Cat Brain Neuroanatomy using Cryosectioning, Magnetic Resonance and Computed Tomography Imaging Modalities

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ABSTRACT

Magnetic resonance imaging (MRI) and computed tomography (CT) imaging modalities are invaluable for the diagnosis and treatment of neurological diseases. This study aimed to correlate the anatomical sectional data of the cats’ brain to the sections obtained by both MRI and CT examination. The present work was conducted on four cats, 1-4 years old, weighing about (2.5 to 3.5) kg admitted to the hospital with terminal diseases not related to the nervous system. The anatomical sections were taken at intervals of 5 mm, on different planes such as sagittal, frontal and transverse. The sections were obtained, following humane euthanasia, from frozen heads and identified according to previous literatures. The images from both MRI and CT were compared with those of the gross anatomy sections and different structures were identified. To identify arterial distribution in the brain, one cat was injected with red latex through the common carotid artery, frozen, and sectioned. For vascular imaging, the same cat was examined by MRI after intravenous injection of contrast media. The descriptions of the brain anatomy from the MRI and CT images will act as a basis for the diagnosis and treatment of different neurological diseases in cat. This will assist veterinarians and radiologists in the identification of various nervous lesions related to the brain.

Key words: Cat, Brain, Magnetic resonance imaging, Computed tomography, Anatomy

INTRODUCTION

Cats are one of the most popular pets in the world. With the high increase in its number, there is a growing need for new techniques such as CT and MRI, for diagnosis of their diseases (Bishop et al., 2008 and Taeymans et al., 2008). Well-defined, high-quality sectioned images are necessary for accurate interpretation of MRI and CT scans of cats (Rivero et al., 2005; Lauridsen et al., 2011).

This study was performed on healthy cats’ heads to document the detailed anatomical structures of the brain. This knowledge was essential for the interpretation of images obtained by CT and MRI, which acted as a standard model for the recognition of abnormalities and identification of brain lesions in various neurological conditions (Gutierrez-Quintana et al., 2011 and Forterre et al., 2006).

The main aim of this study is to provide high-quality sectioned images and to correlate these with images obtained during MRI and CT scans to assist veterinarians with disease diagnosis in cats’ brain. The original anatomical planes of cats’ head were obtained, and the detailed structures of cats’ brain were identified. These are expected to be viewed as educational and training tools for clinical veterinary medicine and to enhance the value of practice in feline medicine (Park et al., 2009).

The MRI and CT scans, along with the sectioned images of the cats’ frozen head in normal color and with high resolution offer greater insights into our understanding of sectional anatomy (Spitzer & Whitlock, 1997; Dixon et al., 2015) Comparing these sections with the clinical images was helpful in multiple ways (Schiemann et al., 2000 and Nowinski et al., 2012).

MATERIALS AND METHODS

The present study was conducted on four adult Shirazi cats of 1-4 years old, weighing about 2.5 kg to 3.5 kg admitted to the hospital for euthanasia for diseases not related to the nervous system. Cats were humanely euthanized by intravenous pentobarbital overdose (100mg/ kg Anapent, Sigmatec, Egypt) following the American Veterinary Medical Association Guidelines for Euthanasia.

Prior to anesthesia, cats were put on standard feline formula (removed 12 hr. before anesthesia) and given free access to water (removed 2 hr. before anesthesia).

Prior to the MRI and CT scans, the cats underwent a physical examination and hematological study (complete blood count and serum chemistry) to ensure the animals were tolerating anesthesia. All cats were imaged under general anesthesia. Depending on the patient size, a 24- or 26-gauge catheter was placed within the cephalic vein. The anaesthetic protocol followed was dexmedetomidine (0.04mg/ kg, IM, Precedex®, Hospira, Lake Forest, USA) and ketamine (10mg/ kg, Ketamix, Rotexmedica, Tittau, Germany), and then maintained using isoflurane (Isoflurane-Sedico®, SEDICO, 6th October, Egypt) at 0.25-2% with 1L/min 100% oxygen to desired effect. Cats were placed in sternal recumbency for MRI scanning.

Computed Tomography (CT) of the head was performed using helical CT (TOSHIBA, Asteion 4, Japan) with the following technical parameters: 120 kV (peak), 150 mAs, with an image field of view (FOV) of 110 mm. Images were collected from picture archiving and communication system (PACS). RadiAnt Digital Imaging and Communications in Medicine (DICOM) Viewer (Version: 4.6.8.18460) was used for their study.

