Original article

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Anatomical and morphometric study of gastrointestinal tract of donkey (*Equus africanus asinus*)

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Abstract

Introduction: We dissected and described the macroscopic anatomy of the gastrointestinal tract of the donkey. **Materials and Methods:** Eleven domestic donkeys of both sexes from Tunisia were used for this study. **Results:** Although statistically insignificant, length values of the gastrointestinal tract pertaining to the females were generally higher than those pertaining to the males. The ostium cardiacum was very narrow and its diameter was 4.42 ± 0.57 mm in the males and 6 ± 1.22 mm in females. In the first part of the duodenum, we found papilla duodeni major and papilla duodeni minor. Both papillae were located very near to each other with a distance less than 1 cm and very near to the ostium pyloricum. The cecum was divided in parts of basis, corpus and apex. Three flexures divided the ascending colon into four parts: right ventral, left ventral, left dorsal and right dorsal. The cecum, left ventral colon and right dorsal colon had more evident sacculations (Haustra ceci and coli) (Figure 5). Teniae numbers were constant in all animals as 4, 4, 4, 1, 3 and 2 for cecum, right ventral colon, left ventral colon, left dorsal colon, right dorsal colon and descending colon, respectively. **Conclusion:** Although the gross anatomy of the intestines of the donkey was similar to the domestic horse in general, we detected some differences between these equine species.

Keywords: abdominal organs, anatomy, equidae, intestine, stomach.

1 Introduction

Despite the increase in mechanization throughout the world, donkeys are still well deserving of the name 'beasts of burden'. They have an important role to play in transport of people and goods in arid and semi-arid areas and where roads are poor or non-existent. This is shown by the widespread use of donkeys in rural and urban areas in Africa, as well as parts of central America and Asia.

Donkeys seem able to digest high fibre forage diets better than do horses, while maintaining similar or higher intakes of the feed. For example donkeys eating 15.3 g dry matter/kg live weight of an oat straw diet showed an apparent digestibility coefficient of organic matter, neutral detergent fiber and acid detergent fiber of 0.52, 0.49 and 0.44 respectively. Horses eating 13.7 g dry matter/kg live weight of the same diet showed apparent digestibility coefficients of organic matter, neutral detergent fiber and acid detergent fiber of 0.48, 0.41 and 0.37 (CUDDEFORD, PEARSON, ARCHIBALD et al., 1995). Donkeys also seem able to compensate very accurately for the water deficit when drinking following a period of water deprivation (YOUSEF, DILL and MAYERS, 1970). The mechanisms behind these two observations are not understood, but may account for the donkey's seemingly good body condition despite eating poor quality feeds.

According to our knowledge, the macroscopic anatomy and measurements of the stomach and intestines of the domestic donkey has not been published. Anatomical features and measurements of the stomach and intestines and their internal communications are useful for physiologist, veterinarians and surgeons. The knowledge of anatomy is very important for clinical examination and diagnosis, especially in acute abdomen, for radiologic interpretations, exploratory laparatomy and surgery of the abdominal cavity.

In the classical textbooks of veterinary anatomy we have very good descriptions of the horse intestinal anatomy (GETTY, 1975; BARONE, 1997; KÖNIG and LIEBICH, 2012), but there are no researches about stomach and intestines of donkeys and eventual differences of them with horses.

2 Materials and Methods

Eleven domestic donkeys (*Equus africanus asinus)* of both sex from Tunisia; 36° N, 10° W, were used for this study. The animals were euthanized for Veterinary Anatomy course and the gastrointestinal system was used for this work. Four adult females (85.7±4.9 kg in body weight and 135.0±3.9 cm in body length) and seven adult males (77.0±7.8 kg in body weight and 132.1±3.6 cm in body length) in excellent body condition were killed and immediately dissected.

The ventral abdominal wall of each animal was removed, and the gastrointestinal tract was separated after sectioning the oesophagus just prior to the cardia and pylorus just before the duodenum, and dissecting it away from its attachments to the dorsal abdominal wall.

Contents were quantified by weighing the unopened organ and re-weighing it after it had been opened and rinsed clean of all contents with water and dry with paper towels. Measurements of anatomical structures were taken using a soft measuring tape of caliper where appropriate. Pictures were taken with a Nikon digital camera (D5100).

