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RESEARCH

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A comprehensive examination of camel (*Camelus Dromedaries*) otic prominence through morphological and CT imaging studies

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Abstract

Background This study explored the morphological anatomy of otic prominences in camels using advanced computed tomography (CT). Nine adult cadaver camel heads underwent CT scanning to generate detailed images of the otic prominences, mastoid process, styloid process, stylomastoid foramen, external acoustic meatus, bulla tympanica, and muscular processes. The morphological anatomy of otic prominences was studied in nine skulls.

Results The anatomical features were analyzed, revealing a compact and closely collected configuration of otic prominences. Unique characteristics of the mastoid process, bulla tympanica, and styloid process were observed, challenging the conventional descriptions.

Conclusions This study underscores the value of CT scans in enhancing anatomical studies and provides insights into comparative veterinary anatomy, facilitating the evaluation of various conditions and disorders in camels.

Keywords Camel, Computed tomography, Morphology, Otic, Radiology

Background

Meticulous exploration of anatomical structures is crucial for understanding normalcy and for diagnosing pathological conditions (Emam et al., 2020). While various imaging techniques have been employed in previous studies, the use of advanced imaging, specifically computed tomography (CT), in the examination of camel otic prominences anatomy has been limited (Anwar El-Shafey & Kassab, 2012). The camel ear, a pivotal yet insufficiently studied anatomical region, poses challenges for conventional dissection methods because of its intricate and compact configuration (Emam et al., 2020).

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In veterinary medicine, the application of advanced imaging techniques has significantly improved the comprehensive understanding of normal anatomy and diagnosis of various disorders in animals. Computed tomography (CT) stands out among these techniques because of its ability to provide high-resolution, cross-sectional, and three-dimensional images with superior contrast. Despite the numerous CT studies conducted on dromedary camels in recent years exploring various anatomical aspects, such as the eyes, brain, temporomandibular joint, limbs, and craniofacial structures (Abedellaah et al., 2017; Alsafy et al., 2014; Arencibia et al., 2012; Badawy et al., 2016; Blanco et al., 2015; A. El-Shafey & Kassab, 2013; Elnahas et al., 2015), comprehensive data describing the normal features of mature camel otic structures are lacking.

This study aimed to fill this gap by presenting a detailed analysis of the normal anatomical structures of the dromedary camel ear utilizing reconstructed 3D CT images. This study provides valuable insights into the normality of camel ears, facilitating the evaluation of congenital

diseases, fractures, tumors, and other conditions. By leveraging the significant impact of CT in veterinary medicine, researchers have endeavored to address the existing gaps in the literature by elucidating the intricate details of the temporal bone of camels (Alsafy et al., 2014). The goal is to provide insights that will enhance our understanding of comparative veterinary anatomy and foster clinical applications in the diagnosis and treatment of camel ears.

Methods

Computed tomography (CT) imaging

Nine adult cadaver camel heads devoid of pathologies were promptly obtained postmortem for computed tomography (CT) scanning using a 16-slice CT scanner (Supria, Hitachi, Ltd.). The heads were carefully positioned on the table to ensure that the rostral side faced the gantry. Axial CT images were acquired with the following parameters: 120 kV, 100–350 mAs, and 5 mm slice thickness. Initial records of the orbit and ocular contents were captured in the axial plane and subsequently reconstructed into multiplanar and three-dimensional (3D) images (Radiant DICOM viewer Software, Medixant, Poland). Examination of the pulmonary tympanica included assessments of both the bone window (window width, WW = 323; window level, WL = 287) and the soft tissue window (WW = 300, WL = 40).

Morphological anatomy

In this study, a morphological anatomical investigation was conducted. Comprehensive examination of camel temporal bone structure was done. Nine camel skull specimens were meticulously inspected to observe and document intricate details of the otic prominences, including the mastoid process, styloid process, stylomastoid foramen, external acoustic meatus, bulla tympanica, and muscular processes. The combination of dissection and advanced imaging techniques facilitated thorough morphological analysis in this anatomical study.

Results

In the current study, several observations were made. The otic prominences, encompassing the petrous and tympanic parts, exhibited a distinctive compact configuration, forming a singular unit not previously documented in the literature (Fig. 1). This unique characterization establishes their association with the temporal bone, including the mastoid and styloid processes, as well as the stylomastoid foramen within the petrous region. The otic prominences occupied the space between the retro-articular process and foramen rostrally, extending caudally to the jugular process, with the temporal crest dorsally and attachment to the stylohyoid process ventrally (Fig. 2). Regarding