MRI of the head was performed using 0.3 T magnet (Siemens AG 2009, Syngo MR A35, ID: 008). All images were obtained with a brain circular coil in three planes: transverse (axial), sagittal, and dorsal with various sequences specifically for brain investigation (Table 1).

One cat was injected with red latex through the common carotid artery prior to freezing for angiography.

Cats were humanely euthanized by intravenous pentobarbital overdose (100mg/kg Anapental, Signatec, Egypt) following the American Veterinary Medical Association Guidelines for Euthanasia.

The cats’ heads were frozen at −20°C for 3 days. After removal of the skin and temporal muscles, a band saw was used to open the frontal and parietal bony fenestration and expose the brain, which was then dissected along with its major arterial blood supply. The anatomical sections were taken through three anatomical planes: sagittal, frontal, and transverse. The slices were taken at 0.5 cm thickness (Park et al., 2010).

The rostral surface of these sections rinsed with 10% ethyl alcohol and photographed. The images were compared with those obtained from the MRI and CT scans. The identification of the structures followed the literature, [Nomina Anatomica Veterinaria (I.C.V.G.A.N., 2017)]. The experimental protocol was approved by the ethical committee of the Faculty of Veterinary Medicine at Cairo University.

RESULTS

Based on the images produced in this study, we noted that the cat’s brain was divided into three parts: cerebrum, cerebellum, and brain stem. The cerebrum constituted the greater part of the brain and comprised of two cerebral hemispheres (Fig1). The cerebrum had an irregular surface with convoluted folds called gyri separated by grooves termed sulci. The right and the left cerebral hemispheres separated by the deep dorsal longitudinal cerebral fissure (central sulcus) (Fig. 1). The cerebrum was separated from the cerebellum by the transverse fissure (Fig. 1). The surface of the cerebrum was complex with a highly folded surface comprising folia separated by sulci. It was composed of the vermis, median part of the cerebellum, and two cerebellar hemispheres (Fig.1).

The brain stem consisted of thepons (Fig.1) situated on the ventral surface of the brain represented as transverse elevated body, posterior to the cerebral peduncles (Fig. 2,3) and the medulla oblongata (Fig.4), which was considered to be the origin of the spinal cord (Fig. 1, 4). Two small longitudinal bands, which bulged at the caudal margin of the pons were identified as the medullary pyramids of the medulla oblongata (Fig. 2), and a transverse band, the trapezoid body (corpus trapezoideum) (Fig. 4), was located just posterior to the pons.

The major cerebral structures identified in the cat’s brain were the marginal gyrus (mg) (Fig. 3,4), supra sylvian gyrus (sg) (Fig. 3,4), and ectosylvian gyri (Fig. 1). The major cerebral sulci were identified as deepdorsal longitudinal cerebral fissure or central sulcus, lateral sulcus, supra sylvian sulcus (Fig. 1, and cruciate sulcus (Fig. 1, 3, 4).

The cat’s cerebrum was clearly divided into four lobes: frontal (f), parietal (p), temporal (t), and occipital lobes (o) (Fig. 1,2).

This study included six transverse anatomical sections, four frontal sections and three sagittal slices of the cats’ brain. The identification of the main brain structures, as well as the comparison between the anatomical sections, MRI images, and CT images were all presented following a rostro-caudal direction of the brain.

Several landmarks were used to identify the brain parts in the MRI and CT images for comparison with images of the anatomical sections. These landmarks include the frontal bone (Fb) (Fig. 2,3), frontal sinus (fs) (Fig. 2), nasopharynx (np) (Fig.2), oropharynx (op) (Fig. 2), mandible (m) (Fig. 2, 3), parietal bone (pb) (Fig. 2, 3), auditory canal (ac) (Fig. 2,3), laryngeal cartilage (Lc) (Fig. 2), typanic bulla (tb) (Fig. 2), the ethmoid bone (eb) (Fig. 3), and the internal sagittal crest (Ic) (Fig. 3).

