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Computed tomography and dissection anatomy of the frontal and maxillary sinuses in native Egyptian goats

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Heads of 10 native Egyptian goats were used for studying the anatomical features of the frontal and maxillary sinuses, both grossly and by using computed tomographic (CT) imaging. The anatomical features of each sinus, its extent, its divisions, communication between its compartments, its connection with the nasal cavity, and their relation to the adjacent structures and other para-nasal sinuses were studied grossly and by CT. An increase in the thickness and radiopacity of the bones on caudal aspect were observed, that might be for protection to the brain and eyes. The study brings to light the importance of CT scan in viewing the detailed features of the frontal and maxillary para-nasal sinuses, accounting that, unlike gross anatomy, CT is done for live individuals and pre-surgically.

Key words: Anatomy, CT, Frontal, Goat, Maxillary sinus.

Although computed tomography (CT) as a diagnostic imaging technique was developed as early as 1979, it was rarely used in the veterinary field (Dennis, 2003). It is a reliable non-invasive technique, which is useful, particularly for imaging anatomically complex structures like the head (Bergman *et al.,* 2000; Smallwood *et al.,* 2002; Frazho *et al.,* 2008). Moreover, it was found to be more accurate than conventional radiography in determination of location, extension and characterization of head lesions (Gerros *et al.*, 1998; Henninger *et al.,* 2003; Levine *et al.,*2006). In the veterinary literature, CT had been used in goats, horses, dogs, cats and sheep for description of the normal anatomy and diagnosis of pathological conditions of the head (Allen *et al.,* 1987; Ducote *et al.,* 1999; Gonzalo-Orden *et al.,* 1999). At the same time, CT images and measurements were used as a reference for evaluating head diseases in goats (Makara, 2010). Such animal model studies were considered suitable for helping residents to learn sinus surgery (Osman *et al.,* 2012) and dentistry in human (Nevins *et al.,* 1996). Clinically, morphological information about para-nasal sinuses is very important, and it can be used for studying the pathology of the sinus, determination of the treatment, planning surgery (Tingelhoff *et al.,* 2007), reducing endoscopic sinus surgery complications, and correcting the variations that might cause chronic sinusitis (Çaðýcý *et al.,* 2006). Para-nasal sinuses were described as cavities within the skull lined by respiratory mucosa. They are close to brain, eyes and major arteries; therefore endo-nasal sinus operation requires a high degree of accuracy (Burschka *et al.,* 2005; Frandson *et al.,* 2010).

The present study sheds spotlight on the role of CT on exploring the anatomical features of the frontal and maxillary sinuses as they cannot be easily observed grossly, and offers additional information that might be required during surgical interference in such sinuses.

Materials and Methods

Subjects of the study were 10 adult native Egyptian goats of both sexes, aged 9-18 months and weighed 26-30 kg. Moreover they were proved to be healthy by clinical examination prior to euthanasia by chloroform and disconnecting the heads between C2 and C3.

Out of the studied samples, two heads were freshly used for the CT scanning by using technical setting 120 kV and 250 mA, and the transverse CT images were acquired perpendicular to the hard palate. Following scanning, these two heads were frozen, and later on, they were serially cut into cross sections (2 cm thick). These slices were gently cleaned from debris with water and light brushing, numbered and then photographed immediately with the caudal surface of each slice facing the camera.

Other two heads were used as fresh samples to study the para-nasal sinuses by making sagittal sections. The remaining six heads were injected with warm saline, and then fixed by injection of

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10% formalin via the external carotid artery. Two of them were carefully macerated and formations of sagittal sections were made in order to study the relation between sinuses (Onar *et al.*, 1997). The remaining four heads were used to study the anatomy and communications among para-nasal sinuses.

The neck of the premolar and molar teeth were used as landmarks to explore and describe the location and extension of the structures and cavities (Probst *et al.,* 2005; Alsafy *et al.,* 2012).

