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Gross Anatomical and Topographical Studies of the Small Intestine of the Camel (*Camelus dromedarius*)

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ABSTRACT

Morphological studies were carried out on six small intestine of the one humped camel. The measurements of the long axis of the body and the length of each segment of the small intestine were carried in five she-camels by a measuring tape. Topographical study of the small intestine was made in one adult healthy dromedary fixed by perfusion with 10% formalin. While the long axis of the body measured 2.87 m, the small intestine measured 10.97± 0.66 m only. It was observed that the major part of the small intestine was situated in the right side of the abdomen. This study has designated a palpable bony structure to each part of the small intestine and hence the position of all segments can easily be determined.

INTRODUCTION

The camel (*Camelus dromedarius*) is a typical desert animal, well adapted to life in the desert because of its unique metabolic pathways which enable it to survive without food and water for few days (Robert, 2006; Ouajd and Kamel, 2009). The functions of the intestines are stated by Pabst (1987). Furthermore, the gastrointestinal system is well known for fluid and electrolytes transport (Ali *et al.*, 2008).

The length of the intestine and its segments differ with the species and breed or even within the same species of animal (Nickel *et al.*, 1979). The following values were previously reported in a wide range of mammals. In the horse, sheep and goat, and dog, it measured 22m, 25m and 4m respectively (Habel, 1975). In the ox, sheep and goat, it measured 27- 49m, 27- 49m respectively (Shummer *et al.*, 1979).In the dromedary, it measured 40m (Smuts and Bezuidenhout, 1987). In human, it measured 5m (Nakshabendi, 1999). In the addax deer, it measured 6.18m (Perez and Lima, 2006).

Habel (1975) measured the diameter of the small intestine; it is 5- 6 cm in the ox and 2- 3 cm in sheep and goat.

The topography of the small intestine was described in the dromedary by Smuts and Bezuidenhout (1987). They reported that the duodenum begins at the pylorus which is situated below the tenth costochondral junction. The cranial part consists of a prominent ampulla followed by a slender sigmoid flexure which is directed craniodorsally. At the cranial duodenal flexure the strongly convoluted descending duodenum commences, passing in a caudal direction. Ventral to the caudal pole of the right kidney, the duodenum turns medially as the transverse part. It attaches to the last part of the ascending colon, and passes cranially between the latter and the angle formed by the transverse and the descending colon to bend ventrally at the duodenojejunal flexure.

The jejunum is convoluted, placed mainly in the right flank of abdominal region, and on the sternum in the median longitudinal plane. Its terminal portion is placed to the left of the median plane.

The short ileum ends at the ileal orifice which demarcates the cecocolic junction. The latter is on the right of the midline, at the level of the caudal pole of the left kidney. The beginning of the ileum is marked by ileocecal fold, attaching the ileum to the lesser curvature of the cecum.

In ruminants, the topographical anatomy of the small intestine was described by Habel (1975). He stated that the duodenum of the ox begins at the pylorus usually at the ventral end of the tenth rib or ninth intercostal space. It consists of the cranial duodenum which ends by the sigmoid flexure. The second part, the descending duodenum, runs caudally almost to the tuber coxae, then it runs cranially forming the caudal flexure. The third part, the ascending duodenum, extends forward in contact with the distal loop of the colon, and joins the mesenteric part. The jejunum forms numerous close coils arranged in a festoon around the border of the mesentery. It usually lies in the supraomental recess on the right side of the rumen, whereas the ileum extends from the free edge of the ileocecal fold to the ileocecal orifice.

In other animals like Pampas Deer (Perez *et al.,* 2008), the intestinal tract is mainly situated on the right side (within the supraomental recess), and in the caudal left part of the abdominal cavity. The cranial part of the duodenum forms a sigmoid flexure, and then continues with a descending portion, situated in the dorsal part of the right flank. The ascending part of the duodenum runs cranially parallel to the descending part, and is accompanied by the first portion of the descending colon. The mobility of the jejunum is limited by the adherence of the spiral part of the ascending colon to the left sheet of the mesentery. The ileum is connected to the cecum by an ileocecal fold.

The main objectives of this work are; to determine gross anatomically, the extent of each part of the small intestine exactly and thus the length of each part can be measured with accuracy, and to find out gross anatomically, the bony landmarks of each part of the small intestine.

MATERIALS AND METHODS

For gross anatomical study; specimens of small intestine were obtained from 5 healthy adult she-camels (age ranged between 5- 11 years); from Albogaa slaughterhouse, Omdurman, Sudan. The

long axis of the body of the camel was considered to be the distance between the occipital bone and the second coccygeal vertebra. The intestines were freed from the mesentery, spread in straight line, and the lengths and diameters of the different sections were taken with a standard measuring tape.