Anatomy of cats’ brain sections

Telencephalon: Images of the telencephalon clearly showed the cerebral hemisphere (Fig. 2/1) with frontal lobe (Fig. 1,2/1), olfactory bulb (Fig. 2,3,2), olfactory tract (Fig. 2/3), the piriform lobe (Fig. 2/4), caudate nucleus (Fig. 2, 3,4/5) putamen (pu) (Fig. 3), external capsule (ec) (Fig. 3), and the corpus callosum (Fig. 2, 3,4/6). The latter was identified as a white structure consisting of fibers that connect the two cerebral hemispheres. Its anterior, curved part was the genu (Fig. 3,4/6a), its posterior part was the splenium (Fig. 3,4/6b), and between them dorsally was the trunk (body) (Fig. 3,4/6c) of the corpus callosum. The fornix (Fig. 2,4/7) curves anteroventrally from near the splenium. Some gyri were detected in the sagittal section including cingulate gyrus (cing), cruciate gyrus, and frontal gyrus (fg) (Fig. 4). Others could easily be traced in the frontal section: coronal gyrus (cg), composite gyrus (cog) and cruciate gyrus (Fig. 3).
Table 1: Parameters of MRI pulse sequences used for imaging of feline head

<table>
<thead>
<tr>
<th>Sequence</th>
<th>TR (ms)</th>
<th>TE (ms)</th>
<th>FA</th>
<th>NEX</th>
<th>Echo Length</th>
<th>Slice thickness (mm)/Inter-slice spacing</th>
<th>Field of view</th>
<th>Matrix</th>
<th>Acquisition Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 SE</td>
<td>728</td>
<td>25</td>
<td>90</td>
<td>2</td>
<td>1</td>
<td>3 X 3.6</td>
<td>150*150</td>
<td>358*512</td>
<td>5:25</td>
</tr>
<tr>
<td>T2 TSE</td>
<td>3780</td>
<td>86</td>
<td>180</td>
<td>2</td>
<td>7</td>
<td>3 X 3.6</td>
<td>150*150</td>
<td>436*512</td>
<td>7:03</td>
</tr>
<tr>
<td>T1 FLAIR</td>
<td>6780</td>
<td>74</td>
<td>180</td>
<td>1</td>
<td>7</td>
<td>5 X 5.61</td>
<td>250*250</td>
<td>192*115</td>
<td>2:48</td>
</tr>
</tbody>
</table>


Diencephalon: In images of the diencephalon, the parietal lobe (Fig. 1,2/p), the optic chiasma (Fig. 4/8), optic nerve (Fig. 2/9), thalamus (Fig. 2,4/10), hypothalamus (Fig. 2,4/11), lateral ventricles (Fig. 3,4/12), third ventricle (Fig. 2,4/13), and the paired mammillary bodies (Fig. 4/14) were readily identified.

Mesencephalon: Images showed the cerebral peduncle (Fig. 2,3/15), corpora quadrigemina (Fig. 2,3,4/16), temporal lobe (Fig. 1,2/t), hippocampus (Fig. 2,4/17), occipital lobe (Fig. 1,2/o) and the cerebral aqueduct (Fig. 2/18).

Metencephalon: the cerebellum which consisted of the vermis (Fig. 2,3,4/19) and the two cerebellar hemispheres (Fig.2, 3.4/20), the fourth ventricle (Fig. 2,4/21) and the pons (Fig. 2,3,4/22) could readily be seen in images of the metencephalon.

Myelencephalon: These images showed the medulla oblongata (Fig. 4/23) connected to the spinal cord, the medullary pyramids (Fig. 2/24), and the trapezoid body (corpus trapezoideum) (Fig. 4/25).

Arterial blood supply

In this study, the arterial blood supply to the cat’s brain, based on the anatomical sections, was observed to consisted of three cerebral arteries: rostral, middle, and caudal. Blood supply to the brain was mainly from the circulus arteriosus cerebri known as the circle of Willis (CW) (Fig. 5), which was located ventral to the hypothalamus. The formation of the circle of Willis included both the basilar artery posteriorly and the two internal carotid arteries laterally.
Fig. 3: photograph showing frontal sections of cat brain with CT and MRI: A, Anatomical sections; B, MRI; 2, olfactory bulb; 5, caudate nucleus; 6, the corpus callosum; 6a, the genu; 6b, the splenium; 6c, the trunk (body of corpus callosum); 12, lateral ventricles; 15, the cerebral peduncle; 16, corpora quadrigemina; 19, the vermis of cerebellum; 20, the cerebellar hemispheres; 22, lateral ventricles; 25, the trapezoid body (corpus trapezoideum); Fb, frontal bone; fc, falx cerebri; mg, marginal gyrus; pb, parietal bone; pu, putamen; sg, suprasylvian gyrus; sp, spinal cord.

