

## Normal brain of one-humped camel: a study with magnetic resonance imaging and gross dissection anatomy

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*Three brains of healthy adult camels were studied anatomically and with magnetic resonance imaging. The anatomical study accomplished through 12 cross-sections. Grossly, forebrain formed of diencephalon and telencephalon. Diencephalon formed of epithalamus, thalamus, metathalamus and hypothalamus. Telencephalon formed of two completely separated hemispheres, each formed of grey and white matter. T1-weighted images showed the white matter as grey (dark), grey matter light grey and cerebrospinal fluid black. On T2 weighted images, white matter appeared grey (dark), grey matter appeared brighter than the white one, while the cerebrospinal fluid appeared bright white. On STIR images, white matter was dark grey and grey matter more bright than white matter, while cerebrospinal fluid appeared bright and fat appeared dark. Bones appeared black in all sequences. In conclusion, magnetic resonance imaging is an excellent imaging technique for identification and characterization of brain anatomical features in camel.*

**Key words:** Anatomy, Brain, Camel, MRI, Sequence.

In camels, the exploration of the anatomical structures of the brain and associated structures is difficult due to its complex anatomical organization (Blanco *et al.*, 2014). Magnetic resonance imaging (MRI) has become more available to veterinarians, and may supplement the conventional and radiographic anatomy in recognizing structural abnormalities in diseased animals (Morgan *et al.*, 1993; Assheuer and Sager, 1997). This technique can be used to study and evaluate the anatomy of the central nervous system (CNS) (Goncalves-Ferreira *et al.*, 2001), since thorough understanding of normal CNS anatomy on magnetic resonance images is essential to optimize the diagnosis of abnormalities (Stewart *et al.*, 1992; Dennis, *et al.*, 1995). In small animal practice, MRI is frequently used to evaluate the head (Kraft *et al.*, 1989; Kärkkäinen *et al.*, 1991; Hudson *et al.*, 1995), but its use in large animals is limited because of some logistical problems of acquiring MR images. However, some MRI studies were conducted on

head of horses (Morgan *et al.*, 1993; Chaffin *et al.*, 1997; Arencibia *et al.*, 2000) and camels (Arencibia *et al.*, 2005).

The objectives of the current study was to provide an overview of the normal camel brain on MR images and gross anatomic sections to aid in creating an anatomic reference for this species.

### Materials and Methods

Three cadaver heads obtained from symptomatically healthy adult dromedary camels were used in this study. The heads were severed at the atlanto-axial joint and one head was imaged with magnetic resonance within six hours from severing to minimize postmortem changes. MRI was performed through 1.5T apparatus using T1 weighted, T2 weighted and STIR (short TI-inversion recovery) sequences. The transverse images were obtained perpendicular to the soft palate in order to provide a reference for slice orientation (Arencibia *et al.*, 2005). The other two heads were rinsed in 10 L of 10% formalin immediately after severing and fixed for 10 days, subsequently sectioned into 12 cross-sections (thickness: from 3-10 mm). All sections were described anatomically and then photographed. MR images were interpreted and the signal intensities of each structure were detected and matched with the represented structures on gross anatomical sections. Nomenclature was adopted according to Nomina Anatomica Veterinaria (2012).

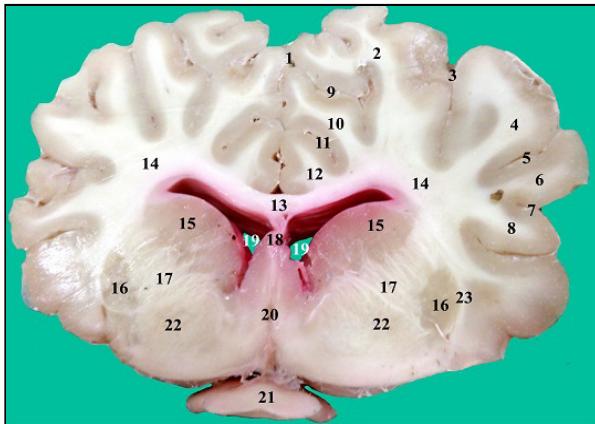
### Results and Discussion

The obtained results were expressed after interpretation of MR images and matching with the gross anatomical observations of the same brain. Anatomically (Figs. 1, 2, 3 & 4), the forebrain included diencephalon and telencephalon. The latter formed of two cerebral hemispheres (Fig. 1) separated by