For the topography of the small intestine, one adult healthy camel (aged 6 years) was used. The camel was obtained from a local market in Omdurman and the dissection was carried out in the Department of Anatomy, Faculty of Veterinary Medicine, University of Khartoum, Sudan. The camel was first anaesthetized with 10% chloral hydrate via the external jugular vein. Then, the common carotid artery and the external jugular vein on the right side were dissected and exposed. The carotid artery was canulated in order to bleed the animal, then perfusion with 10% formalin was carried out until the animal died. The camel was kept in a sitting position and left for 7 days before carrying out the dissection. The abdominal muscles were dissected first on the right side, and the greater omentum was removed to expose the intestines. In addition, the intercostal muscles from the 9^{th} to the 11^{th} intercostal spaces were removed on the same side. The site of the dissection was photographed using Canon digital camera (Canon Company, Tokyo, Japan). At the left side, the abdominal muscles were also dissected and the intercostal muscles from the 9^{th} to the 11^{th} intercostal spaces were removed, and the abdominal organs were photographed in situ. The ribs, lumbar transverse processes and the ilia were used as landmarks to determine the position of the various parts of the small intestine.

RESULTS

Measurements: Measurements of the long axis of the body, and the various segments of the small intestine of she-camels were shown in Table 1 which showed that there was variation in the long axis of the body and different segments of the small intestine. The mean of the long axis of the body was 2.87 meters, the mean length of the small intestine was 10.97± 0.66 meters, and its ratio to the long axis of the body was 3.82.

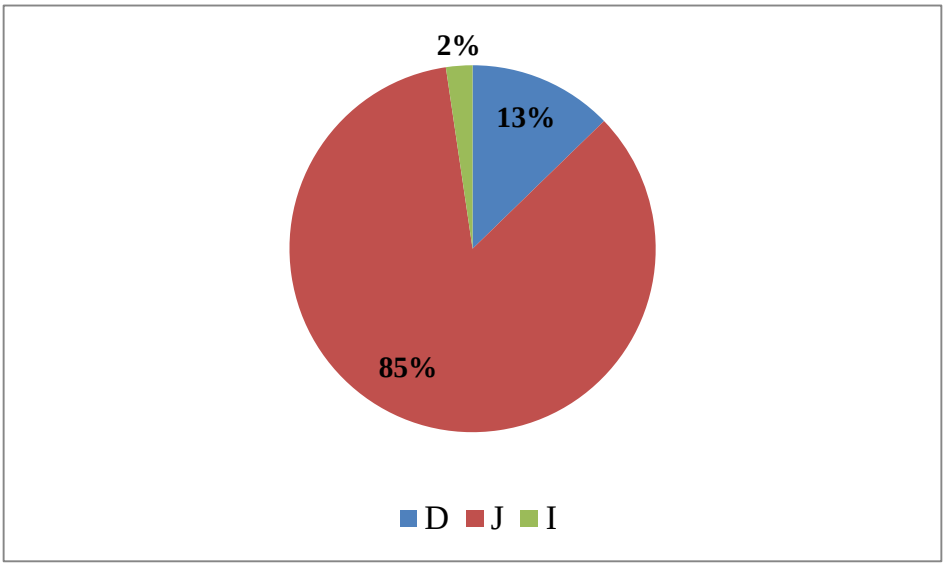
Table 1: The length of The long axis of the body showing the various segments of the small intestine, total length of fresh samples of the intestine in each of the 5 she-camels at different age (in meter).

She-camel	Age (year)	Long axis of the body	D	J	I	Total length of S.int.
1	5	2.72	1.29	8.64	0.23	**10.16**
2	6	3.04	1.42	9.28	0.24	**10.94**
3	8	2.68	1.41	8.75	0.25	**10.41**
4	9	2.89	1.43	9.77	0.33	**11.53**
5	11	3.03	1.44	10.12	0.23	**11.79**
Mean		2.87	1.40	9.31	0.26	**10.97**
SD		0.15	0.05	0.57	0.04	**0.66**

D, duodenum; J, jejunum; I, ileum; S.int, small intestine.

