



Research Journal of **Veterinary Sciences**

ISSN 1819-1908



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Foetal Circulation of the Dromedary Camel (*Camelus dromedarius*)

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ABSTRACT

In this study, we examined 22 dromedary camel foetus (101-393 days of gestation). Blood enters the fetus through 2 large umbilical veins that unite in a large intra-abdominal venous sinus, about 1-8 cm from the liver and then drains into the liver via a single vein. The umbilical vein is joined by the portal vein and empties into the ductus venosus. The ductus venosus then join the vena cava caudalis intrahepatically. The hepatic sinusoids join some branches of the portal vein. Beyond the origin of the external iliac arteries, 2 large umbilical arteries which are branches of the aorta abdominalis, reach the placenta where they divide into smaller branches. This study was conducted to investigate the foetal circulation of the dromedary camel during the 3 trimesters. specimens were dissected either in a fresh state or after intravenous fixation in 10% formalin. Five specimens were injected with vinyl acetate. In the camel fetus, blood from the placenta is carried to the fetus by 2 large umbilical veins that empty in an intra-abdominal venous sinus; 1 vein emerges and enters the liver.

Key words: Ductus venosus, ductus arteriosus, venous sinus

INTRODUCTION

In the mammalian foetus, blood passes from the placenta and enters the foetus via a single large umbilical vein within the umbilical cord. Blood from the umbilical vein goes to the liver. Most of the blood continues via the ductus venosus into the vena cava caudalis and finally into the right atrium (Kent and Carr, 2000) while a small amount of blood enters the liver sinusoids and then the vena cava caudalis. From the right atrium, the majority of blood passes through an interatrial foramen (foramen ovale) into the left atrium, bypassing the lungs. From the left atrium, blood is pumped to the left ventricle and then to the systemic circulation. Only a small quantity of deoxygenated blood returns to the left atrium from the lungs and mixes with the blood that comes in through the foramen ovale. Most of the blood returning to the right atrium from the major venous channels enters the right ventricle and is pumped into the pulmonary trunk; all but a small amount of this blood is shunted away from the lungs via the ductus arteriosus into the aortic arch (Kent and Carr, 2000). Blood is returned to the placenta through 2 large umbilical arteries (Getty, 1975). Barclay *et al.* (1945) created a figure of a transverse section of the umbilical cord of a dromedary fetus of unknown age, illustrating the allantoic duct, the yolk sac remains and amniotic pustules. Morton (1961), Benirschke and Miller (1982), Fowler and Olander (1990), Ghazi *et al.* (1994) and Tibary and Anouassi (1997) referred to, but did not describe the entire dromedary fetal circulation. In light of the absence of a complete description of the dromedary camel fetal circulation, this study examined the fetal circulation during the 3 trimesters of the dromedary camel *Camelus dromedarius*.

MATERIALS AND METHODS

Fifty foetus were obtained immediately after their mothers were slaughtered. The ages of the foetus were estimated according to the equation $Y = 0.366X - 23.99$ depending on the Curved Crown-rump Length (CVRL), where, X = unknown fetal age in days and Y = body dimensions (cm) (Elwishy *et al.*, 1981). Thirty specimens were dissected either in a fresh state or after intravenous fixation in 10% formalin for examining the route of blood within the embryo and for measuring the dimensions of the ductus venosus and ductus arteriosus. Five specimens were injected with vinyl acetate, according to the method reported by Tompsett (1970). This technique was employed for studying the detailed distribution of blood vessels within the liver. The fresh specimens were used for studying the distribution of the blood vessels within the liver and for examining the relationship between the 2 umbilical veins before they enter the liver, their location in the umbilical cord and their ramifications in the placenta.

RESULTS

In the camel fetus, blood from the placenta is carried to the fetus by 2 large umbilical veins that empty in an intra-abdominal venous sinus; 1 vein emerges and enters the liver. The umbilical vein joins the portal vein within the liver and empties into the ductus venosus (Fig. 1). The ductus venosus then joins the vena cava caudalis intrahepatically. Some branches of the portal vein join the hepatic sinusoids. The pulmonary trunk emerges from the right ventricle and joins the aortic arch through the ductus arteriosus. Two large umbilical arteries which are branches from the aorta abdominalis beyond the origin of the external iliac arteries, reach the placenta where they divide into smaller branches.

