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Original Research

Computed Tomographic Features of the Osseous External Ear Canal, Tympanic Membrane, and Tympanic Bulla in Clinically Normal Horses

Annemarie Blanke [a], Stefanie Ohlerth [b], Josef Hollerrieder [c], Gerald Fritz Schusser [a,*]

[a] Department of Large Animal Medicine, Faculty of Veterinary Medicine, University of Leipzig, Leipzig, Germany
[b] Clinic of Diagnostic Imaging, Vetsuisse Faculty, University of Zurich, Zurich, Switzerland
[c] Tieraerztliche Klinik Domaene Karthaus, Duelmen, Germany

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ABSTRACT

Only sparse anatomic and morphometric information exists concerning the equine acoustic organ. The aim of the present study was, therefore, to describe the computed tomographic (CT) anatomy and determine the CT dimensions of the osseous external ear canal (OEEC), tympanic membrane (TM), and tympanic bulla (TB) in clinically normal horses. Computed tomography of the head was performed in 23 horses, presented for reasons unrelated to the auditory organ, with a 4-slice (group 1) or a 40-slice (group 2) CT scanner, respectively. The following measurements of the OEEC were performed: volume, dorsal, ventral and central length, halfway of central length, and inner diameter at four different locations. Length of the TM, width of the hypotympanon and the largest width and height of the external acoustic porus (EAP), and the TB were also recorded. The OEEC in all ears was of an oval, truncated cone shape running in a dorsolateral to medioventral direction. The TM coursed at a flat angle from dorsolateral to medioventral and had a wave-like appearance on transverse CT images. Significantly lower width and height of the EAP, inner diameter of the OECC at its narrowest point, and OEEC volume were found in group 1. A significant positive correlation between OEEC volume and head length or body weight, respectively, was found in group 2. Results of the present study may serve as reference values and aid the diagnosis of aural abnormalities and disease conditions. Moreover, they provide a basis for the adjustment of audiometric testing devices to horses.

1. Introduction

Computed tomography (CT) has been proven an excellent technology for the investigation of the normal anatomy and geometry of the auditory organ [1–3], as well as middle and inner ear diseases in humans and small animals [4–7]. Computed tomography reference values for external and middle ear structures were reported in detail for a sample of normal llamas [8] and, so far, only in one dissected normal equine head [9]. However, knowledge about the CT anatomy and dimensions of the equine auditory organ could prove useful for the diagnosis of aural malformations and diseases. It may also provide a basis for the adjustment of human audiometric testing devices (measurement of otoacoustic emissions, tympanometry) for horses. In particular, the size and shape of the external ear canal (EEC) influence transmission of sound waves and, finally, determine sound pressure at the tympanic membrane (TM) [10]. Geometrical dimensions of the EEC (length, radii, shape, and volume) vary significantly among species and, therefore, influence audiometric

* Corresponding author at: Gerald Fritz Schusser, Department of Large Animal Medicine, Faculty of Veterinary Medicine, University of Leipzig, An den Tierkliniken 11, Leipzig 04103, Germany.
E-mail address: schusser@vetmed.uni-leipzig.de (G.F. Schusser).

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measurements. Otoacoustic emission in cats, for example, can be measured twice as fast as in human ears due to the smaller volume of the feline EEC [11].

Equine ear diseases have been reported infrequently in the past. Diseases mainly related to the external ear, such as polyps, othematoma, chondrosis, plaques, parasites (ticks, mites, and culicoides), aural foreign bodies, and various stages of otitis externa have been described previously [9,12–17]. Examination of the equine ear is also part of the workup of headshaking, temporohyoid osteoarthropathy, vestibular disease, facial nerve paralysis, and head trauma [9,16–19]. However, otoscopic examination is challenging in the horse due to difficulties in visualizing the EEC and the TM. Patient compliance is often poor. A recent report described the usefulness of veterinary video endoscopes for the otoscopic examination in sedated standing horses [17].

The aim of the present study was to describe the anatomy and determine the dimensions of the osseous EEC (OEEC), TM, and tympanic bulla (TB) in clinically normal horses with CT.

2. Materials and Methods

2.1. Animals

Computed tomography scans of 23 equine patients (46 ears) were included in the study between March 2013 and April 2014. Horses underwent CT because of diseases unrelated to the auditory organ (e.g., dental disease, sinusitis, ethmoid hematoma, idiopathic headshaking, retrobulbar mass, brain tumor, laryngeal disease). Animals were included only if (1) body weight was between 400 and 700 kg, (2) signs of aural diseases were absent during clinical examination, and (3) the CT scan of the ears was considered normal. The study sample comprised 19 warmblooded horses of various breeds, one Quarter Horse, and three Arabian horses; 13 were male and 10 were female.