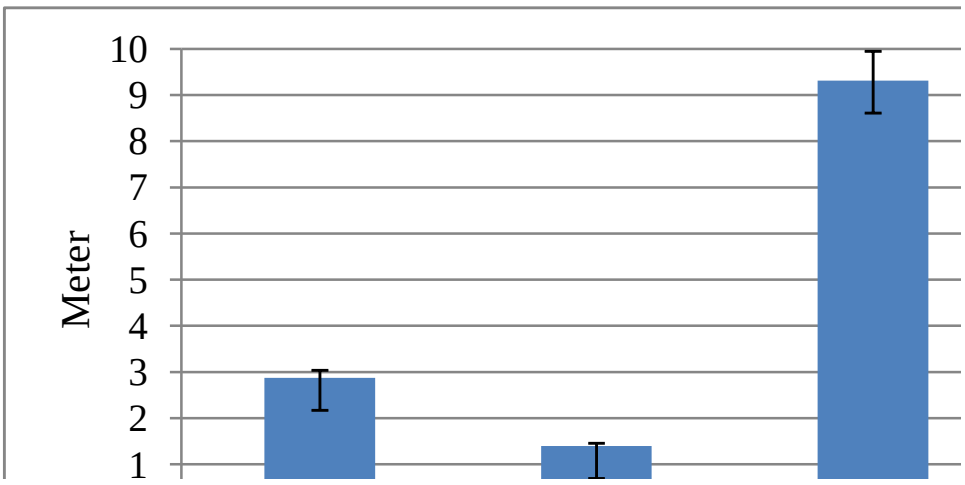
The length of the duodenum, jejunum and ileum formed 13%, 85% and 2% of the total length of the small intestine respectively (Figure 1). Also, the ratio of each segment of the small intestine to

the long axis of the body was 0.48, 3.24 and 0.09 respectively (Figure 2).



D, duodenum; J, jejunum; I, ileum

Figure 1: The percentage of each segment of the small intestine to the total length of the small intestine.



D, duodenum; J, jejunum; I, ileum

Figure 2: The length of the long axis of the body and the segments of the small intestine in meter (n=5).

The values for the length and the diameter of the ampulla of the duodenum were shown in Table 2. The diameter of ampulla ranged between 21-23 cm, and the length ranged between14 to 17 cm.

Table 2: The length and diameter of the ampulla duodeni, and the length of the duodenum in 4 she-camels at different age (in centimeter)

She-camel	Age (year)	Am. length	Am. diam	D. length	Am. Length/D. Length
1	5	15	23	129	11.6%
2	6	16	22	142	11.3%
3	8	14	21	141	9.9%
4	11	17	22	144	11.8%
mean		15.50	22	139	
SD		1.12	0.71	5.87	

Am., ampulla duodeni; Am. diam, ampulla duodeni diameter; D. Length, duodenal length; am. Length/ d. Length%, percentage of ampulla duodeni length to the duodenum length.

The average diameter of each segment of the small intestine was recorded in Table 3. The ampulla of the duodenum was excluded from the duodenum. The table showed that the diameter of the small intestine ranged between 5 to 16 cm. The diameter of the cranial duodenum next to the ampulla was narrow, it became wider in the descending duodenum, and once again became narrower in the ascending duodenum near the junction with the jejunum. The diameter of the jejunum varied along its length. The initial part had a diameter similar to that of the last part of the duodenum. Then, it gradually increased in diameter until the beginning of the ileum. The diameter of the ileum decreased gradually until the ileocecal opening.

Table 3: The diameter of the various segments of the small intestine in 4 she-camels at different age (in centimetre). The ampulla duodeni is excluded from the duodenum.

She-camel	Age (year)	D	J	I
1	5	6- 9	7- 10	9- 11
2	6	5- 9	7- 16	10- 14
3	8	7- 9	7- 13	10- 13
4	11	10- 11	5- 14	13- 14

D, duodenum; J, jejunum; I, ileum

***Topography*:** The organs present in the right side of the abdominal cavity were concealed by the greater omentum except the right kidney and the descending duodenum (Figure 3).

The duodenum which represented the first segment of the small intestine could be divided into three parts: cranial, descending, and ascending. The cranial duodenum began at the pylorus having a narrow diameter. It suddenly expanded to form the ampulla, which was oval-shaped and measured 15 cm. in length and 23 cm. in diameter (Table 2). The ampulla was located at the level of the caudal border near to the distal end of the 11^{th} rib (Figure 4), and on the right aspect of the rumen (Figure 5). Then, the duodenum became slender-shaped with a narrow diameter, and it ran dorsally and cranially to the visceral surface of the liver (Figure 6) forming a sigmoid flexure.