Results and Discussion

Grossly, the frontal sinus (Figs. 1-7) was located rostro-dorsal to the brain, extended into the cornual process in the horned animals, and subdivided into interconnected chambers of various sizes by bony septa, which had greater thickness in caudal ones (May, 1970; Dyce *et al.,* 2010), while in longitudinal CT images the bony septa appeared as linear radiopaque structures within a radiolucent air-filled sinus cavity, and caudal ones appeared more opaque (May, 1970; Schummer *et al.,* 1979).

Grossly each frontal sinus consisted of lateral and medial groups of compartments, mainly three for each, and the compartments of the medial group communicated with the dorsal nasal sinus. On the other hand, the lateral group sub-divided by oblique transverse septa into rostral, middle and caudal compartments. The middle compartment was the post-orbital diverticulum, while the caudal compartment extended into the cornual process and sub-divided by septa into three tubular parts and it extended about 5 cm into the horn. This anatomical order (Schummer *et al.,* 1979; Frandson *et al.*, 2010) cleared that the best site for trephining the frontal sinus existed at a point about one centimeter dorso-lateral to the point of connection between the midline and a horizontal line passing midway between the medial canthus and the supra-orbital foramen.

According to Frandson *et al.* (2010) trimming of the horn in young small ruminants could expose the interior of the frontal sinus and predisposes to its infection. It was suggested that trimming of the horn is best done at about 6-7 cm from the horn base to avoid affection of the sinus.

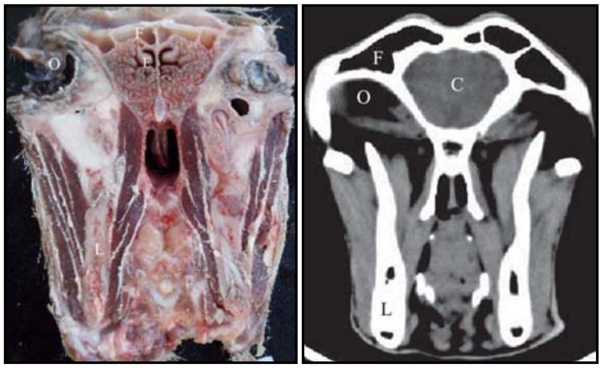
On transverse CT images, the frontal sinus was identified as an irregular radiolucent cavity containing several transverse radiopaque linear structures at some scanning levels while on the longitudinal CT images, it appeared more regular and had some opaque bony septa extended, between the floor and roof of the sinus, along the radiolucent cavity. The connection between the lateral rostral compartment of the frontal sinus and the maxillary one was identified as a radiolucent opening, at the level of second molar teeth, disconnecting the radiopaque bony partition between the two sinuses.

The axial CT images showed that the frontal sinus located rostro-lateral to the brain and divided by many radiopaque partitions to radiolucent compartments. The horn core connected with the frontal sinus above the roof of the cranium and the boney internal layer of the corneal process appeared more radiopaque than the rest of the bones.

Generally, there was an increase in the radiopacity of bones caudally, and this thickening and opacity of the caudal bony septa and the increased hardness of the skull at this area might be a sort of protection to the brain and eyes during fighting.

Regarding the gross anatomy of the maxillary sinus (Figs. 5&8), their cavity appeared irregular and triangular in shape with the apex directed cranially up to the infra-orbital foramen. On transverse and longitudinal CT images, the maxillary sinus appeared as radiolucent cavity containing soft tissue densities in some levels, in addition to the presence of some radiopaque linear structures like those of the frontal sinus. The dorsal limit of the sinus cavity represented by a line extending from the infra-orbital foramen to the medial canthus of eye, while the ventral limit was one centimeter above the alveolar border of maxilla, and extended from the orbit to the infra-orbital foramen. Both gross dissection and CT imaging proved that the level of the rostral extension of the maxillary sinus was the infra-orbital foramen at the level of the caudal border of the second premolar tooth (Estaca *et al.,* 2008; Makara, 2010), and this disagree with older records, which stated that the rostral extension of the maxillary sinus in small ruminants located at the level of first premolar tooth (Sisson, 1975).