2.2. CT Examination

A 4-slice (SOMATOM Plus four Power, Siemens AG, Munich, Germany) and a 40-slice CT scanner (SOMATOM Sensation Open, Siemens Schweiz AG, Zurich, Switzerland) were used in 10 (group 1) and 13 (group 2) horses, respectively. All horses were under general anesthesia and positioned in dorsal recumbency to obtain transverse contiguous slices. Settings for group 1 were: 120 KV, 200 mAs, 0.75 seconds tube rotation, pitch of 1, and increment of 1 mm and 2 mm slice collimation. Settings for group 2 were: 140 KV, 300 mAs, 1 second tube rotation, pitch of 0.55, and increment of 1.2 mm and 3 mm slice collimation. The CT data were reconstructed to images with 2-mm (group 1) and 0.6-mm (group 2) slice thickness using a medium frequency image reconstruction algorithm (soft tissue) and a high-frequency image reconstruction algorithm (bone), respectively. A board-certified radiologist (S.O.) and the first author (A.B.) reviewed all CT images with dedicated software using multiplanar and 3D reconstruction modes (OsiriX v.4.1.2. Foundation, Geneva, Switzerland). A bone window was applied for the assessment of the OEEC and TB (window width, 3,000 Hounsfield units; window level, 400 Hounsfield units). Window settings were minimally adapted for the evaluation of the TM.

2.3. Measurements on CT Images

Measurements of the skull were performed to address individual differences. Because the brain was not included in the scan field in group 1, only the head length was measured in group 2 and defined as the distance from the rostral border of the palatine process to the external occipital protuberance on sagittal CT images at the level of the nasal septum. On a transverse CT image at the level of the OEEC, the head height was obtained in both groups by measuring the distance from the dorsal internal cortex of the skull, at the level of the sagittal crest, to the internal cortex of the base of the basisphenoid.

Measurements of the right and left ear were obtained in every horse. The length of the OEEC was assessed on a transverse CT image in which it was visible at its maximal length and width (Fig. 1). Its ventral length and dorsal length (Ld) were measured along the ventral and dorsal wall from the external acoustic porus (EAP) to the ventral or dorsal aspect of the TM, respectively. Additionally, the central length was determined along a central line from the midpoint of the TM to the midpoint of the EAP. On the same transverse image, the length of the TM was also measured along its course. Furthermore, the inner diameter of the OEEC was determined at four different locations: at the EAP from its dorsal to ventral aspect (DEAP), halfway of the central length (DCL1/2), at the narrowest point of the OEEC (DNP), and at the tympanic annulus (TA) from its dorsal to ventral aspect. The diameters DCL1/2 and DNP were measured at a 90° angle to the dorsal wall. Finally, the width of the hypotympanon, as well as the largest width and height of the TB (HB), were obtained on the same

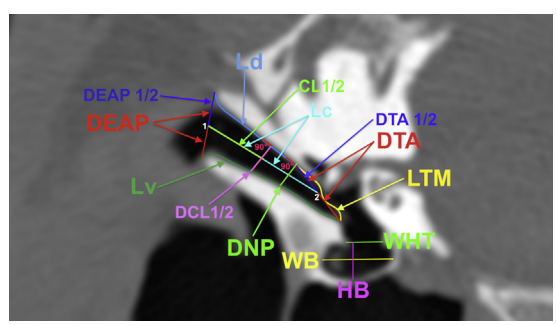

Fig. 1. Evaluated CT features of the osseous external ear canal (OEEC) and tympanic bulla (TB; transverse CT image of the left ear in a 15-year-old Hanoverian warmblood mare [0.6-mm slice thickness; WW: 3,000 HU; WL: 400 HU]). CL1/2, half of central length; DCL1/2, diameter halfway of central length; DEAP, diameter of the external acoustic porus (EAP); DEAP1/2, half diameter of the EAP; DNP, diameter at the narrowest point of the osseous ear canal; DTA, diameter of tympanic annulus (TA); DTA1/2, half diameter of TA; HB, height of TB; HU, Hounsfield units; Ld, dorsal length of the OEEC; LTM, length of the tympanic membrane (TM); Lv, ventral length of the OEEC; Lc, central length; WB, width of TB; WHT, width of hypotympanon; WL, window level; WW, window width; 1, midpoint of the EAP (MPEAP); 2, midpoint of the TM (MPTM).