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Ultrasonographic examination of the normal caprine neonatal brain

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Abstract

Ultrasonography is a safe, rapid, and non-invasive diagnostic tool that has been previously used for imaging infants and canine neonatal brains. The purpose of the present study was to describe the ultrasonographic appearance of the brain in clinically normal caprine neonates. Ultrasonographic examination was done on 12 day-old goat kids, transverse and sagittal transcranial scans were obtained through the frontal bone. Three image planes were recorded through transverse scans including plane I (level of the caudate nucleus), plane II (level of the rostral diencephalon) and plane III (level of the caudal diencephalon). Parallel post mortem examinations were done for two kids that died a day following examination due to accidental trauma by the dam. Reliable and repeatable ultrasonographic images of the goat kid's brain were described based on the gross post mortem findings. The head of the caudate nucleus was taken as an anatomical landmark in the plane I where it appeared as a curved hyperechoic structure. In plane II, the longitudinal fissure with its characteristic umbrella-like structure was taken as a landmark, while in plane III, the laterally located hyperechoic hippocampus was taken as a landmark. Normal ultrasonographic examination of the caprine neonatal brain represented the basis for diagnosing congenital brain lesions as well as intracranial hemorrhage.

Introduction

The goat is a fast gaining species representing an essential source of meat and milk production, especially in developing countries due to its efficient feed usage and disease tolerance.[1] Several brain lesions have been documented in goats including encephalitic listeriosis,[2] cerebral coenurosis,[3] meningocele, meningoencephalocele[4] and brain lesions produced by Border disease virus.[5] Most of these brain lesions were mostly identified through post-mortem, histopathologic and immunohistopathologic examinations.[2,6] These lesions usually result in severe tissue damage, reduction in production as well as breeding losses and considerable economic losses.[7]

Ultrasonography is a safe rapid and non-invasive diagnostic tool that has been used to diagnose brain lesions in infants and canine neonates.[8-13] The experimental and clinical applications of brain ultrasonography have been documented in diagnosing brain lesions.[11,14] Regardless of the advances in magnetic resonance imaging and computed tomography in imaging the brain, ultrasound is still an effective, convenient and economical diagnostic tool in imaging the neonatal brain.[10-13] Moreover, ultrasonography does not require general anesthesia as is the case in magnetic resonance imaging or computed tomography.[10,12-16]

To the authors' knowledge, no available literatures have been published describing the ultrasonographic appearance of the caprine neonatal brain. The aim of the present study was to describe the ultrasonographic characteristics of the caprine neonatal brain to provide a basis for diagnosing congenital brain lesions in goats.

Materials and Methods

The present study was performed on 12 day-old Egyptian Baladi goat neonates obtained from six dams. The dams were clinically healthy and were kept at the Department of Surgery, Anesthesiology and Radiology-Faculty of Veterinary Medicine, Cairo University for educational and research purposes. All study procedures were done in accordance with the Cairo University

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Institutional Animal Care and Use Committee approval number (CU/II/F/57/18). Before including in the study, all neonates underwent complete physical and neurological examination to exclude the evidence of systemic and/or neurologic disease. All neonates were free from neurological manifestations, circling, head shacking, ataxia, tremors, and visual or postural deficits, based on neurological examination.[17]

Ultrasonographic examination was performed using an 8.00 MHz linear transducer attached to an ultrasound machine (Just Vision 200; Toshiba, Osaka, Japan). The transducer was applied over the frontal bone after shaving the hair and application of the coupling gel. Visualization of the neonatal brain was done through four image planes (three transverse and one sagittal plane).[9,18] The transverse planes were performed by placing the transducer perpendicular to the neonatal head over the frontal bone and three image planes were collected through the movement of the transducer rostrally to caudally (Fig. 1). These image planes included: Plane I: level of the head of caudate nucleus; Plane II: level of rostral diencephalon and Plane III: level of the caudal diencephalon.