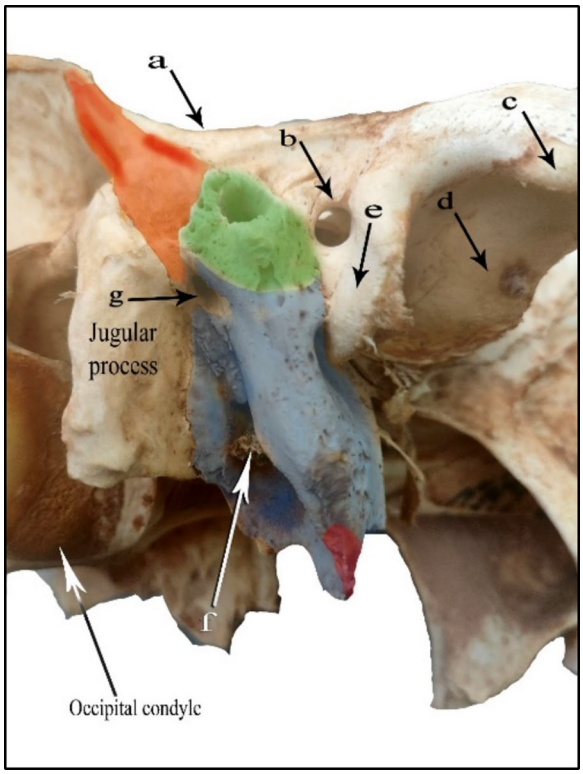

Fig. 1 Photograph showing the right otic prominence (lateral view). **a** Temporal crest, **b** retro-articular foramen, **c** articular tubercle, **d** mandibular fossa, **e** retro-articular process, **f** temporal styloid process, **g** stylomastoid foramen. The green area indicates the external acoustic meatus, orange area indicates the mastoid process, blue area indicates the bulla tympanica, and red area indicates the muscular process

the tympanic region, our examination revealed a concise bony tube with a hollow cylindrical cavity in the external acoustic meatus, differing from the elongated structure reported in other animal species. The bulla tympanica, the largest segment among the petrous and tympanic parts, presented as a compressed, irregular bony dilatation bridging the retro-articular and jugular processes (Figs. 3 and 4). Notably, the mastoid process exhibited a tuberculous base with a unique structure, including a triangular apex fused to the tubercular part, a feature not reported in the literature. The present study emphasizes the significance of CT scans in revolutionizing the exploration of camel temporal bone anatomy, providing high-resolution, three-dimensional images with practical implications for veterinary medicine (Figs. 3 and 4).

Discussion

The distinctive characterization of the otic prominences in dromedary camel, which has not been documented in extant literature, delineates their association with

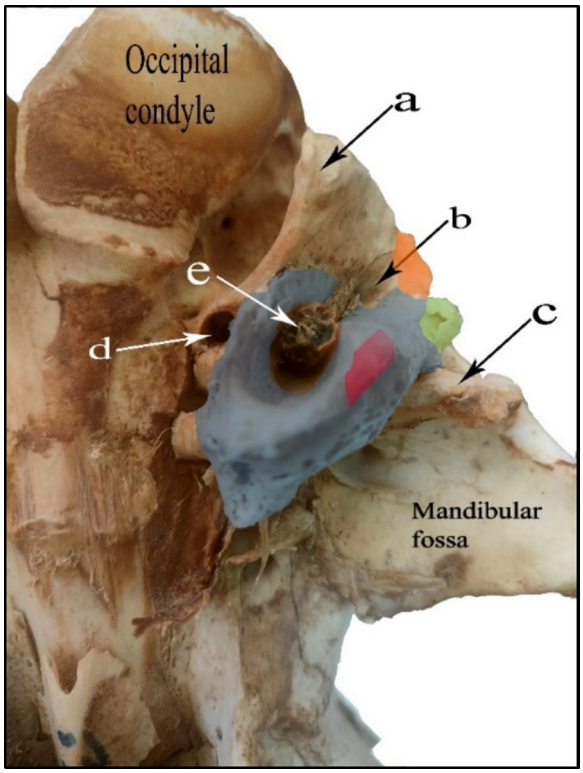

Fig. 2 Photograph showing the right otic prominence (ventral view). **a** Jugular process, **b** stylomastoid foramen, **c** retro-articular process, **d** oval foramen, and **e** temporal styloid process. The green area indicates the external acoustic meatus, the orange area indicates the mastoid process, the blue area indicates the bulla tympanica, and the red area indicates the muscular process