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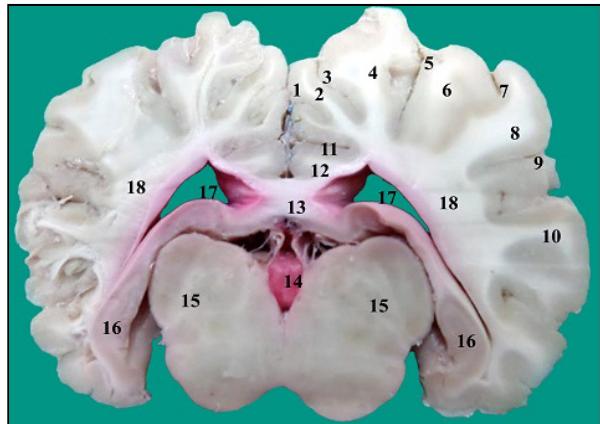


**Fig. 1:** Cross- section of the brain of the camel at the rostral part of the forebrain.

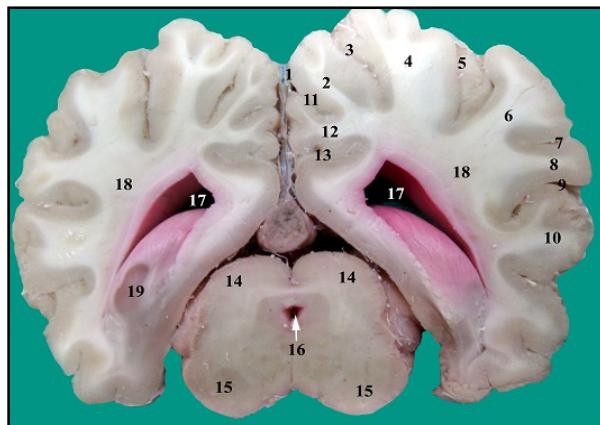


**Fig. 2:** A transverse cross-section of the brain in the area of the optic chiasm: 1. cerebral longitudinal fissure, 2. marginal gyrus, 3. marginal sulcus, 4. middle suprasylvian gyrus, 5. ectomarginal sulcus, 6. middle suprasylvian gyrus, 7. middle suprasylvian sulcus, 8. middle ectosylvian gyrus, 9. suprasplenial sulcus, 10. cingulate gyrus, 11. splenial sulcus pseudosylvian fissure, 12. cingulum, 13. corpus callosum, 14. semioval center, 15. caudate nucleus, 16. lateral geniculate body, 17. internal capsule, 18. septum mesenchali, 19. lateral ventricle, 20. third ventricle, 21. optic chiasma, 22. striatum, and 23. external capsule.

longitudinal fissure (Fig. 2/1) and were connected by corpus callosum (Figs. 2/13 and 3/13), which form the roof of the lateral ventricles (Figs. 2/19, 3/17 and 4/17). The corpus callosum was thick with respect to the size of the cerebral hemispheres. The same results were reported in elephant (Shoshani *et al.*, 2006). The outer surface of hemispheres had clear gyri and sulci, moreover each hemisphere was formed of gray matter that form the cerebral cortex or pallium, while the white matter showed a striated appearance due to the afferent and efferent fibers and