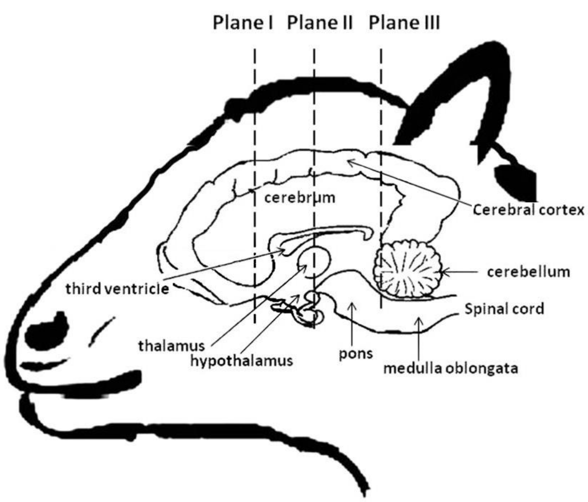

Fig. 1. Schematic illustration of the transcranial transverse ultrasound scan obtained through the frontal bone. Three image planes were recorded including plane I (level of the caudate nucleus), plane II (level of the rostral diencephalon) and plane III (level of the caudal diencephalon).

The sagittal plane was performed by placing the transducer on the midline parallel to the long axis of the neonatal head.[3] The focal zone of the transducer, degree of resolution and the time gain compensation were fixed for all image planes. All examinations were done by the same examiner. Post mortem examinations were performed on two of the neonates that died one day following examination due to accidental trauma by the dam. The brain was dissected and the anatomical planes were compared to the obtained ultrasonographic images.

Results

The use of an 8.00 MHz linear transducer allowed the achieving of descriptive and repeatable fair quality images of the caprine neonatal brain as well as visualization of the superficial and deep brain structures including the mesencephalon and diencephalon.

Transverse scan. In transverse scans, the hyperechoic longitudinal fissure which represents the falx cerebri and pia mater were taken as a landmark for the determination of midline of the brain. This longitudinal fissure was observed bisecting the brain into two identical halves.

Plane I (level of the head of the caudate nucleus). The head of the caudate nucleus was taken as an anatomical landmark for this image plane where it was identified as a curved hyperechoic structure on each side. The caudate nucleus was more echogenic than the longitudinal fissure, represented by falx cerebri and pia mater. The characteristic umbrella-like structure formed by the hyperechoic longitudinal fissure and splenial sulci was identified on the upper part (near field) of the image plane. A centrally located ovoid anechoic fornix was clearly identified. This anechoic fornix was bounded dorsally by the hyperechoic corpus callosum and ventrally by the hyperechoic corpus of the fornix (Fig. 2).

Plane II (level of the rostral diencephalon). This image plane was obtained by downward tilting of the neonatal head (15.00 to 30.00°) and caudal direction of the transducer. In this image plane, the characteristic umbrella-like structure was clearly identified while the caudate nucleus was less curved and less echogenic than plane I. The hypoechoic cingulated gyrus was identified ventral to the hyperechoic splenial sulci. The centrally located fornix appeared as a small anechoic structure. The boundaries of the fornix were less echogenic when compared to the same boundaries at plane I. The lateral ventricles could be identified as small anechoic structures on both sides of the image plane. The choroid plexus was observed as a hyperechoic curved structure on both sides of the cranium separating the hypoechoic diencephalon dorsally from the hypoechoic pyriform lobes ventrally (Fig. 2).

Plane III (level of the caudal diencephalon). This image plane was achieved by downward tilting of the head (30.00 to 45.00°) with the caudal direction of the transducer. In this image plane, the characteristic umbrella-like structure and fornix were lost. The caudate nucleus was appeared thin and less echogenic than a plane I and II. The characteristic landmark of this image plane was the laterally located hyperechoic hippocampus on both sides. Ventral to the thin hyperechoic corpus callosum, bilobed hypoechoic thalamus was identified on both sides of the image plane. A small round anechoic opening ventral to the thalamus representing the third ventricle was identified between the hypoechoic pons (Fig. 2).

