Stuttgart: Enke Verlag.

Smuts, M. M. S. and A. J. Bezuidenhout. 1987. Anatomy of the dromedary. Clarendon press, Oxford.

Tarpley, R. J. and S. H. Ridgway. 1994. Corpus callosum size in delphinid cetaceans. Brain Behav. Evol. 44:156-165.