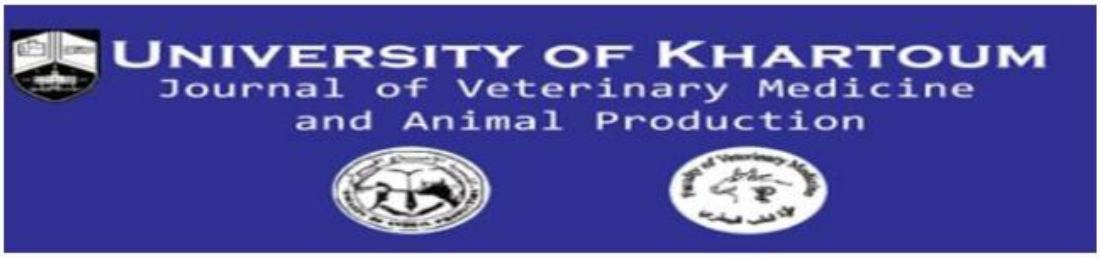
U. of K. J. Vet. Med. Anim. Prod., Vol.8, Issue 2 (2017) p 76 - 83
ISSN: 243456



Prenatal Development of Compartment 1 of the Stomach in the One-Humped Camel (*Camelus dromedarius*): Topography and Gross Anatomy

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Abstract

Gross anatomical and biometric study was conducted on compartment 1 of the stomach of 18 fetuses of the one-humped camel (*Camelus dromedarius*). The approximate age of the fetuses was estimated according to the curved crown vertebral rump length (CVRL) and accordingly, they were classified into first trimester (71 to 131 days old foetus), second trimester (134 to 243 days old foetus) and third trimester (245 to 393 days old foetus). During Morphogenesis, the stomach was differentiated into four compartments (1, 2, 3, and 4) at 89 days old foetus. During the three trimesters, compartment 1 formed the largest part of the stomach. During the first trimester, compartment 1 was smooth, oval in shape, and composed of two sacs; cranial and caudal. In fetuses from 119 days of age and up to the time of delivery, compartment 1 was round in shape, and separated by an oblique transverse groove into two sacs: small cranioventral and large caudodorsal. The cranioventral sac extended ventrally and covers compartment 2. The caudodorsal sac presented a glandular region ventrally which is sacculated externally and in relation to the small intestine. During the second and third trimesters, compartment 1 was gradually increased in size, and extended from the 8th rib to the 4th lumbar vertebra. The cranioventral sac presented ventrally two blind sacs. Biometrical results showed that during prenatal development, the average body weight, stomach weight, and the diameter of compartment 1, were strongly correlated with the CVRL.

Key words: *Gross embryonic development, compartment 1, dromedary camel*

المستخلص

أُجريت دراسة تشريحية عيانية وقياسات بيولوجية علي الغرفة 1 من المعدة في 18 من أجنة الإبل وحيدة السنام. قدر عمر الأجنة حسب طريقة قياس طول المنحني من التاج إلي بداية الذيل (CVRL) , هذا وقد تم تصنيف الاجنةإلى: الثلث الاول من الحمل (71-131 يوم من عمر الجنين)، الثلث الثاني من الحمل (134-243 يوم من عمر الجنين) و الثلث الثالث من الحمل (245-393 يوم من عمر الجنين). أثناء النمو الشكلي, تمايزت معدة الإبل في الجنين عمر 89 يومإلي أربعة غرف: الغرفة 1 والغرفة 2 والغرفة 3 والغرفة 4.الغرفة 1 هي أكبر أجزاء المعدة في كل مراحل الحمل. خلال الثلث الاول من الحمل, تكون الغرفة 1 ملساء وبيضاوية الشكل, وتحتوي على كيسين: قحفي وذيلي. في عمر 119 يوم وحتي عمر الولادة, الغرفة 1 دائرية الشكل وتحتوي على كيسين: قحفي بطني صغير و ذيلي ظهري كبير. الكيس القحفي البطني يمتد بطنياً ليغطي الغرفة 2. الكيس الظهري الزيلي يحتوي على منطقة غدية بطنياً و أكياس منالخارج و يكون ملامس للأمعاء. خلال الثلث الثاني والثالث من الحمل, يزداد حجم المعدة تدريجيا وتمتد من الضلع رقم 8 الي الفقرة القظنية رقم 4, كما يحتوي الكيس البطني علي كيسين أعورين بطنيا . اظهرت القياسات ال بيولوجية أنهخلال فترة التطور الجنيني, يرتبط كلا من متوسط وزن الجسم و وزن المعدة و قطر الغرفة 1 ارتباطا وثيقا مع CVRL.