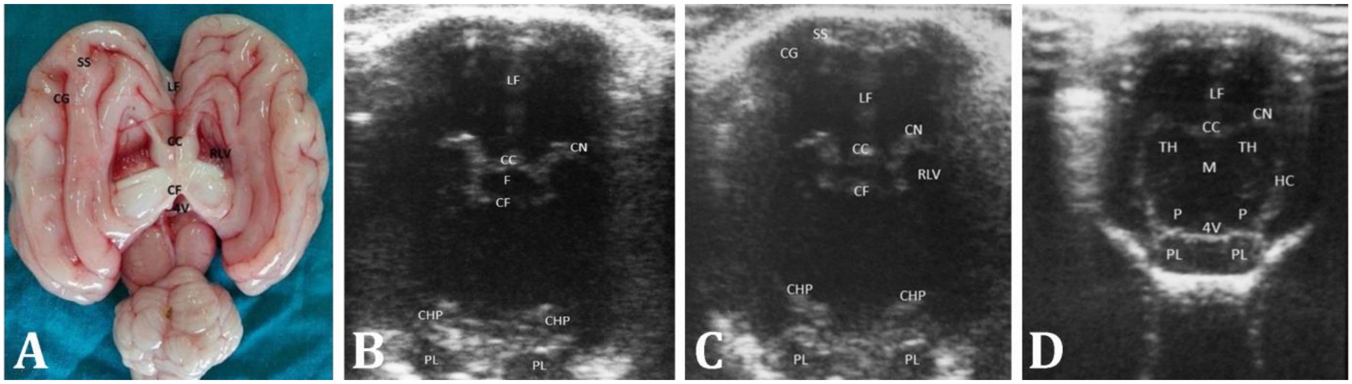

Fig. 2. A) Post mortem photograph of brain, **B)** Transcranial transverse ultrasound scan at the level of the head of the caudate nucleus (Plane I), **C)** Transcranial transverse ultrasound scan at the level of the rostral diencephalon (Plane II), and **D)** Transcranial transverse ultrasound scan at the level of the caudal diencephalon (Plane III) of a day old neonatal goat. 4V: Fourth ventricle, CC: Corpus callosum, CF: Corpus of the fornix, CG: Cingulated gyrus, CHP: Choroid plexus, CN: Caudate nucleus, F: Fornix, HC: Hippocampus, LF: Longitudinal fissure, M: Mesencephalon, P: Pons, PL: Pyriform lobe, RLV: Right lateral ventricle, SS: Splenial sulcus, TH: Thalamus.

Sagittal scan. In this scan, the brain was seen as a multilayered structure, each layer was differentiated from each other by their varied echogenicity. These structures were represented by the frontal lobe including the hyperechoic splenial sulcus and hypoechoic cingulate gyrus in the near field of this scan. An anechoic slit-like structure representing the third ventricle was bounded dorsally by the hyperechoic corpus callosum and ventrally by the hyperechoic corpus of the fornix. Ventrally, the thalamus, mesencephalon and the cerebellum were identified as hypoechoic structures with hyperechoic borders. A clearly identified anechoic cerebral aqueduct was visualized rostral to the cerebellum (Fig. 3).

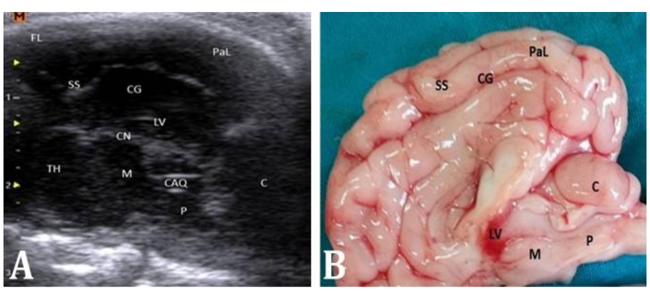

Fig. 3. A) Transcranial sagittal ultrasound scan and **B)** Post mortem photograph of a day old neonatal goat. C: Cerebellum, CAQ: Cerebral aqueduct, CG: Cingulated gyrus, CN: Caudate nucleus, FL: Frontal lobe, LV: Left ventricle, M: Mesencephalon, P: Pons, PaL: Parietal lobe, SS: Splenial sulcus, TH: Thalamus.