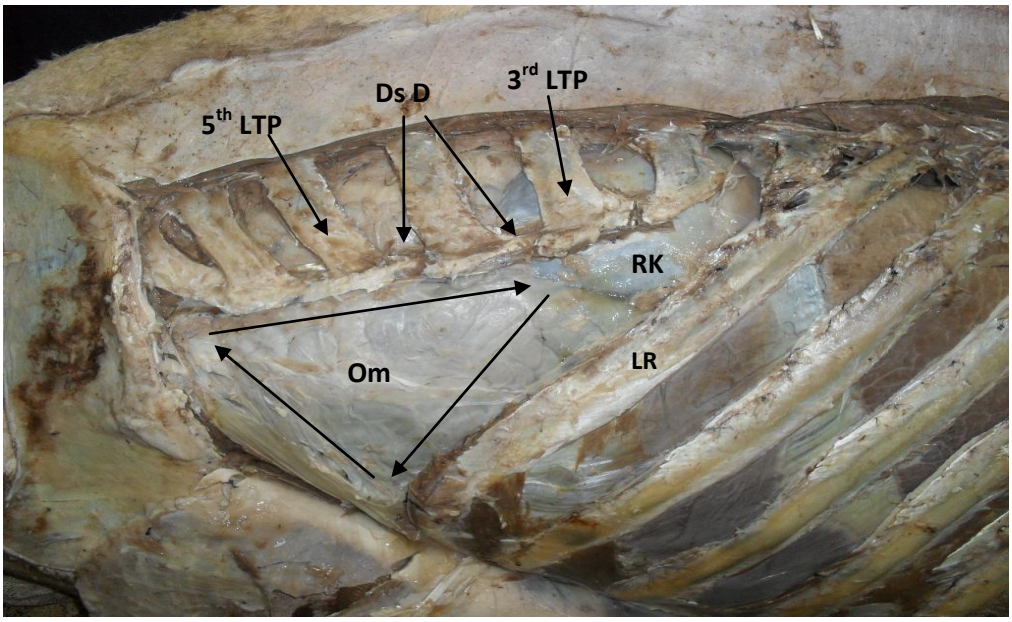


Figure 3: Right view of the abdominal cavity after removal of the intercostal, intertransversaris lumborum, and abdominal muscles showing that most of the abdominal organs are concealed by the greater omentum (**Om**) except the right kidney (**Rk**) and the descending duodenum (**DsD**) which is partially obscured by the transverse processes of the lumbar vertebrae from the 3rd to the 5th. **LR,** last rib; **3rd LTP**, third lumbar transverse process; **5th LTP**, fifth lumbar transverse process.

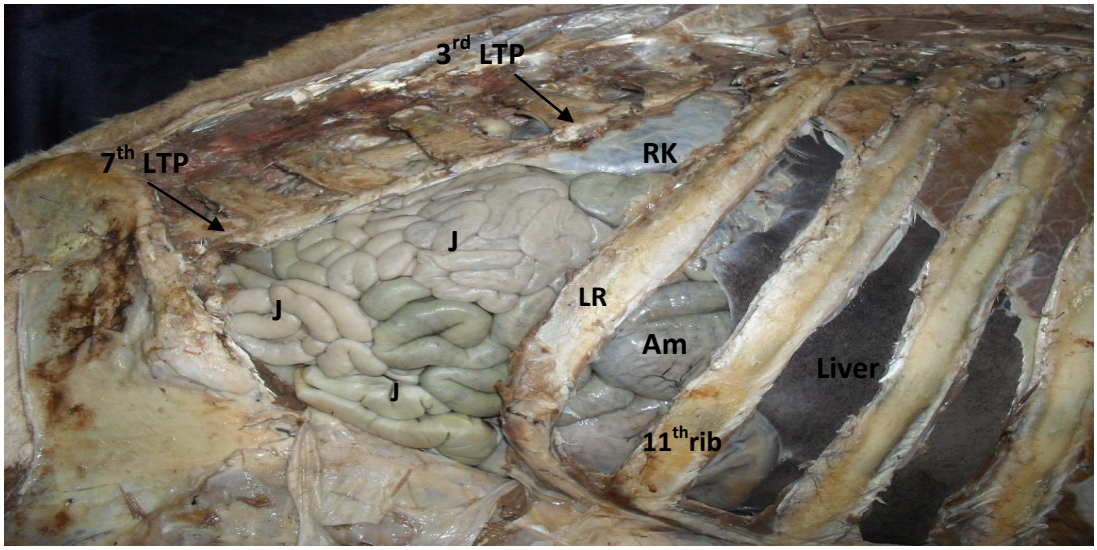


Figure 4: Right view of the abdominal cavity after removal of the omenta, intertransversaris lumborum, and intercostal muscles showing Ampulla duodeni (**Am)** and jejunum **(J**). Note that: the ampulla duodeni is located at the level of the caudal border near to the distal end of the 11th rib. The jejunum is bounded cranially by the last rib (**LR**), caudally by the transverse process of the 7th lumbar vertebra, dorsally by the free ends of the lumbar transverse processes from the 2nd to the 7th, and ventrally by abdominal floor. **Rk,** The right kidney; **3rd & 7th LTP,** Third and seventh transverse processes of the lumbar vertebra.