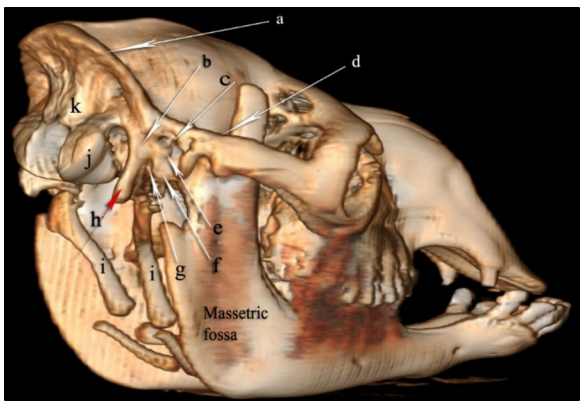

Fig. 3 3D remodeling computed tomography (CT) image of the camel skull (right and lateral views). **a** Nuchal crest, **b** mastoid process, **c** retro-articular foramen, **d** temporal crest, **e** external acoustic meatus, **f** bulla tympanica, **g** stylomastoid foramen, **h** jugular process, **i** stylohyoid process, **j** occipital condyle, **k** nuchal tubercle

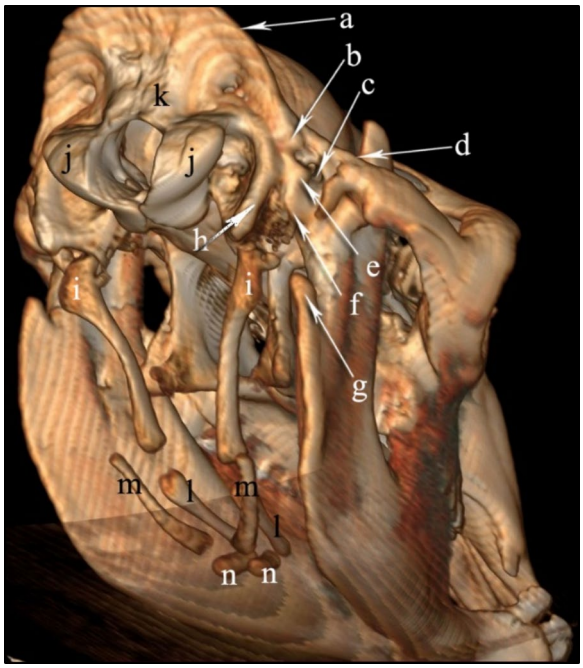

Fig. 4 3D remodeling computed tomography (CT) image of the camel skull [right, ventrolateral view]. **a** Nuchal crest, **b** mastoid process, **c** retro-articular foramen, **d** temporal crest, **e** external acoustic meatus, **f** bulla tympanica, **g** angular process, **h** jugular process, **i** stylohyoid process, **j** occipital condyle, **k** nuchal tubercle, **l** ceratohyoid process, **m** thyrohyoid process, **n** basihyoid bone

the temporal bone, comprising the mastoid and styloid processes as well as the stylomastoid foramen within the petrous region. The tympanic part includes the external acoustic meatus, bulla tympanica, and muscular processes.

Supporting our findings, Sisson and Grossman Sisson et al. (1975) and Allouch et al. (2023) reported similar features for camels. The current study reveals that otic prominences in dromedary camels extend between the retro-articular and rostral foramen, with dorsal borders defined by the temporal crest and ventral attachment to the stylohyoid process. These findings align with observations made in camels by Smuts and Bezuidenhout (1987) and (Allouch et al., 2023), as well as in other species, such as ox (Raghavan, 1964; Sisson et al., 1975), domestic animals (Dyce et al., 2010), and chital deer (Kumawat et al., 2014).

Regarding the tympanic region, our examination revealed a concise bony tube with a hollow cylindrical cavity in the external acoustic meatus. This is in contrast to the elongated external acoustic meatus, which reaches approximately 4 cm in length, as reported for goats (Goodarzi & Shah Hoseini, 2014), sheep (Jashari et al., 2022), ox (Dyce et al., 2010), and camels (Allouch et al., 2023; Parodi, 2011; Smuts & Bezuidenhout, 1987). Our findings, in agreement with those of buffaloes (Raghavan, 1964) and cattle (Budras et al., 2011), indicate an extruded bony elevation from the bulla tympanica.

In relation to the petrous part of the temporal bone, Dyce et al. theorized its separation from the squamous part in equines (Dyce et al., 2010), a perspective that does not universally contribute to the literature. This divergence highlights the need for further comprehensive investigations to elucidate nuanced anatomical variations within and across species.

Examination of the bulla tympanica within the camel's temporal bone revealed that it was the largest segment among the petrous and tympanic parts. The bulla tympanica presented as a compressed, irregular bony dilatation bridging the gap between the retro-articular process rostrally and jugular process caudally. It articulates with the latter and obfuscates the foramen lacerum medially. In contrast to established literature, Allouch et al. (2023) noted a rounded bulla tympanica with a rough surface in contrast to the non-prominent nature reported in cattle (Budras et al., 2011). Barone and Simoes observed an enlarged protrusion of the temporal bone, emphasizing the species variability (Parodi, 2011).