كلمات مفتاحية: *التطور الجنينى العيانى، الغرفة 1، الجمل وحيد السنام*

Introduction

The digestive system of the camel is identical to ruminants in several aspects, which including regurgitation of ingesta, and active microbial fermentation in the stomach (Frandson *et al.*, 2003). However, the compartments of the stomach of the camel are quite different in many aspects from the stomach of ruminants (Church, 1976; Osman *et al*., 2001). Langer (1988) has named the stomach compartments as rumen, reticulum, and gastric tube, whereas other authors termed the stomach compartments as rumen, reticulum, omasum and abomasum (Hegazi, 1950; Hansen and Schmidt-Nielson, 1957; Bohken, 1960; Czerkawski, 1985; Smuts and Bezuidenhout, 1987). Nevertheless, other authors stated that, the stomach of the camel consists only of three compartments (Vallenas *et al*., 1971; Dougbag and Berg, 1980, 1981; Eerdunchaolu*et al*., 1999; Abdel-Magied and Taha, 2003). Yet, Osman *et al*. (2001) has named the compartments as compartment 1, compartment 2, compartment 3 and compartment 4 rather than rumen, reticulum, omasum, and abomasum. Research work dealing with the morphogenesis of dromedary stomach has been carried out only by few authors (Mayhew and Cruz-Orive, 1974; Bello *et al.*, 2014). Mayhew and Cruz-Orive (1974) reported that, during the development of the camel foetus, the stomach is composed of four compartments (rumen, reticulum, omasum and abomasum). However, Bello *et al.* (2014) stated that during development, the dromedary stomach has only three compartments (rumen, reticulum and abomasum) while the omasum is absent. There is paucity of information about the prenatal development of the camel stomach and controversy on the published work. It was therefore decided to undertake a detailed study on the prenatal development of compartment one of the dromedary stomach.

Materials and methods

A total of 18 camel (*Camelus dromedarius*) embryos and foeti representing all stages of prenatal development until birth, were included in

the study. All embryos and fetuses were obtained from Elsalam slaughter house and Tamboul slaughter point (Sudan). Gestational age was estimated on the basis of CVRL according to previously described age classification methods for camel (El-Wishy *et al.*, 1981) (Table 1). Foeti were perfused with 4% formalin through the carotid artery. Then they were dissected and examined for shape, relationships and topography of compartment 1 of the stomach. The weight of foeti and the stomach were determined by using either an electronic balance (for the stomach and smaller foetuses), or compression CAMRY balance, (sensitivity 10 g - 50 kg) (for the bigger foeti). The diameter of compartment 1 was measured using a tape meter and a metric ruler. The depth of the chambers of compartment 1 (glandular region), was measured using a wooden ruler and a metric ruler. The data were analyzed using analysis of variance. A value of $P<0.05$ was considered significant.

Results

Morphogenesis

In 71 days old foetus, the stomach appeared as dilated region in the foregut, situated dorsally on the abdominal cavity. At day 89 of gestation, the stomach was differentiated into four compartments: compartment 1, compartment 2, compartment 3, and compartment 4 (Fig. 1). During the three trimesters compartment 1 was the largest of the remaining three.