The infra-orbital canal, on gross examination was found to divide the sinus into a small ventro-medial part and a large dorso-lateral one; however, ventro-medial part in small ruminants (May, 1970; Schummer *et al.*, 1979; Dyce *et al.*, 2010) and in buffaloes (Alsafy *et al.,* 2012) was named the palatine sinus. Moreover, the maxillary sinus communicated with the caudo-dorsal part of the middle nasal meatus through naso-maxillary opening (Hare, 1975) at the level of second molar teeth (Makara, 2010), about 1 cm rostral to the



Figs. (1) Cross section of the head showing F: Frontal sinus, E: Ethmoidal conchae, O: Orbit, and L: Mandible; (2) Cross CT of the head showing F: Frontal sinus, O: Orbit, L: Mandible, C: Cranium.

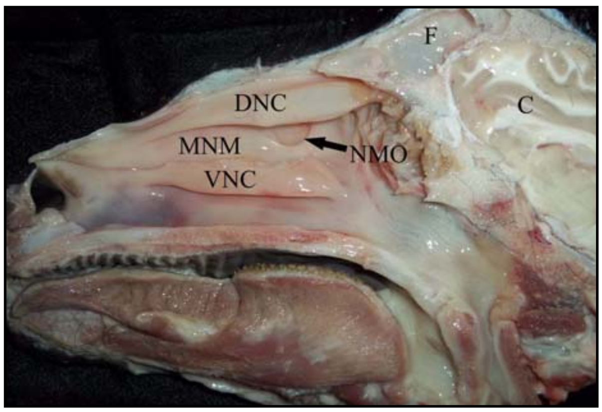


Fig. 3: Longitudinal section of the head showing C: Cranium, F: Frontal sinus, DNC: Dorsal nasal concha, VNC: Ventral nasal concha, MNM: Middle nasal meatus, and NMO: Naso-maxillary opening.

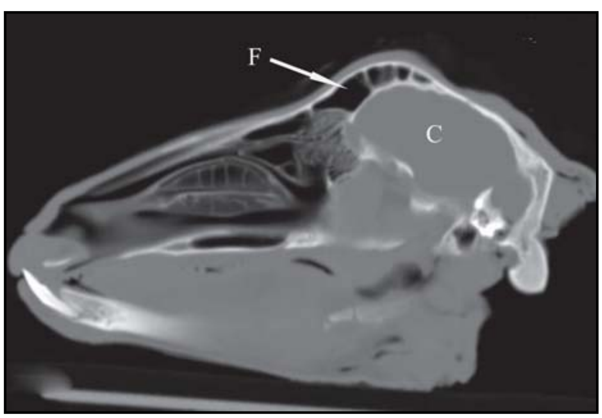


Fig. 4: Longitudinal CT showing C: Cranium and F: Frontal sinus.

medial canthus and 7 cm caudal to the nostril. It had dimensions of 0.5x1.0 cm, appeared as semi-lunar opening and directed rostro-dorsally.

The connection between the maxillary and palatine sinuses was proved grossly and tomographically at a level rostro-ventral to the

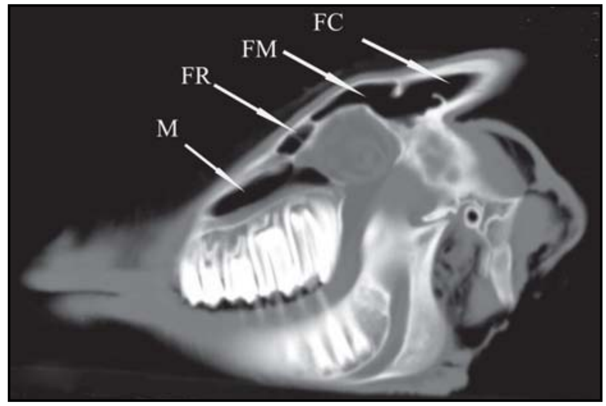


Fig. 5: Longitudinal CT showing M: Maxillary sinus, FR: rostral compartment of frontal sinus, FM: Middle compartment of frontal sinus and FC: Cornual extension of frontal sinus.

