Computed tomographic imaging of the brain of normal neonatal foals

Tomografía computarizada del cerebro en potrillos neonatos

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RESUMEN

El objetivo de este estudio fue proporcionar una descripción detallada de la anatomía normal del cerebro de potrillos neonatos y de las estructuras asociadas mediante tomografía computarizada (TC) y cortes anatómicos. Se utilizó un escáner de cuarta generación y se adquirieron imágenes transversales con un grosor de dos milímetros. Tras el estudio por TC, los animales fueron sacrificados por razones no relacionadas con patologías de la cabeza. Para ayudar en la identificación precisa del cerebro y las estructuras asociadas, las imágenes de TC fueron comparadas con las correspondientes secciones de la cabeza. Las imágenes de TC se correlacionaron de buena manera con sus correspondientes secciones anatómicas, mostrando una buena diferenciación entre el tejido óseo y el tejido blando de la cabeza. Las imágenes obtenidas mediante TC pretenden ser una referencia anatómica inicial para la interpretación de los estudios clínicos del cerebro y las estructuras asociadas en potros vivos recién nacidos.

Palabras clave: tomografía computarizada, anatomía, cerebro, potro neonato.

SUMMARY

The aim of this study was to provide a more complete description of normal cross-sectional anatomy of the neonatal brain of the foal and associated structures by computed tomography (CT) and gross anatomical sections. Using a fourth-generation CT scanner, 2-mm contiguous transverse images were acquired from two neonatal 5-days-old Quarter horse foals. After the study the animals were euthanised for reasons unrelated to head pathology. To assist in the accurate identification of brain and associated structures, transverse CT images were obtained and compared with the corresponding frozen cross-sections of the head. CT images matched well with their corresponding transverse gross sections and provided good differentiation between the bones and the soft tissues of the head. These CT images are intended to be a useful initial anatomic reference in the interpretation for clinical CT imaging studies of the brain and associated structures in live neonatal foals.

Key words: computed tomography, anatomy, brain, neonatal foal.

INTRODUCTION

In the last years, the use of modern images techniques such as computed tomography (CT) or magnetic resonance imaging (MRI) has greatly improved the way of making a diagnosis in veterinary medicine. CT is a non-invasive imaging modality that provides excellent spatial resolution and good discrimination between bone and soft tissue (Barbee et al 1987, Peterson and Bowman 1988). These characteristics are very useful to obtain anatomial information about different regions of the animal body. Most of the published reports deal with the normal description of cranioencephalic structures in small and large animals (Fike et al 1981, Kaufman et al 1981, Feeney et al 1991, George and Smallwood 1992, Solano and Brawer 2004). In equine medicine, the contribution of CT or MRI to anatomical and clinical knowledge is very limited due to the high cost and the lack of suitable design of this equipment when treating older foals and adult horses. The CT scanners used in veterinary medicine are designed to use in human patients; therefore, this type of machines are only suitable for neonatal foals due to size constraints of the CT gantry and scanning table. Due to all these limitations, reports of CT in the horse have been focused on technical procedures (Barbee et al 1987), studies of the head (Vink-Nooteboom et al 1998, Morrow et al 2000, De Zani et al 2010), distal extremities (Peterson and Bowman 1988) and cervical spine (Zafra et al 2012). However, most of these studies were performed on cadaver specimens, but to the author’s knowledge similar CT studies in live neonatal foals have not been reported.

The aim of this study was to provide a more detailed description of the normal cross-sectional anatomy of the equine neonatal brain and associated structures using CT images and transverse gross anatomic sections. These CT images are intended to be a useful and complementary anatomic reference for clinical studies of the head of neonatal foals such as fractures, malformations, hydrocephalus and other neurological disorders.
MATERIAL AND METHODS

CT images were obtained from two neonatal 5-days-old Quarter horse foals. Before the evaluation of the head by CT, the animals were pre-anesthetised with xylazine at 0.5 mg/kg, IV (Rompun®, Bayer HealthCare AG, Germany). The anesthesia was induced with a bolus of propofol at 2.0–2.5 mg/kg IV (Diprivan®, AstraZeneca, UK) administered through a jugular catheter. An infusion of propofol (0.2–0.4 mg/kg IV) was initiated after intubation. The infusion rate was regulated to maintain immobilization without over anaesthetising the foal. The foals were intubated with auffed endotracheal tube to maintain an airway. Anaesthetised foals were placed in sternal recumbence on the scanning table. Foals were monitored by counting respiratory and pulse rates. A serie of 2-mm thick transverse CT images from the occipital condyles to the olfactory bulb was obtained with a fourth generation CT equipment (General Electric Medical System, Milwaukee, WI). The parameters used for CT imaging were 120 kVp, 560 mAs. A soft tissue window setting (WW = 190; WL = 35) was applied. After CT study, the foals were euthanised for reasons unrelated to head diseases. This protocol was done following the recommendations approved by the Ethical Committee of the Veterinary Faculty of Las Palmas de Gran Canaria University (Protocol 52/2009). To better evaluate CT images, the heads were frozen and sectioned (10 mm thick), using an electric saw with the slabs cut transversely to correspond with the CT images. All sections were cleaned, photographed and replaced in the freezer. Each gross section was compared to the corresponding CT images obtained from the head of normal adult horses (Morrow et al 1991, Solano and Brawer 2004, Probst et al 2002). Therefore, the use of live neonatal foals instead of cadaver specimens or isolated heads was an important aspect to consider. Several reports of CT imaging of the head used live animals (Hathcock et al 1995, Solano and Brawer 2004, Probst et al 2005), but they were not focused in the study of the brain anatomy. Other reports used isolated heads for the study of the equine adult head (Morrow et al 2000), the foal head (Smallwood et al 2002), and the paranasal sinuses of adult horses (De Zani et al 2010). In these studies there were soft tissue findings associated with post-mortem changes such as the brain retraction or enlargement of cerebral ventricles due to the effect of air-filled cavity. In contrast, in the present study, the normal appearance of the different structures of the central nervous system such as the hippocampus, the pineal gland or specific ear anatomic structures were better visualised. In addition, the use of contrast enhanced CT images provided more anatomic detailed information regarding to different encephalic structures such as the choroid plexus of the lateral ventricles or the falc cerebri that were not well identified by other CT studies (Arencibia et al 2000, Morrow et al 2000, Smallwood et al 2002).