All data were entered into the computer and analyzed using the SPSS 17.0 system for Windows (SPSS 17.0, SPSS, Inc., Chicago, IL). Data are presented as median ± standard error, as well as minimum and maximum values. The nonparametric Kruskall-Wallis test was applied to determine whether there was significant difference in measurements of some digestive organs between the genders. Differences were considered significant at $p<0.05$.

Terms are used in agreement with the Nomina Anatomica Veterinaria (2012).

3 Results

The stomach was strongly incurved, the cardia and pylorus were very close to each other and the saccus cecus ventriculus was very evident (Figure 1). The weight of the full and empty stomach was 2230 ± 420 and 548 ± 28.26 g, respectively. The capacity of the stomach was 815 ± 36.20 ml. The length of the curvatures of the stomach had significant difference only in terms of lesser curvature of stomach (Table 1). However, although statistically insignificant, length values of the greater curvature pertaining to the females were generally higher than those pertaining to the males. In the internal surface of the stomach, the irregular and sinuous margo plicatus was detected between cutaneous and glandular mucosa. While cutanous proventricular part of the stomach was yellow or white, glandular parts was darker with red colour (Figure 2). The ostium cardiacum was very narrow and its diameter was 4.42 ± 0.57 mm in the males and 6 ± 1.22 mm in females, and numerous mucosal folds occluded this ostium (Figure 2). The ostium pyloricum had a 7.14 ± 0.96 mm and 10.25 ± 2.78 mm in diameter in females and males, respectively (Figure 3). The measurements of these orifices no differed significantly between the two genders ($P>0.05$).

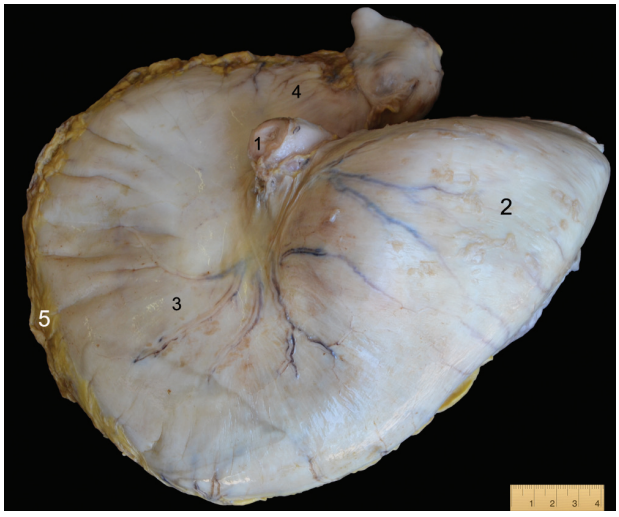

Figure 1. Diaphragmatic surface of the stomach. 1: Esophagus, 2: Saccus cecus ventriculi, 3: Corpus ventriculi, 4: Pylorus, 5: Curvatura ventriculi major.

The length of the small intestines varied between 7 and 8 m and the large intestines had a length of 4 m. The lengths of intestinal tracts were evaluated according to each gender (Table 1). There was no significantly difference between two genders in terms of intestine lengths ($P>0.05$) (Table 1). However, although statistically insignificant, length values pertaining to the females were generally higher than those pertaining to the males.

The duodenum was separated into cranial part with a dilatation or ampulla duodeni, descending part, transversal part and an ascending part before joining to jejunum. In just first part of the duodenum, we found papilla duodeni major and papilla duodeni minor. Both papillae were located very near to each other with a distance less than 1 cm and very near to the ostium pyloricum (Figure 3).

It was determined that donkey jejunum was too long and mobile structure (Figures 4, 5). The large part of the jejunum was found in the left half of the abdominal cavity and mixed with large parts of descending colon (Figure 2).

The cecum was divided in parts of basis, corpus and apex (Figures 4, 5). In the basis of the cecum, we detected the presence of the ileal and cecocolic ostia (Figure 6). The ileal ostium had a diameter of 2.25 ± 0.22 mm in the males and

Table 1. Mean values of the some digestive tract measurements according to genders (n=11).