The internal carotid artery (IC) (Fig. 5) was identified as a terminal branch of the common carotid that ran toward the base of the skull. The rostral cerebral artery (RCA) (Fig. 5) originated from the rostral border of the circle and passed medial to the medial olfactory tract. It supplied the falx cerebri (fc) (Fig. 3) and frontal dura with one major branch: the frontal artery (FA) (Fig. 5). Meanwhile, the anterolateral surface of the piriform lobe and the lateral surface of the cerebral hemispheres were supplied by the middle cerebral artery (MCA) (Fig. 5) and its dorsal branches: the central, parietal, and temporal arteries (Fig 5). The MCA anastomosed with several branches of the RCA and the caudal cerebral artery (CCA) (Fig. 5).

**DISCUSSION**

Structural information regarding the anatomy of cats’ brain retrieved from the anatomical sections was compared with the images obtained from both MRI and CT scans.

Fig. 4: photograph showing sagittal sections of cat brain with CT and MRI: A, Anatomical sections; B, MRI; 2, olfactory bulb; 5, caudate nucleus; 6, the corpus callosum; 6a, the genu; 6b, the splenium; 6c, the trunk (body of corpus callosum); 10, thalamus; 11, hypothalamus; 12, lateral ventricles; 13, third ventricle; 14, the paired mammillary bodies; 16, corpora quadrigemina; 17, hippocampus; 19, the vermis of cerebellum; 21, the fourth ventricle; 22, pons; 23, the medulla oblongata; 25, the trapezoid body (corpus trapezoideum); Cing, cingulate gyrus; crg, cruciate gyrus; crs, cruciate sulcus; f, frontal lobe; fg, frontal gyrus; mg, marginal gyrus; pb, parietal bone; pu, putamen; sg, suprasylvian gyrus; sp, spinal cord.

Fig. 5: photograph showing the arterial blood supply of cat brain: BA, basilar artery; CA, central artery; CCA, the caudal cerebral artery; CCLA, caudal cerebellar artery; CW, (the circle of Willis); FA, frontal artery; IC, the internal carotid artery; MCA, the middle cerebral artery; PA, parietal artery; RCA, the rostral cerebral artery; RCLA, rostral cerebellar artery; A, temporal artery.

Several studies (Nepomuceno et al., 2016; Gutierrez-Quintana et al., 2011; Forterre et al., 2006) recommended the use of the CT imaging as a rapid and easy diagnostic method for brain injuries in cats; however, we found that the level of detail achieved in gross sectional anatomy and MRI images could not be matched in the CT image where the brain appeared as a homogenous gray mass with little differentiation in density. Our findings were supported by those of previous studies on the quality of CT images (Nepomuceno et al., 2016).
Unlike dogs, the cerebellum could be easily seen from the dorsal surface as supported by previous studies (Smith et al., 2001). The medulla oblongata appeared somewhat rounded in cross-section for cats, in accordance with (Welker et al., 2009). In contrary, the medulla was dorsoventrally flattened in dog (Whalen, 2003) and brown bear (Sienkiewicz et al., 2019).

The arterial blood supply to the cats’ brain was identified in this study as comprising three cerebral arteries; rostral, middle and caudal. These observations matched those of previous MRI studies (Gray-Edwards et al., 2014).

The rostral cerebral artery and the middle cerebral artery anastomosed then the middle cerebral artery communicated with the caudal cerebral artery. This provided a powerful collateral circulation in case of blood vessel blockage as described in previous study (Vander Eecken, 1953).

These finding could be used as a guide for diagnosis of lesions in cats’ brain using both MRI and CT images as had been suggested by previous studies (Nepomuceno et.al., 2016 and Troxel et al., 2003).

The cat model offered many insights into the anatomy of cats’ brains and the potential usefulness and limitations of MRI and CT scans in the diagnosis and treatment of neurological diseases as that mentioned in (Gutierrez-Quintana et al., 2011). Detailed anatomical structures obtained using technologies, such as CT and MRI, might lead to improved diagnosis of various forms of epilepsy (Woermann and Vollmar, 2009) multiple sclerosis (Wattjes et al., 2006) and other neurological disorders.

Conclusion

The obtained results could be used as a guide for veterinarians concerned with the cat neurological diseases. The cats’ brain structure was most clearly elucidated through anatomical sections and MRI imaging, whereas CT images lacked the differentiation and definition achieved by the other two techniques. The results of this paper indicated that MRI provided a reliable method for the diagnosis of alterations in cats’ brains, particularly when accompanied by physical and neurological examinations.

Author contributions

All authors had been equally participated in the work.

REFERENCES


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