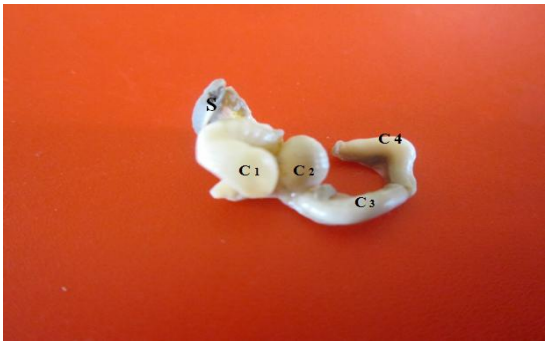

Fig. 1: A photograph of the dromedary camel stomach during the first trimester, showing compartment 1 (C1), compartment 2 (C2), compartment 3 (C3) and compartment 4 (C4) and spleen (S) CVRL = 10 cm

During the first trimester, in 89 day old foetus, compartment 1 was oval in shape, located on the dorsal aspect of the left side of the abdominal cavity, extended from the 8th rib cranially to the 2nd lumbar vertebra caudally. Compartment 1 was completely covered by the diaphragm craniodorsally and the liver caudoventrally and composed of two sacs: cranial and caudal separated by transverse groove (Fig. 2). Bothexternal and internal surfaces of the compartment 1 were smooth.

Fig. 2 Aphotograph of the left part of the abdominal cavity after a removal of a large part of the left lobe and the ribs during the first trimester, illustrating atransverse groove (arrow) separating the cranial (CR) and the caudal (CA) sacs of compartment 1, the relationship

between compartment 2 (C2) and compartment 3 (C3), liver (L), spleen (S) and intestine (I). CVRL = 12.5 cm.

In foeti between 112 and 131 days of age, compartment 1 occupied most of the left side of the abdominal cavity and extended ventrally. It was round in shape and divided by an oblique groove into two sacs: cranioventral and caudodorsal. The cranioventral sac was larger than the caudodorsal sac, and extended ventrally and covered the compartment 2 (Fig. 3). The caudodorsal sac presented a sacculated area externally and is related to the small intestine (Fig. 3). Compartment 1 presented four surfaces: parietal, visceral, dorsal, and ventral.

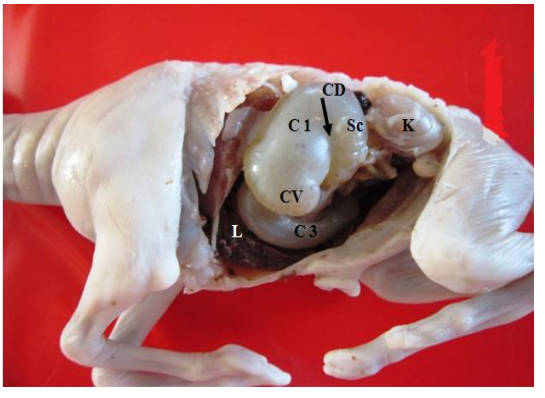

Fig. 3: Aphotograph of the leftpartof the abdominal cavity after removal ofa large part of the left lobe of the liverand intestine during the first trimester, illustrating an oblique groove (arrow) demarcating the large cranioventral sac (CV) from the small caudodorsal sac (CD) of compartment 1 (C1). Note the caudodorsal sac presented sacculated area (Sc) externally. C3, Compartment; L, liver; K, kidney.
CVRL = 19.5 cm

The parietal surface faced the left side of the abdomen and was related to the diaphragm and liver. The visceral surface was related to compartments 2 and 3 and the liver. The dorsal surface was related to the spleen and the abdominal roof. The ventral surface was related to the liver. The external surface of compartment 1 was smooth except the sacculated caudal region of the caudodorsal sac. The mucous membrane of compartment 1 presented an elevated growth (pillar), between the two sacs, which corresponded to the oblique groove. The glandular region of the caudodorsal sac was divided into chambers by eight thick longitudinal bands interconnected by many transverse folds. A few of these chambers were further subdivided into smaller chambers by other small longitudinal folds. The glandular region of the cranioventral sac was relatively large and was divided into many small chambers by 10 to 12 small longitudinal bands.

During the second trimester, in fetuses between 134 and 243 days of age, compartment 1 was rounded in shape and extended between the 8thrib to the 4th lumbar vertebra. In foeti between 167 and 202 days of age, the cranioventral sac presented ventrally two blind sacs: small cranial and large caudal (Fig. 4). In 229 day old foetus, the cranioventral sac extended ventrally and covered compartment 3.