Fig. 6: Axial section of the head showing M: Medial group of compartments of frontal sinus and F: Lateral group of frontal sinus.

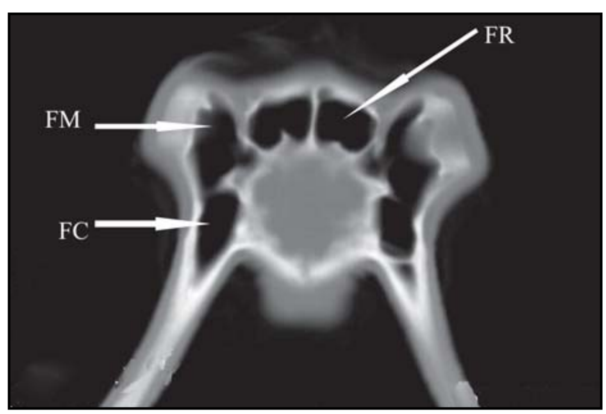


Fig. 7: Axial CT of the head showing FR: Rostral frontal sinus, FM: Middle frontal sinus, and FC: Cornual extension of frontal sinus.

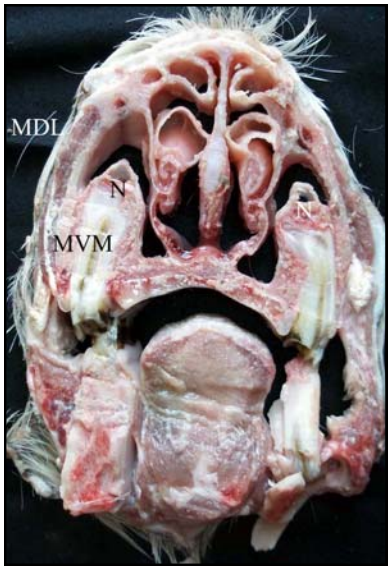


Fig. 8: Cross section of the head showing MDL: Dorso-lateral room of maxillary sinus, MVM: Ventro-medial room of maxillary sinus, and N: Nasolacrimal duct.

naso-maxillary opening. Findings of our study run on the same lines of other colleagues (Allen *et al.*, 1987; Frandson *et al.*, 2010; Makara, 2010). Accordingly, it was suggested that the best site of trephining exists about 0.5 cm dorsal to the facial tubercle and should not exceed one centimeter depth to avoid any injury to the nasolacrimal duct.

The integration between the conventional dissection anatomy and CT imaging in understanding the anatomical details of frontal and maxillary sinuses was found beneficial. Proper understanding of the position and extent of the paranasal sinuses, their communication with each other, associated structures and nasal cavity was found important in the interpretation of upper respiratory passage diseases, adjacent structures and the pathological lesions that may occur in such structures (Morrow *et al.*, 2000; Probst *et al.*, 2005; Reetz *et al.*, 2006).

Although CT scanning has allowed visualization of anatomical structures with improved detail (Brenner and Hall, 2007), proper understanding of anatomy, biology and behaviour of animals was highly recommended, in terms of producing models that could be applied on human beings (Palumbo *et al.*, 2004). In conclusion, the study illustrated the golden role of the modern tools of diagnostic imaging in viewing the detailed features of frontal and maxillary sinuses, with assumption that unlike gross anatomy, CT is done for live individuals, and it should be emphasized that there is a potential need for some anatomical clarifications prior to sinus surgery or applying some surgical techniques on goats as a model for human surgery.

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