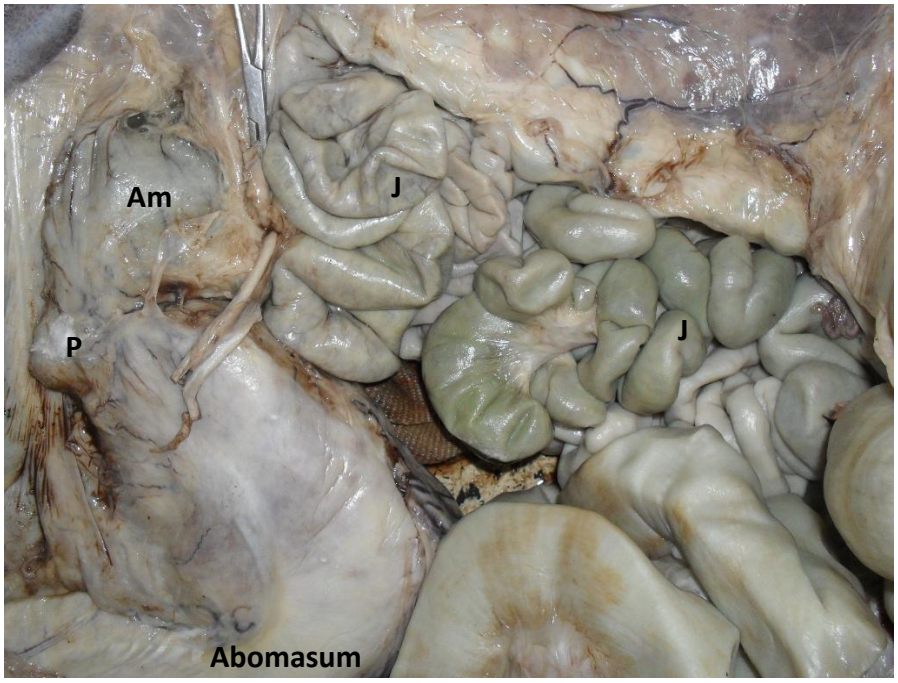


Figure 5: Left view of the abdominal cavity after removal of the rumen showing the ampulla duodeni (**Am**) and the jejunum (**J**).**P,** pyloric region of the abomasum.

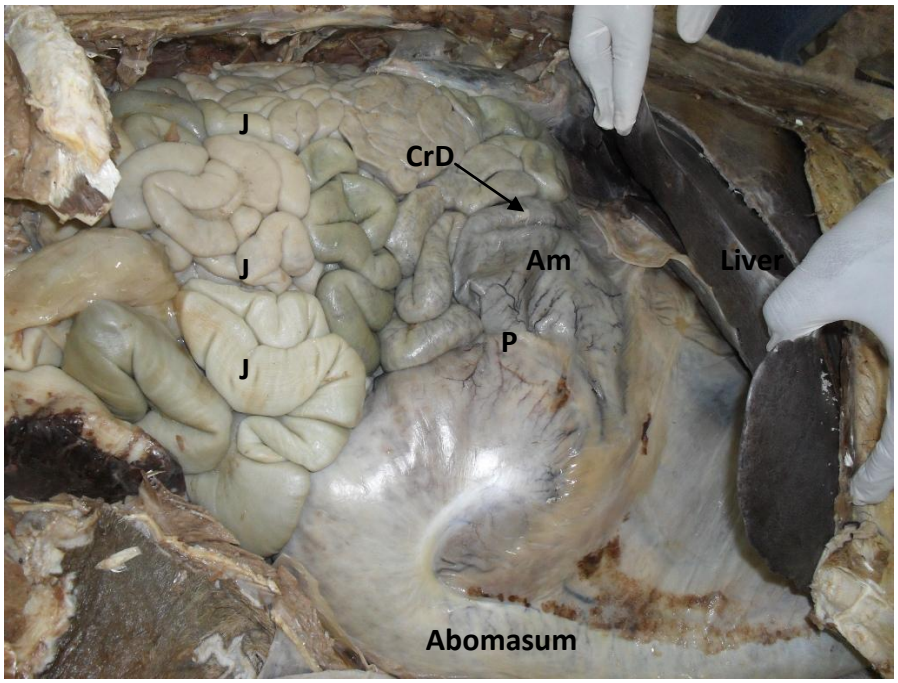


Figure 6: Ventro-caudal view of the right abdominal cavity occupied mainly by the jejunum (**J**). **Am,** ampulla duodeni; **P,** pyloric region of the abomasum; **CrD,** slender part of the cranial duodenum.