Our current findings revealed that the base of the bulla tympanica is connected to the external acoustic meatus, stylomastoid foramen, mastoid process, and foramen lacerum. Its apex forms a short bony eminence, the muscular process of the temporal bone, and a short triangular prominence extending from the ventral boundary of the bulla tympanica. Similar observations have been reported in camels (Allouch et al., 2023), whereas in equines and ruminants, a longer muscular process has been described (Dyce et al., 2010; Parodi, 2011).

Conversely, the petrous part of the temporal bone of the camel, encompassing the mastoid and styloid processes and the stylomastoid foramen, was consistent with observations in cattle (Budras et al., 2011; Dyce et al., 2010; Sisson et al., 1975) and camels (Allouch et al., 2023).

Notably, the mastoid process in our study exhibited a tuberculous base that was directed rostrally and articulated toward the jugular process, bulla tympanica, and external acoustic meatus. This unique structure, which consists of a triangular apex fused to the tubercular part, has not been reported in the literature. Dissimilar descriptions included the fusion of the mastoid process to the jugular process and serration in camels (Allouch et al., 2023; El Allali et al., 2017), lateral compression in cattle (Budras et al., 2011), and roughened areas in small ruminants (Nickel et al., 1979). Choudhary and Singh recorded the absence of a mastoid process in black bucks (Kalita, 2019).

Concerning the styloid process, our examination revealed a cylindrical bony tube measuring approximately 1.4–1.6 cm in length enclosed between the rostral and caudal extensions of the bulla tympanica. These findings are consistent with previous reports on camels (Smuts & Bezuidenhout, 1987), cattle (Budras et al., 2011; Dyce et al., 2010), and horses (Dyce et al., 2010; Parodi, 2011).

Moreover, CT scans have revolutionized the exploration of the temporal bone in camels, providing high-resolution, three-dimensional images that reveal unique features and configurations not previously documented (Blanco et al., 2014). This detailed imaging has practical implications for veterinary medicine, contributing to a more accurate understanding of normal anatomical structures in the camel ear, which is crucial for diagnosing various conditions such as congenital diseases, fractures, and tumors (Ah et al., 2019; Blanco et al., 2014). The combination of dissection and CT imaging enhances the reliability and comprehensiveness of morphological analyses, providing valuable tools for anatomical studies in veterinary medicine (Ah et al., 2019). Additionally, CT scans have been utilized in the analysis of temporal bone fractures and cochlear implant visualization, demonstrating the diverse applications of CT imaging in the field of veterinary medicine (Simons et al., 2005; Szczupak et al., 2020).

CT imaging has also been instrumental in analyzing anatomical variations in the nose and paranasal sinuses, highlighting its significance in capturing fine bone architecture and soft tissue structures (Makhdoomi et al., 2021). Furthermore, the use of CT scans for temporal bone analysis has been emphasized in the literature, indicating its crucial role in providing detailed and accurate imaging for diagnostic and surgical purposes (Polanski et al., 2018).

The findings of this study assume significant surgical relevance, particularly concerning interventions in the temporal region of dromedary camels. The utilization of computed tomographic scanning enhances surgical precision. Moreover, the unique anatomical features of camels, including the relatively shorter external acoustic meatus compared to equines (Sommerauer et al., 2012) cattle, and buffalo (Al-Sadi et al., 2012), may predispose middle ear infections. The direct communication between the pharynx and middle ear in camels increases the risk of ascending infections. Furthermore, the larger bulla tympanica in camels increase susceptibility to fractures. Other surgical conditions as bulla exostosis, osteomyelitis, tumors, and infections further underscore the clinical relevance of this anatomical investigation in informing surgical strategies.

Conclusions

The present study revealed unique anatomical features of the camel's temporal bone, emphasizing the compact configuration of otic prominences and distinctive bulla

tympanica morphology. The mastoid process, which involves a tuberculous base and triangular apex, contrasts with conventional descriptions, contributing to a deeper understanding of the comparative veterinary anatomy. Computed tomography (CT) scans proved invaluable in uncovering these nuances, highlighting the crucial role of advanced imaging techniques in enhancing anatomical studies and advancing veterinary surgery.

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Author contributions
M.W.E. conceived the research, performed the radiological experiments, collected, and analyzed the data, and finalized the manuscript. M.A.N. contributed to the morphological anatomical study, data analysis, and drafted the manuscript.

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Availability of data and materials
Data are available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate
The research was approved and conducted in accordance with the Animal Ethical Committee's guidelines at the Faculty of Veterinary Medicine, New Valley University, El-Kharga, New Valley, Egypt (approval number: VM/NVU/27(1)-04). All methods are reported in accordance with ARRIVE guidelines.

Consent for publication
All authors have thoroughly reviewed and granted approval for the final manuscript's publication. It is essential to note that there is no identifiable data concerning the participant animals or their owners within our study. Therefore, the matter of publication consent is not applicable in this context, adhering to ethical standards in veterinary research.

Competing interests
The authors declare no competing interests.

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