The depth of the chambers of the caudodorsal sac was about 6 mm. The blind sacs of the cranioventral sac were sacculated internally and presented 10 bands and the depth of the chambers was varied between 3 and 4.5 mm.

During the third trimester, in foetuses between 245 and 393 days of age, compartment 1 was similar to that of the second trimester but it increased in

size. It extended from the 8th rib cranially to the 3rd lumbar vertebra caudally (Fig. 5).

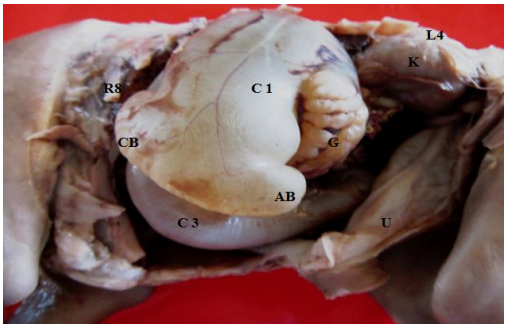

Fig. 4: Aphotograph of the leftpartof the abdominal cavity after a removalof the ribs and left lobe of the liver during the third trimester, showing compartment 1 (C1) with cranial blind sac (CB), caudal blind sac (AB) and glandular sac (G). C3, Compartment; 3U, Urachus; K, kidney;R8, 8th rib;L4, 4thlumbar vertebra. CVRL = 37 cm.

In fetuses of 281 and 289 days of age, the lower part of the cranioventral sac was covered with the visceral surface of the left lobe of the liver. In fetuses between 339 and 380 days of age, the cranioventral sac was covered by the diaphragm cranially, and rested on the visceral surface of the left lobe of the liver ventrally.

The sacculated region of the caudodorsal sacwas divided by 9 to 10 thick longitudinal bands and many small transverse folds into numerous chambers. A few of these chambers were further divided further into smaller chambers by other small longitudinal folds. The depth of these chambers varied between 6 and 8 mm.

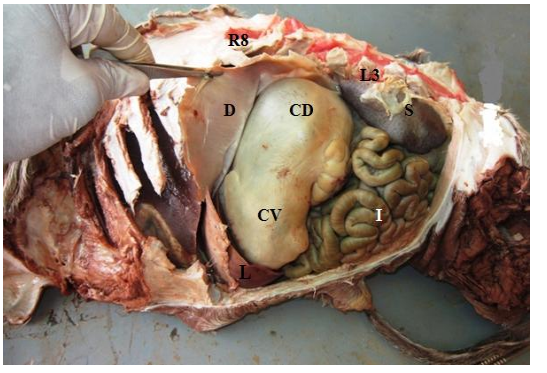

Fig.5: Aphotograph of the leftpartof the abdominal cavity during the third trimester, demonstrating the relationship between the caudodorsal (CD) and cranioventral (CV) sacs of compartment 1and between them and the liver (L), intestine (I), spleen (S), diaphragm (D), 8th rib (R8), and 3rd lumber vertebra (L3). CVRL = 111 cm

The glandular region of the cranioventral sac was also divided into numerous chambers by 12 to 14 thick longitudinal bands. The depth of these chambers ranged between 4 and 6 mm (Fig. 6).

Fig.6: Aphotograph of the stomach during the third trimester, illustrating the internal surface of compartment 1. Note the non-glandular (NG) and glandular regions (G), the internal surface of compartment 2 (C 2) and the oesophageal groove (arrow head).Arrowspoint to the pillar which corresponds to the oblique groove.
CVRL = 85 cm

Biometry

The average body and stomach weights and the diameter of compartment 1, during prenatal development were strongly correlated with the crown vertebral rump length (CVRL). The diameter of compartment 1 at the third trimester increased 2.3 times compared to that of the second trimester and 4.7 times compared to that of the first trimester (Table 2).