RESULTS

Six CT images with their corresponding transverse cryosections were presented from caudal to rostral progression, from the level of the myelencephalon (figure 1) to the level of the olfactory bulbs (figure 6). The CT images were displayed to the viewer’s left, whereas the gross anatomic sections were displayed to the viewer’s right. No internal head lesions were seen on CT images. Clinically relevant anatomic structures of the brain and associated structures were evaluated and labelled according to location and the characteristics of degree of attenuation of the different tissues. No anatomic or degree of attenuation variations were detected in the head of the two neonatal foals used in the study because of the similar size of the animals. The transverse CT images provided excellent depictions of anatomical structures of the brain. Detailed anatomy of the central nervous system and associated formations was acquired. Thus, bones of the head were easily identifiable by their high degree of attenuation compared to adjacent or surrounding structures, such as the paranasal sinuses, guttural pouch and encephalic ventricular system. Several structures of the central nervous system such as myelencephalon (figure 2), cerebellar vermis and hemispheres (figures 2–3), cerebral hemispheres (figures 3–7), hippocampus (figure 4), roof of mid-brain (figure 4), thalamus, hypothalamus and hyphophysis (figure 5), optic nerves (figure 6), olfactory bulb (figure 7), as well as the muscles of the head and glands showed intermediate degree of attenuation. Cerebrospinal fluid appeared black on the CT images and could be visualized in the ventricular system and the subarachnoid spaces. In addition to these structures, there are the eyeball and retrobulbar area, as well as different component of the ear were clearly seen.

DISCUSSION

In the present study, the CT images of the brain and associated structures of normal neonatal foals provided excellent detail of clinically relevant anatomy and correlated well with corresponding gross specimens. Some reports that described the normal anatomy of the equine head showed similar results (Arencibia et al 2000, Smallwood et al 2002, De Zani et al 2010). However, in most of these studies the normal anatomy of the brain was scarcely described.

Most of the anatomic atlases for tomographic imaging modalities are made by direct comparison between images obtained in vivo and the corresponding anatomic slices obtained ex vivo. Therefore, the use of live neonatal foals instead of cadaver specimens or isolated heads was an important aspect to consider. Several reports of CT imaging of the head used live animals (Hathcock et al 1995, Solano and Brawer 2004, Probst et al 2005), but they were not focused in the study of the brain anatomy. Other reports used isolated heads for the study of the equine adult head (Morrow et al 2000), the foal head (Smallwood et al 2002), and the paranasal sinuses of adult horses (De Zani et al 2010). In these studies there were soft tissue findings associated with post-mortem changes such as the brain retraction or enlargement of cerebral ventricles due to the effect of air-filled cavity. In contrast, in the present study, the normal appearance of the different structures of the central nervous system such as the hippocampus, the pineal gland or specific ear anatomic structures were better visualised. In addition, the use of contrast enhanced CT images provided more anatomic detailed information regarding to different encephalic structures such as the choroid plexus of the lateral ventricles or the falc cerebri that were not well identified by other CT studies (Arencibia et al 2000, Morrow et al 2000, Smallwood et al 2002).

Despite the higher usage in the last years of CT imaging in veterinary medicine, there are limiting factors such
Figure 1. Representative image of equine brain. Each line and number (I-VI) represents the approximate level of the following transverse CT images (Figures 2-7).

Imagen representativa de un encéfalo equino. Cada línea y número (I-VI) representa el nivel aproximado de las TC transversales (Figuras 2-7).


as the cost, limited availability and the physical size of some large animals such as older foals and adult horses that influence its usage in equine medicine. However, for neonatal foals, CT may be a clinically useful and effective imaging modality to study selected cases such as skull fractures, malformations, hydrocephalus, neonatal encephalopathy and hypoxic ischemic encephalopathy (MacKay 2005, Dickey et al. 2011). In the future would be
interesting to perform further studies with multidetector CT equipment on live animals and with the administration of contrast medium to establish a protocol for CT angiography.

In conclusion, the anatomical sections were useful tools for a correct morphological and topographic evaluation of the CT images of neonatal foals’ brain and associated structures. Findings from this study indicated that CT images resulted in a useful imaging modality for its anatomic evaluation and to aid in the diagnosis by CT of brain disorders of normal neonatal foals.


REFERENCES