The descending duodenum started at the second curvature of sigmoid flexure at the visceral surface of the liver, ran caudally ventral to the transverse processes of the 4th and 5th lumbar vertebrae and almost to the level of the cranial border of the transverse process of the 6th lumbar vertebra and turned medially to form the caudal flexure (Figure 7). Then it ran cranially to form the last part of the duodenum, the ascending duodenum.

The ascending duodenum extended from the caudal flexure of the duodenum at the level of the cranial border of the transverse process of the 6th lumbar vertebra cranially and ventrally. It joined the jejunum ventral to the right kidney at the duodenojejunal junction (Figure 8), at the level of the transverse process of the 3rd lumbar vertebra.

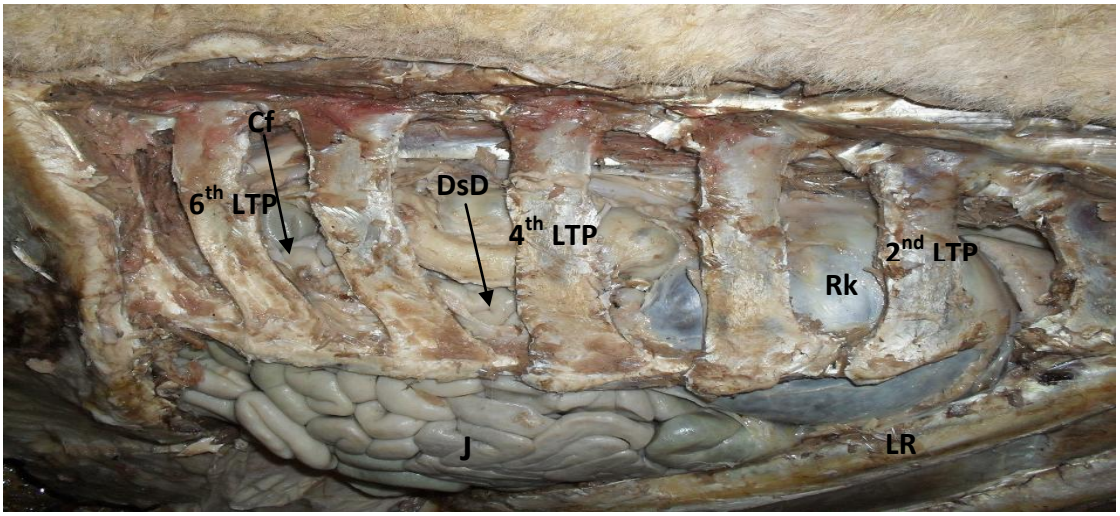


Figure 7: Dorso-lateral view of the right abdominal cavity showing the descending duodenum (**DsD)** running ventral to the t4th and 5th transverse processes of the lumbar vertebrae. The caudal flexure (**Cf**) is present in the 5th intertransverse space of the lumbar vertebra. **2nd**, **4th & 6th LTP,** the transverse processes of the second, fourth & sixth lumbar vertebra; **J,** the jejunum; **LR**: the last rib; **Rk,** the right kidney.