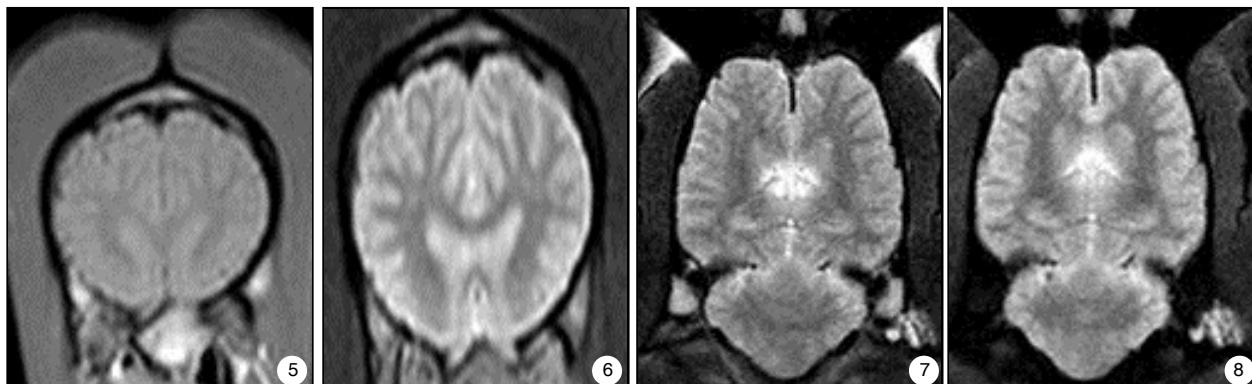


**Fig. 3:** A transverse cross-section of the brain just caudal to the tuber cinereum: 1. cerebral longitudinal fissure, 2. marginal gyrus, 3. marginal sulcus, 4. middle suprasylvian gyrus, 5. ectomarginal sulcus, 6. middle suprasylvian gyrus, 7. middle suprasylvian sulcus, 8. middle ectosylvian gyrus, 9. suprasplenial sulcus, 10. cingulate gyrus, 11. splenial sulcus pseudosylvian fissure, 12. cingulum, 13. corpus callosum, 14. third ventricle, 15. thalamus, 16. hippocampus, 17. lateral ventricle, and 18. semioval center septum mesenchali.



**Fig. 4:** A transverse cross-section of the brain, 1cm caudal to the tuber cinerum and 1 cm rostral to the pons: 1. cerebral longitudinal fissure, 2. marginal gyrus, 3. marginal sulcus, 4. middle suprasylvian gyrus, 5. ectomarginal sulcus, 6. middle suprasylvian gyrus, 7. middle suprasylvian sulcus, 8. middle ectosylvian gyrus, 9. suprasplenial sulcus, 10. cingulate gyrus, 11. splenial sulcus pseudosylvian fissure, 12. cingulum, 13. corpus callosum, 14. superior colliculus, 15. thalamus, 16. cerebral aqueduct, 17. lateral ventricle, 18. semioval center septum mesenchali, and 19. lateral geniculate body.

called the striatum (Fig. 2/22). The striatum was the great basal nuclei of the hemisphere situated rostral to the thalamus, as reported by Zhaohui *et al.* (2012)



**Figs. 5-8:**(5) T1-weighted transverse MR image of the brain. Notice the signal intensity and appearance of the cranium bones, grey matter and the white matter; (6) T2-weighted transverse MR image of the brain. Notice the signal intensity and appearance of the cranium bones, grey matter and the white matter; (7) T2-weighted MR image of the brain. Notice the signal intensity and appearance of the cranium bones, grey matter, the white matter, cerebellum and CSF; (8) STIR-weighted MR image of the brain. Notice the signal intensity and appearance of the cranium bones, grey matter, the white matter and CSF.

in camel. The striatum was subdivided into the paleostriatum (pallidum or globus pallidus), the neostriatum (caudate nucleus and putamen) and the archistriatum (amygdaloid body). The caudate nucleus (Fig. 2/15) is a large grey mass (about 20 mm in length and 10 mm width) forming the floor of the lateral ventricle together with the more developed hippocampus (about 20 mm length and 5 mm width) (Fig 3/16). However, Zhaohui *et al.* (2012) in the same animal recorded the caudate nucleus only forming the floor of the lateral ventricles.

The diencephalon was located ventrally in the cross sections and formed of epithalamus, thalamus, metathalamus and hypothalamus. On the other hand, Junge (1977) in cow added subthalamus part. Our study similar to that of Diepen *et al.* (1956) showed that structures visible with the naked eye found in the diencephalon include the thalamus with medial and lateral geniculate nuclei, and the hypothalamus. The thalamus (Fig. 3/15) was the largest part and the two thalami were connected by the interthalamic adhesion, which was encircled by the third ventricle (Fig. 3/14).

