Anatomic study of the normal Bengal tiger (*Panthera tigris tigris*) brain and associated structures using low field magnetic resonance imaging

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SUMMARY

The aim of this paper was to study the brain and associated structures of the Bengal tiger’s (*Panthera tigris tigris*) head by low-field magnetic resonance imaging (MRI). A cadaver of a mature female was used to perform spin-echo T1 and T2-weighting pulse sequences in sagittal, transverse and dorsal planes, using a magnet of 0.2 Tesla. Relevant anatomic structures were identified and labelled on the MRI according to the location and the characteristic signal intensity of different organic tissues. Spin-echo T1 and T2-weighted MR images were useful to demonstrate the anatomy of the brain and associated structures of the Bengal tiger’s head. This study could enhance our understanding of normal brain anatomy in Bengal tigers.

Key words: MRI – Anatomy – Brain – Bengal tiger

INTRODUCTION

Veterinarians and wildlife researchers are involved in large feline conservation tasks that include clinical, physiological and behavioural studies (Weissengruber et al., 2002; Bollo et al., 2011; Sajjad et al., 2011; Farooq et al., 2012; Maas et al., 2013), as well as researches in order to better understand its normal anatomy (Khan, 2004; Mazák et al., 2011; Diogo et al., 2012). The application of modern diagnostic imaging techniques such as computed tomography (CT) or magnetic resonance imaging (MRI) have revolutionized the diagnostic imaging in feline medicine, being used sparingly for descriptive anatomical research (Hudson et al., 1995; Mogicato et al., 2012), as well as in diagnosing diseases of the head (Negrin et al., 2010; Gunn-Moore and Reed, 2011). Reports of MRI in large felines such as the Bengal tiger have been limited to the study of central infarction and haemorrhage (Snow et al., 2004), suspected neurotoxicity (Zeria et al., 2012) and normal anatomy of stifle joints (Arencibia et al., 2015). Although MRI was used to examine the Bengal tiger’s brain (Snow et al., 2004), no detailed anatomical information has been described to date. The evaluation of the feline brain is particularly interesting due to its complex anatomy, and the different types of pathologies described such as neoplasia (Dietz et al., 1985; Kang et al., 2006) or head trauma (Ketz-Riley et al., 2004). Therefore, the purpose of this study was to provide an overview of the anatomy of the brain and associated structures of the Bengal tiger, using sagittal, transverse and dorsal MRI.

MATERIALS AND METHODS

Animals

A cadaver of 6-year-old female Bengal tiger

Magnetic resonance imaging of normal Bengal tiger brain

(Panthera tigris tigris) with a weight of 105 kg, born in captivity in Cocodrilos Park Zoo (Gran Canaria, Canary Islands, Spain) was used. This animal died of natural causes not related to head disorders. The study was conducted with the control of the Ethical Commission of Veterinary Medicine of the University of Las Palmas de Gran Canaria (agreement MV-2015/05).

MRI technique

The tiger was frozen immediately after death. Two days later, the cadaver was thawed during 48 hours to perform the MR study using a 0.2-Tesla magnet (Vet-MR Esaote, Genova, Italy) and a head coil. The animal was positioned in lateral recumbency during the MRI procedure. MR images were acquired by spin-echo pulse sequences (SE). T1 and T2-weighted MR images were obtained in sagittal, transverse and dorsal planes. Basic technical parameters are presented in Table 1.

Anatomic evaluation

Anatomic details of the Bengal tiger’s brain and associated structures on the MR images were evaluated according to the characteristic signal intensity of the different bony components and soft-tissues structures. Identifiable anatomical structures were labelled with the aid of anatomical texts (Schaller and Constantinescu, 2007) and reports on feline MRI (Hudson et al., 1995; Snow et al., 2004; Mogicato et al., 2012). In addition, osseous preparations were used to facilitate accurate anatomic interpretation.

RESULTS

Nine representative MR images of the Bengal tiger’s head were selected. A midsagittal MR image is presented in Fig. 1. Transverse MR images are shown in a rostral to caudal progression from the level of the olfactory bulb to the myelencephalon, and oriented so that the left side of the head is to the viewer’s right and dorsal is at the top (Figs. 2-8). A dorsal MR image at the level of olfactory bulb and peduncle is presented in Fig. 9.

Spin-echo T1 and T2-weighted MRI of the tiger’s head provided adequate details of clinically relevant anatomical structures, showing good discrimination between soft and mineralized tissues. Therefore, bony structures such as the frontal bone (with their orbital part and squama), parietal, temporal (including the squamous, petrous and tympanic parts), the presphenoid bone (corpus and wing), the basisphenoid bone (body and wing) and the occipital bone (with their basilar and lateral parts, and squama) could be identified. These bony components could be visualized due to the fat that in the bone marrow appeared with intermediate signal intensity, as well as by the area of negligible signal corresponding to the cortical bone margins (Figs. 1-9). In addition, the lumen of air-filled structures such as frontal and sphenoidal sinuses (Figs. 1-4), tympanic bulla (Figs. 7-8), nasopharynx and oropharynx (Figs. 1-8) appeared with low signal intensity in the images, and were well differentiated by MRI.