Lengths of digestive tracts (cm)	Female (n= 4)			Male (n=7)		
	Mean±SE	Min.	Max.	Mean ±SE	Min.	Max.
Greater curvature of stomach	73.75±3.11	70	83	63.07±3.71	51.5	77.5
Lesser curvature of stomach	13.87±1.12[a]	12	17	10±0.37[b]	8	11
Duodenum	43.5±1.04	41	46	44.14±2.15	38	54
Jejunum	799.25±84.72	607	1020	631.57±35.43	476	790
Ileum	22.5±1.19	21	26	20.14±2.12	15	31
Cecum	68±6.10	56	79.5	76.35±5.05	54.5	94.5
Ventral colon	125.62±3.48	119	135	124.28±6	97	150
Dorsal colon	104.5±4.85	92	114	108.2±5.57	92	136
Rest of colon and rectum	112±5.95	97	123	101.78±5.2	86	128.5
Cecocolic fold	8.85±1.17[a]	5.8	11.5	12.01±0.71[b]	9.2	14.5

Different superscripts 'a' and 'b' in the same line indicate significant differences ($P<0.05$). (All measurements are in centimeters, SE = Standard error, Min. = Minimum, Max. = Maximum).

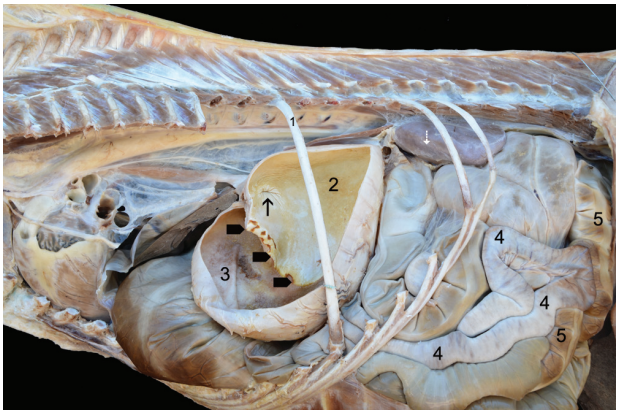

Figure 2. Left side topography after removing of abdominal and thoracic wall. 1: Thirteenth rib, 2: Aglandular part of the stomach, 3: Glandular part of the stomach, 4: Jejunum, 5: Colon descending, arrow: Ostium cardiacum, big black arrows: Margo plicatus.

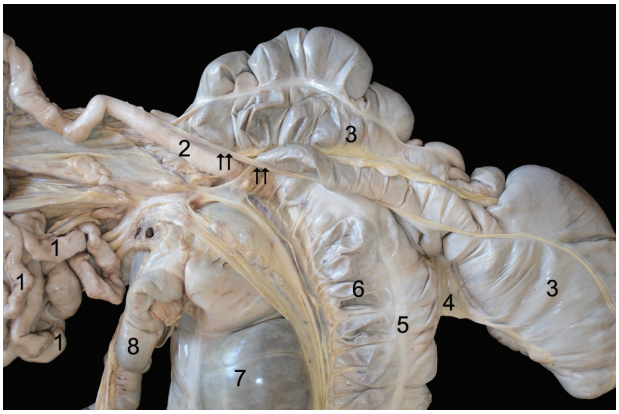

Figure 4. General view of the intestines. 1: Jejunum, 2: Ileum, 3: Cecum, 4: Cecocolic fold, 5: Tenia of the right ventral colon, 6: Right ventral colon, 7: Right dorsal colon, 8: Colon descending, arrows: Ileocecal fold.

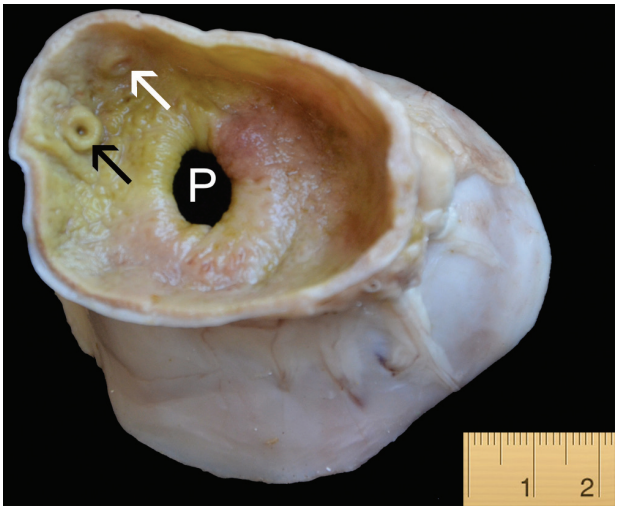

Figure 3. Internal view of the cranial part of the duodenum. White arrow: Papilla duodeni minor, black arrow: Papilla duodeni major, P: Ostium pyloricum.