Discussion

In 89 days old foetus, the stomach of the dromedary was differentiated into four compartments (1, 2, 3 and 4). This observation is in agreement with the previous studies (Hegazi, 1950; Mayhew and Cruz-Orive, 1974). In the adult camel, Osman *et al.* (2001) and Abuagla (2014) reported that the stomach consists of four compartments. However, Abdel-Magied and Taha (2003) considered the dromedary stomach to be divided into three compartments (1, 2, and 3); they reported that none of these compartments can be considered homologous to those of the rumen,

Table 1: The different groups of camel foeti, their age (in days), and their number in each group.

No.	Groups	CVRL (cm)	Age (days)	Number of foeti
1	First trimester	2-24	71 – 131	8
2	Second trimester	25-65	134 – 243	5
3	Third trimester	66-120	245 – 393	5

Table 2: Body weight (g), stomach weight (g) and diameter of compartment 1 during the three trimesters (Mean ± Standard error)

Parameters	Stage of gestation		
	First trimester	Second trimester	Third trimester
Body weight (g)	$873^{c} \pm 459$	$2238^{b} \pm 398$	$11600^{a} \pm 3414$
Stomach Weight	$3.57^{c} \pm 0.58$	$63.80^{b} \pm 9.58$	$262.00^{a} \pm 12.40$
Diameter of C 1 (cm)	$4.40^{c} \pm 0.85$	$8.89^{b} \pm 0.99$	$20.48^{a} \pm 1.42$

^{abc} Means on the same row with different superscripts are significantly different at $P<0.05$

reticulum, omasum and abomasum of cattle and sheep. On the other hand, Bello *et al.* (2014) stated that the camel stomach was divided into three major compartments (rumen, reticulum, and abomasum) as there is no omasum in all the three phases of the gestational age. The present investigation illustrated that during the three trimesters, compartment 1 was the

largest part of the stomach. During the first trimester it was oval in shape and occupied the dorsal part of the abdominal cavity. During the second and third trimesters, it was round in shape, and located on the left side of the abdomen. These observations were in accordance with the findings of Bello *et al.* (2014) who reported that during the three trimesters the rumen is voluminous smooth compartment in the camel foetus. On the other hand, in sheep foetus of 38 days of age, the rumen is the largest part of the stomach while in 47 days of age foetus, the rumen and reticulum were equal in size and the abomasum is the largest part of the stomach (Hejazi and Erik-aghaji, 2013). The development of the camel stomach was different from that of ruminants.

The present study showed that in a foetus of 89 days of age, compartment 1 was divided by a transverse groove into two sacs: cranial and caudal, and in a foetus of 112 days of age and up to the time of the birth, it was divided by oblique groove into two cranioventral and caudodorsal sacs. During the prenatal development, the caudodorsal sac of compartment 1 presented ventrally a glandular region which is sacculated externally and the cranioventral sac has two blind sacs: cranial and caudal, which are to become the glandular region of the cranioventral sac. In contrast, Bello *et al.* (2014) reported that during the second and third trimesters, compartment 1 is subdivided by a strong muscular pillar into a dorsal smooth part and a ventral coarse one. Noteworthy, the glandular regions were found only in the camel stomach and not found in ruminants. Moreover, Amasaki*et al.*(1992) reported that, the glandular regions of compartment 1 secrete pepsinogen-pepsin in the bacterian camel.

Biometrical study showed that in the camel, during the prenatal development, the average body weight, stomach weight, and the diameter of compartment 1, were strongly correlated with CVRL. This result was in agreement with those reported by Bello *et al.*(2012) and Bello *et al.* (2014). They founded that, there is an increase in the body weight, and the weight of the individual compartments of the stomach in the fetuses with the advancement of gestation period.

Conclusion

As a conclusion, this study showed that the prenatal development of compartment 1 of the dromedary stomach was different from the development of that of ruminants, and was strongly correlated with CVRL.

Acknowledgments

This research has been carried out in the Department of anatomy, Faculty of Veterinary Medicine, University of Khartoum (Sudan) and was funded by the University of West Kordofan.

Conflict of interest

The authors of this article declare that there is no conflict of interest.

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