The hypothalamus formed the floor and wall of the third ventricle and it included the optic chiasma (Fig. 2/21), infundibulum, tuber cinereum and mammillary body, while the metathalamus was represented by medial and well developed lateral geniculate bodies; about 5 mm length and 2-3 mm width (Figs. 2/16, 4/16 and 4/19).

The large size of the cerebrum in our findings is in accordance with Nzalak *et al.* (2005 and 2008) in African Giant rat, the authors attributed it to allow neocortical recording of biological activity.

The signal intensity and MR appearance of different brain structures is described in Table 1. On T1-weighted images (Fig. 5) and on all imaging planes, the bones that constitute the cranium and other bones of the skull had low signal intensities and appeared black, the cerebral white matter appeared grey and had more signal intensity than skull bones, while the cerebral grey matter was more intense than white matter and appeared light grey. Cerebrospinal fluid (CSF) which was present in the subarachnoid space and the ventricular system appeared black in color with low signal intensity. A similar study (Arencribia *et al.*, 2005) with T1 weighted sequence was conducted to describe the anatomy of the camel cranocephalic structures. This sequence provides good spatial resolution and better anatomic contrast for identification of the main structures on MR images (Mogicato *et al.*, 2011). On brain, T1 sequence used to evaluate the gross anatomy and gave a better anatomical definition and underlying lesion that may be obscured on T2 weighted images by the hyperintensity of the intraparenchymal oedema. Moreover, this sequence provides a good contrast between grey and white matter (Parizel *et al.*, 2010).

On T2 weighted images (Figs. 6 and 7), the bones appeared black with low signal intensity, the

**Table 1:** The signal intensities and MR appearance of different brain structures.

	Image contrast		
	T1	T2	STIR
Skull bones	Black	Black	Black
White matter	Grey	Grey	Dark grey
Grey matter	Light grey	Bright grey	Bright grey
CSF	Black	White	White

cerebral white matter appeared grey and the grey matter was with obvious high signal intensity than the white matter. CSF everywhere appeared hyperintense with bright white signals and colour. T2 weighted images are very important, because most pathological processes in the brain result in increased water content and are therefore readily identified (Parizel *et al.*, 2010).

On STIR sequence images (Fig. 8), bones were without signals and appeared black, the white matter had intermediate signal intensity and looked dark grey in colour, while the grey matter appeared more intense and brighter than the white matter. CSF appeared hyperintense and bright white in colour. Fat rich structures like white matter emitted low signals on this sequence. STIR sequence (fat suppression sequence) is used to detect the pathology in fat rich tissues like orbits and bone marrow (Lisle, 2012). Superiority of STIR sequence upon imaging of these structures comes from the fact that suppression of fat signals will make signals of abnormal tissues to become clearer. STIR is used to enhance contrast between white and grey matter and gives better visualization for structures such as optic nerve (Hickman and Miller, 2005).

Since the first application of MRI in the veterinary practice in 1980, the use of this technique is not widely expanded yet. In large animal practice, the use of MRI is limited due to some logistical problems (Arencibia *et al.*, 2005), however, our approach upon MRI on camel brain is unconventional in many aspects, first is that it is concerned with camel which is a rarely studied animal (Sohail, 1983; Iqbal, 1999). Limitation of scientific researches on camels may relate to the limitation of their distribution over the land. Second aspect is concerned with studying the brain which is not a priority in veterinary practice, and last aspect is the use of the most modern diagnostic imaging technique (MRI) (Abedellaah, 2010), which is considered unusual especially in developing countries. Advantages of MRI include excellent soft tissue contrast, lack of artifacts from adjacent bones, in addition to lack of harmful ionizing radiation (Lisle, 2012).

In conclusion, MRI was found an excellent diagnostic imaging tool for identification and characterization of the anatomical features of brain tissues in one humped camel. This could be useful in creating an anatomic reference data for camel brain for future studies.

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