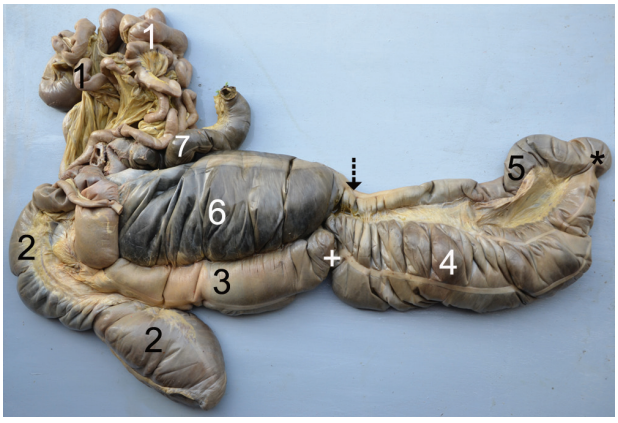

Figure 5. General view of the intestines. 1: Jejunum, 2: Cecum, 3: Right ventral colon, 4: Left ventral colon, 5: Left dorsal colon, 6: Right dorsal colon, 7: Colon descending, sternal flexure (+), pelvic flexure (*), diaphragmatic flexure (arrow).

3.1 ± 0.33 mm in the females. The cecocolic ostium was 2.08 ± 0.21 mm in and 1.72 ± 0.28 mm in diameter in the males and females. Two peritoneal folds including cecocolic and ileocecal folds fixed the cecum to another parts of the intestine (Figure 4). The cecocolic fold was short and situated between the tenia lateralis of the cecum and the first part of the ascending colon and their free border had a length of 12.01 ± 0.71 mm in the males and 8.85 ± 1.17 mm in females. The ileocecal fold was situated between the antimesenteric side of the ileum and the tenia dorsalis of the cecum and their free border had a length of 18.71 ± 0.65 mm in the males and 18.10 ± 1.03 mm in the females.

The ascending colon has more than 2 m length (Table 1) and this measurement had no differences between both sexes. The lengths of the ventral and dorsal parts were similar. The first part of the ascending colon, right ventral colon, was narrower near to the cecum, and after this part ascending colon markedly increased in diameter. Three flexures divided the ascending colon into four parts: right ventral, left ventral, left dorsal and right dorsal (Figures 5, 7). The sternal flexure was located between the two parts of the ventral colon. While the pelvic flexure was border between ventral and dorsal colon, the diaphragmatic flexure was border between the two parts of dorsal colon (Figures 5, 7). The diameters of sternal, diaphragmatic and pelvic flexures were 22.3, in 13.9, 18. 2 cm, respectively.

The caliber of the ventral colon was similar between the right and left parts, the left dorsal colon was the narrowest part and the right dorsal colon was the widest part of the ascending colon. The dorsal and ventral parts of the ascending colon were attached by the ascending mesocolon, and this mesocolon was wider between two left parts of ascending colon and narrower between right parts of the ascending colon (Figure 5).

The cecum, left ventral colon and right dorsal colon had more evident sacculations (*Haustra ceci* and *coli*) (Figure 5). Teniae numbers were constant in all animals as 4, 4, 4, 1, 3 and 2 for cecum, right ventral colon, left ventral colon, left dorsal colon, right dorsal colon and descending colon, respectively.

Figure 6. Internal view of the cecum. White arrow: ileal ostium, black arrow: cecocolic ostium.

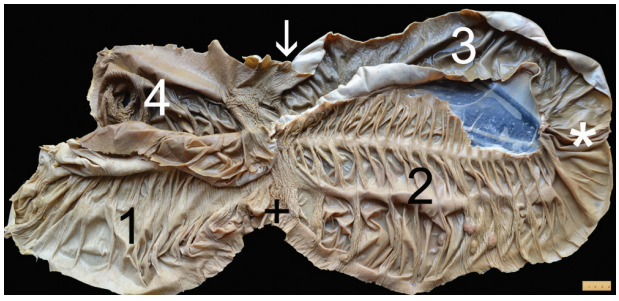

Figure 7. Internal view of the ascending colon. 1: Right ventral colon, 2: Left ventral colon, 3: Left dorsal colon, 4: Right dorsal colon, sternal flexure (+), pelvic flexure (*), diaphragmatic flexure (arrow).

The transverse colon was other constricted portion located between the ascending and descending colon. The descending colon had a long descending mesocolon and had two teniae in their surface, one fixed to the mesocolon and the other free one located on antimesocolic side.