Discussion

The use of an 8.00 MHz linear transducer provided a reliable and repeatable image for the superficial and deep brain structures of caprine neonates. The identification of these structures was confirmed by the parallel necropsy examination.

The obtained ultrasonographic images were of fair quality as the transducer was applied over the frontal bone which is a poor acoustic window. In canine neonatal transcranial ultrasonography, the bregmatic fontanelle remains open until early life which could be taken as a good acoustic window for visualization of brain structures.[9] It has been reported that the bregmatic fontanelle remains open until 30 days of life in dogs.[18] While in caprine neonates, the anterior fontanelle is closed intrauterine around the 84 days of gestation, and the frontal suture is usually closed on 112 days of gestation.[19]

Fair quality images could be obtained as the ossification of the frontal bone that was not that hard enough to act as an intense reflective interface.

Three image planes were obtained in a transverse scan according to the head position and the direction of transducer. The appearance and echogenicity of brain structures were varied within these image planes. These structures included the longitudinal fissure, splenial sulci, cingulate gyri, caudate nucleus, fornix, corpus callosum, a corpus of the fornix, lateral ventricles, thalamus, choroid plexus, hippocampus, and pyriform lobes. The identification of these structures was based on the anatomic structures of the goat brain,[20] as well as the matching with a brain in the post mortem study.

The hyperechoic umbrella-like structure which formed by the longitudinal fissure and splenial sulci were taken as a landmark for the identification of brain midline. This landmark is particularly useful for comparing the identical halves of the brain and subsequently being useful when a natural or created defect in the skull is located asymmetrically.[9] The echogenic appearance of caudate nucleus could be attributed to its fibrous composition as well as the acoustic enhancement produced by the lateral ventricles located on the medial aspects of the caudate nucleus. These findings were also previously recorded in dogs.[9,18] The cerebrospinal fluid (CSF) within the ventricle is responsible for the anechoic appearance of ventricles and fornix. The increase in the amount of CSF enhances the visualization of brain ventricles and facilitates the diagnosis of cases of hydrocephalus and hydranencephaly.[9]

The choroid plexus located on the floor of the central portion of the lateral ventricles and roof of the temporal horn was observed as a hyperechoic structure in all image planes owing to its complex nature as well as the acoustic enhancement caused by the lateral ventricles and vessels. Similar findings and explanations were mentioned in dogs.[9,21] Although most of the brain is uniformly hypo-echoic, the pyriform lobes could be differentiated from surrounding structures due to the presence of hyperechoic meninges and choroid plexus dorsal to each lobe.[18]

Unlike the previous findings on in canine neonates,[9] which reports the hippocampus as a hypoechoic structure located close to the midline; it appeared as hyperechoic structure located on each side of the image plane (level of the caudal diencephalon) in neonatal goats. The variation in the position of the hippocampus could be attributed to the anatomical variation between dogs and goats.

In a sagittal scan, the multilayered appearance of brain structures could be attributed to the different echogenicity of the structures as well as the acoustic enhancement produced by ventricles. These structures were recognized based on the descriptive anatomy of goat brain[20] and matching with the dissected brain. The identified structures included the frontal and parietal lobes dorsally, splenial sulci, cingulate gyri, corpus callosum, ventricles, thalamus, mesencephalon, cerebral aqueduct, and cerebellum.

In conclusion, ultrasonography could be used for imaging neonatal brain in goats by transcranial technique through the frontal bone during the first day of the goat's neonatal life. Identification of the normal ultrasonography of the caprine neonatal brain is beneficial for diagnosing congenital brain lesions and/ or intracranial hemorrhage. The main limitation of the present study was the use of a small number of goats. Further studies on the use of ultrasonography for diagnosing pathological conditions in the goat's brain are recommended.

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Conflict of interest

The authors have no competing interests to declare. This research did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

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