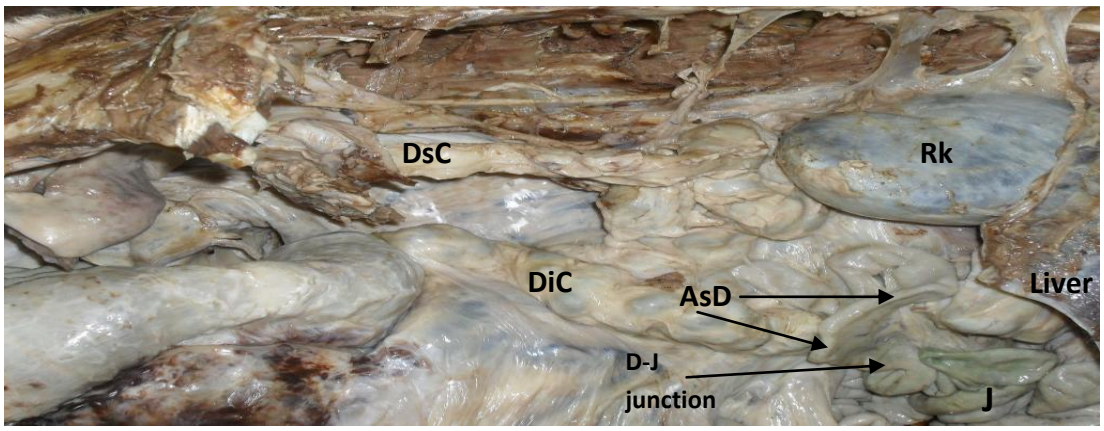


Figure 8: Right view of the abdominal cavity displaying part of the jejunum (**J**) and showing the duodenojejunal junction (**D-J junction**) ventral to the right kidney (**Rk**). **AsD,** the ascending duodenum; **DiC,** the distal loop of the ascending colon; **DsC,** the descending colon.

The jejunum occupied the major part of the right abdominal cavity (Figures. 4, 6, 7 & 9). It had a diameter slightly wider than that of the duodenum. Cranially, it lay immediately caudal to the last rib (Figures 4 & 7). Caudally, it was bounded by the transverse process of the 7th lumbar vertebra (Figure 4). Dorsally, it was located ventral to a line joining the free ends of the lumbar transverse processes from the 2nd to the 7th (Figure 7). Ventrally, it lay on most of the abdominal floor from the level of the 11th rib to the 7th lumbar transverse process (Figure 4). The jejunum displayed numerous coils which were arranged in a festoon shape around the distal border of the mesentery (Figure 9).

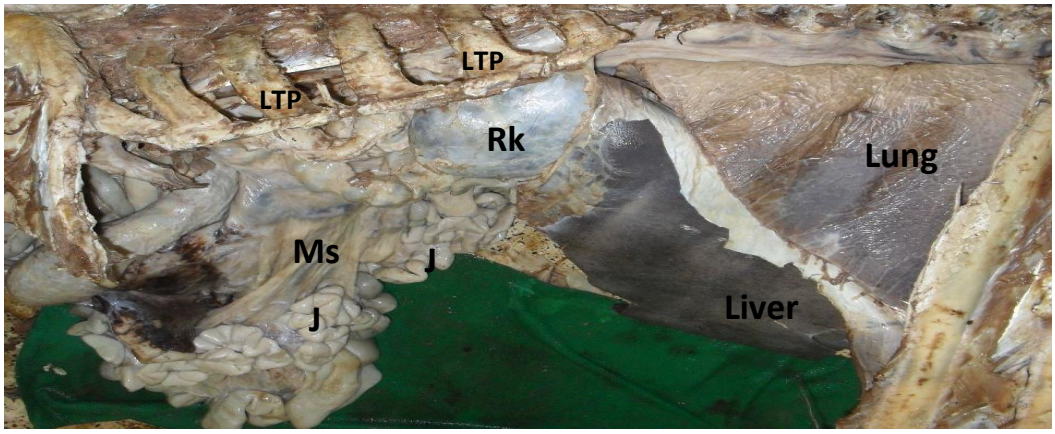


Figure 9: Right view of the abdominal cavity showing the mesentery (**Ms**) of the jejunum (**J**). **Rk,** the right kidney; **LTP**, lumbar transverse process

The ileum lacked the characteristic coils of the jejunum, and had a wider diameter of the small intestine. It extended from the pelvic inlet cranially to join the cecum at the level of the body of the 5th lumbar vertebra in the right side of the abdominal cavity. The ileum was connected to the cecum along its whole length by a short peritoneal fold known as the ileocecal fold (Figure 10).

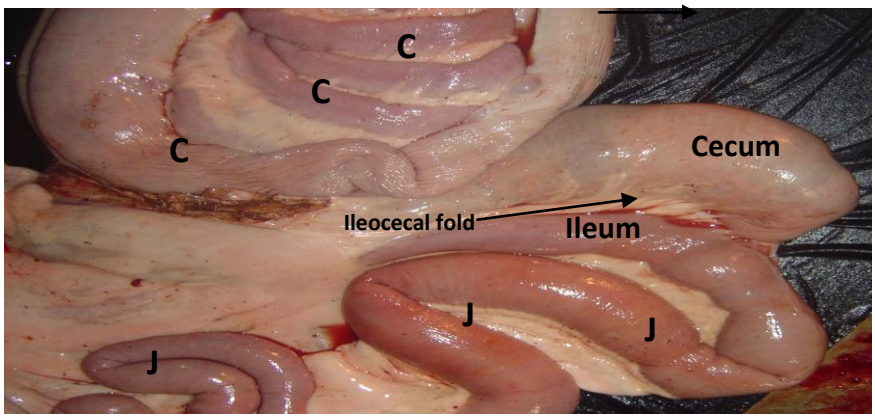


Figure 10: View showing the ileocecal fold connecting the ileum to the cecum **J,** the jejunum; **C,** the colon