4 Discussion

According to our knowledge, this is the first anatomical description of the gastrointestinal tract of the domestic donkeys. Although the gross anatomy of the intestines of the donkey was similar to the domestic horse in general, we detected some differences between these equine species.

The anatomy of the stomach of the donkey was similar to the horse in conformation (GETTY, 1975; BARONE, 1997; KÖNIG and LIEBICH, 2012). Barone (1997) reported that the empty weight of the stomach was 1.5 kg in donkey. In our study, this weight was almost smaller as much as one-third of value by reported Barone (1997). Similar to reports in horses (BARONE, 1997), aglandular cutaneous part of the stomach was white and glandular mucous part was reddish.

Barone (1997) mentioned that the length of the intestines of the horse was 22 m for small intestine and 8 m for large intestine, and length of the intestine of the donkey was 12 m for small intestine and 6 m for large intestine. Our length results were more than the reports of Barone (1997) textbook, but the relation between small and gross intestine was of 2 vs 1, similar to the information of Clauss, Hummel, Schwarm et al. (2008), and there was no striking difference between the equine species in agreement with these authors.

In the donkeys the duodenal papillae were located very near to each other and very close to the ostium pyloricum. In the horse, Barone (1997) reported that the major duodenal papilla is located at 15 cm from the pylorus on the dorsal wall of the duodenum and the minor papilla is located on ventral wall in opposite of the dorsal wall.

The number and disposition of cecal and colonic teniae were similar to those of horses (GETTY, 1975; BARONE, 1997; KÖNIG and LIEBICH, 2012). Burns (1992) studied the disposition and histology of the horse teniae and their relationship with their function. Some anatomical peculiarities are very important in relation to pathology such as equine acute abdomen. The transition of wide parts to each other by very narrow orifices, especially in the ileal and cecocolic ostium, so this can favor the obstructions or intussuception. Similar situation occurs in the flexures of ascending and transverse colon where the intestines have a subit change of direction.

The first part of the right ventral colon is described as very narrow and this part is mentioned by Barone (1997) with the name of "neck of the colon". This neck has length of 10 to 12 cm and diameter of 6 to 8 cm in the horse according to the same author. Clauss, Hummel, Schwarm et al. (2008) describe this part as isthmus of the cecocolical junction in Przewalski horse and zebra. This small part of the intestine is considered to contribute to the selective retention of particles in the cecum (DROGOUL, PONCET and TISSERAND, 2000). This isthmus is the reason why domestic horses can suffer from cecal impaction after excessive intake of insufficiently comminuted particles such as lawnmower grass, and standard surgical techniques have been developed to bypass this isthmus by cecocolical anastomosis in the case of cecal impaction (RAKESTRAW and HARDY, 2006). The transverse colon is other predilection site for obstruction or even rupture of the intestine in zebra, for example in case of enterolith distention (DECKER, RANDALL and PRIDEAUX, 1975).

According to Clauss, Hummel, Schwarm et al. (2008), this isthmus was described as general feature of the equine intestinal tract, but these authors dissected only one horse, one przewalski and one zebra. In addition, Clauss, Hummel, Schwarm et al. (2008) reported that this feature should also be described in species wild and domestic donkeys, and in this study we also described this part of the colon.

Similar to horses, the ascending colon of donkey was mobile within the abdomen, especially the left parts and the pelvic flexure. These parts have minor fixation and a wide ascending mesocolon between ventral and dorsal parts, these characteristics may favor displacements, torsion, strangulating or nonstrangulating.

Other parts of the intestine like jejunum and descending colon are high mobiles and may favor intussusceptions, inguinal hernia or internal herniation. In equines entrapment of jejunum (TURNER, ADAMS and WHITE, 1984) or ascending colon (SEGURA, GARZÓN, NOMEN et al., 1999; MARIEN, 1999) in the omental foramen is a frequent cause of colic or maybe in the so called hepatorenal recess (MARTIN and GUARDA, 1999).

5 Conclusion

In general we conclude that the anatomy of the gastrointestinal system of the donkey was similar to horses, in spite of some differences in dimensions, but we don't have similar morphometric works in horses in comparison. For better understanding of the gastrointestinal anatomy of the digestive tract and similarities or differences with other equine species, specific future researches in donkey are necessary in relation to peritoneal folds, topography, laparoscopic anatomy and histology of the intestine and their teniae.

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