Several parts of the encephalon such as the olfactory bulb and peduncles (Figs. 1-3 and 9), corpus callosum, fornix, internal capsule, optic chiasm, thalamus, hypothalamus, hypophysis, cavernous sinus, mesencephalon (including the mesencephalic tectum and cerebral peduncles), pons, myelencephalon, cerebral hemispheres and cerebellum (with their vermis and hemispheres), as well as the encephalic ventricular system could be...


identified on MR images (Figs. 1 and 3-9). Cerebrospinal fluid from the subarachnoid space and the cerebral ventricles appeared with low signal intensity (dark gray) on the T1-weighted MR images. However, in T2-weighted images, this fluid appeared with high signal intensity (white).

Associated structures of the head such as the eyeball with the lens, as well as anterior and vitreous chambers were also identified. The aqueous and the vitreous humors appeared with low signal intensity in T1-weighted MR images and with high signal intensity in T2-weighted MR images. Lens appeared with low signal intensity in both MR images, whereas the capsule was better identified in T1 compared to T2 weighted MR images (Fig. 9).

**DISCUSSION**

Evaluation of anatomic structures of the Bengal tiger’s head is laborious because of an anatomical complexity that makes difficult to diagnose morphological changes by means of physical examination and conventional radiographic studies. Moreover, the use and comparison of cadaver sections with diagnostic images in endangered species is difficult due to the fact that these animals are under very strict regulations.

In large felines, contemporary image-based diagnostic techniques such as CT and MRI made possible to obtain images of body sections from different anatomic planes, with good anatomic resolution, high contrast between various structures, and excellent tissue differentiation (Snow et al., 2004; Zeira et al., 2012; Dziallas et al., 2012). Similar results were obtained in our work, where low-field MRI unit with head coil clearly delineated each anatomical portion of the tiger’s brain and associated structures of the head. In comparison with other conventional image-based techniques, MRI allows discriminating between soft tissues and fluids of the feline head particularly well (Hudson et al., 1995; Snow et al., 2004; Mogicato et al., 2012). On the other hand, its use in endangered species is justified by the amount of diagnostic information obtained with little risk to the animals evaluated (Snow et al., 2004; Zeira et al., 2012).

In our study, low-field MRI of the tiger’s head showed good spatial and contrast resolution of the different brain regions such as the cerebrum, cerebellum, and brain stem, mainly in T2-weighted MR.
images. Similar results were observed in the central nervous system of small felines (Yamada et al., 1995) and dogs (Snellman et al., 1999), using low-field strength. However, due to the nature of the low-field MRI and the size of the tiger head, some of the anatomical structures of the caudal part of encephalon were not clearly defined in T1 weighted images. Low-field (0.2-0.4T) MRI unit predominates in veterinary practice (Konar and Lang, 2011) due to their reduced costs compared to high-field MRI unit (Hayashi et al., 2004). Adequate quality examinations can be achieved using appropriate protocols and investing more scanning time than with high-field systems. The main disadvantage of low-field MR equipment is the reduced signal to noise ratio compared with high-field systems, where higher signal-to-noise ratio results in improved imaging (Konar and Lang, 2011; Gray-Edwards et al., 2014), but recent technological developments of low-field MR units will lead to higher image quality, shorter scan times, and refined imaging protocols (Hayashi et al., 2004; Konar and Lang, 2011).

In our study, spin-echo T1 and T2-weighted MRI of the Bengal tiger’s head provided good discrimination between the cranial bones, the encephalic tissues and associated structures of the head. Contrast between gray and white matter was higher in T2-weighted images, compared with T1-weighted images. Similar results were observed in other studies using spin-echo pulse sequences (Leigh et al., 2008; Mogicato et al., 2012). Most of the studies in domestic animals were imaged in sagittal, transverse and dorsal planes, showing relevant brain structures (Leigh et al., 2008; Conchou et al., 2012; Mogicato et al., 2012). In the present study, similar planes were used and allowed good differentiation of the anatomic structures on the median aspect (sagittal plane), the anatomic relationships of the cerebral structures (transverse plane), as well as adequate assessment of the encephalon (dorsal plane). The parameters (repetition time, echo time, number of acquisitions, section thickness, interslice spacing and acquisition matrix) utilized in this study could be used as a valid reference for exploratory evaluation of the Bengal tiger’s brain and associated structures.

The application of MRI in large feline medicine is currently limited because of its expense, availability, and the logistic problems of acquiring MR images. With developing technology, including new developments in open magnet design, MR imaging could become more readily available for tiger imaging. Future MRI studies of this kind of endangered species should be examined and discussed with a higher Tesla device.

In conclusion, MRI using spin-echo pulse sequence (T1 and T2-weighted images) provided adequate anatomical details of the tiger head and its associated structures that could be used as initial reference in future anatomical, functional and clinical studies of this region.

ACKNOWLEDGEMENTS

This work was supported by funds of the Department of Morphology of Las Palmas de Gran Canaria University (Spain).

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