DISCUSSION

In this study, different relationships between the length of the different segments of the small intestine and body length were noted. The mean length of the small intestine of the dromedary was 10.97± 0.66 meters; a value which is less than half that reported by Smuts and Bezuidenhout (1987). Whereas, the length of the duodenum of the camel in this study range between 1.2- 3.1 meters, as reported by Althnaian *et al.* (2012).

However, Nickel et al. (1979) stated that the length of the intestines may vary from animal to animal within the same species; Habel (1989) has explained that the variation vary greatly by the difference in the state of contraction of the musculature. The differences in the relative intestine of factors length of the rodents are correlated with sex, breed and body size (Korn, 1992). Hounnou *et al.* (2002) confirmed these factors in human, and added that the weight and height also affect the length of the intestines. According to the latter authors, the length of the intestines in man ranged from 5.50 to 13.21 meters and in women ranged from 3.78 to10.13 meters, so that there was a big variation in the length of the intestines in human. Smuts and Bezuidenhout (1987) did not consider the age or sex of animals when they reported the length of the intestines.

This study reports for the first time that the length of the small intestine in the one-humped camel equals almost four times (3.82) the length of the long axis of the body.

In all domestic mammals, in the giraffe, and in man, the jejunum represented the longest segment and the ileum the shortest of the small intestine (Habel, 1975; Nickel *et al.,* 1979; Hounnou *et al.,* 2002; Perez *et al.,* 2009). Regarding this point, the camel is not different from other mammals as shown in this study.

According to the present data, the average diameter of the small intestine (excluding the ampulla of the duodenum) ranged from 5 to 16 centimeters. This data was different from that reported by Tharwat *et al.* (2012) in the same animal in which they stated that the diameter of the small intestine was 2.62± 0.47 cm. Also, the present values in the camel were larger than the corresponding values in the intestines of ruminants (Habel, 1975). The large diameter of the intestines of the camel may compensate for their shortness in relation to their ability of absorption. Generally it appeared that the diameter of the various segments increased with age.

However, Kuczynski (1890) classified mammalian species into three categories depending upon the length of the intestine into short, moderate and long. He considered carnivores as short, omnivores as moderate, and herbivores as long. This study did not confirm with that classification and has concluded that the camel has a relatively shorter small intestine compared to other herbivores.

It is well established that in ruminants the omentum covers the organs in the right side of the abdominal cavity except the right kidney, the descending duodenum and the apex of the cecum (Habel, 1975). The observations in the present study are similar to those reported for ruminants even though the descending duodenum was obscured by the intertransversarius lumborum muscle and the transverse processes of the 4^{th} & 5^{th} lumbar vertebrae.

Generally, the topography of the intestinal tract of the camel in this study was similar to that described by Smuts

and Bezuidenhout (1987). The ampulla of the duodenum was observed for the first time by Smuts and Bezuidenhout (1987) and it actually represents a characteristic feature of the duodenum of the camel and is not found in any other animals. It is an expansion in the cranial duodenum with a diameter of 22 cm, and it is located at the caudal border of the 11th rib near its distal end.

In the present study, the topography of other parts of the duodenum was similar to those described in the camel (Smuts and Bezuidenhout, 1987; Althnaian *et al.*, 2012) and ruminants (Habel, 1975) except that the caudal flexure of the descending duodenum was observed to be located at the level of the cranial border of the transverse process of the 6th lumbar vertebra, a little bit cranial to the pelvic inlet. This position is somewhat different from that reported in the ox which is at the level of the pelvic inlet (Habel, 1975). On the other hand, a landmark for this flexure was not mentioned by Smuts and Bezuidenhout (1987) and Althnaian et al. (2012).

The position of the jejunum and ileum observed in the present study is similar to that described by Smuts and Bezuidenhout (1987) in the camel and in the ox (Habel, 1975). The jejunum with its usually festoon-shaped coils was observed to lie mainly in the right side of the abdominal cavity occupying the major part of it. The straight ileum extended cranially to join the cecum at the level of the 5th lumbar vertebra in the right side of the abdominal cavity. The ileocecal fold that was mentioned by previous authors was also recognized in this study.

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