Umbilical cord and vessels: The umbilical cord of the dromedary camel contains 4 blood vessels (2 arteries and 2 veins) and a large allantoic duct covered with the amnion (Fig. 2). The amnion has bracteolae amnioticae, is white to yellow in color and varies in size; this makes the surface



Fig. 1: Photograph of a cast of foetal blood vessels during second trimester, showing V: Umbilical veins, R: Umbilical arteries S: Sinus region, DV: Ductus venosus, DA: Ductus arteriosus, A: Aorta and C: Caudal vena cava

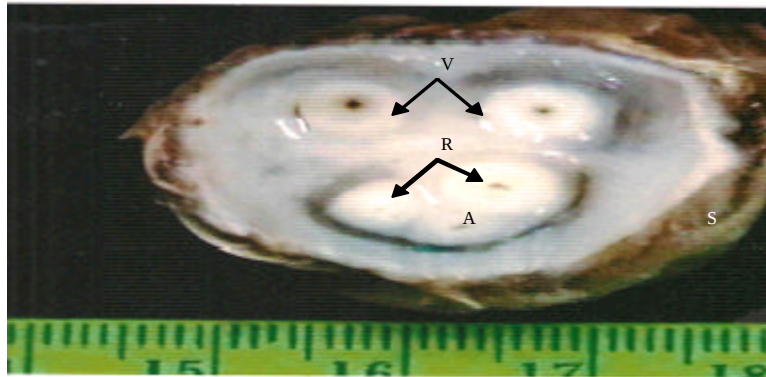


Fig. 2: Photograph of a cross section of an umbilical cord consisting of two V: Umbilical veins, R: Two umbilical arteries and A: A large allantoic duct. The skin (S) covered the proximal part of the umbilical cord near the navel

rough, except at the first quarter near the navel which is covered with skin (Fig. 2). The umbilical vessels are convoluted and form clockwise spirals along the umbilical cord. The length and diameter of the cord increase progressively with gestation (age). The blood vessels are buried within the mesenchyma umbilicalis. More mesenchyma umbilicalis are observed at the proximal part of the cord than at the middle and distal parts. The allantoic duct exhibits tubular invaginations that extend from the hindgut to the body stalk; it has both intra- and extra-embryonic parts. The amniotic membrane covers the allantois at its distal end and the 2 membranes fuse together to form the allantoamniotic membrane. The allantoic duct is large in caliber at the distal part of the umbilical cord and occupies about 20% of the volume of the cord. The allantoic duct divides the umbilical cord at its distal part into 2 almost equal halves. The allantoic duct gradually decreases in caliber toward the navel and occupies about 3% of the volume of the cord; thus, the circumference of the cord varies. The 2 umbilical veins have different sizes; they emerge from the placenta and unite in a venous sinus near the liver: 0.5 cm from the liver during the first trimester and 8 cm during the third trimester (Fig. 3). The venous sinus is located near the abdominal wall; it contacts the wall during the third trimester. The 2 veins proceed together until they enter the abdominal cavity. The locations of the umbilical veins and arteries vary along the length of the cord. At the umbilical ring, the 2 veins proceed together cranially toward the liver; the 2 arteries together with the allantoic duct are situated between the veins and proceed caudally toward the bladder. At the proximal part, the 2 veins are situated at the periphery of the cord while the 2 arteries are at the center of the cord near the allantoic duct (Fig. 2). At the middle part of the cord, the 2 veins and 2 arteries are found on opposite sides; the allantoic duct is found at the center of the cord. At the distal part, 1 artery and 1 vein proceed together toward 1 of the 2 horns of the placenta; the large vein together with the large artery proceed toward the left horn while the small vein together with the small artery proceed toward the right horn; the allantoic duct is at the center of the cord. The large artery gives rise to many branches in the left horn. Moreover, the large vein is formed by the union of veins that are satellites of the branches of the artery.

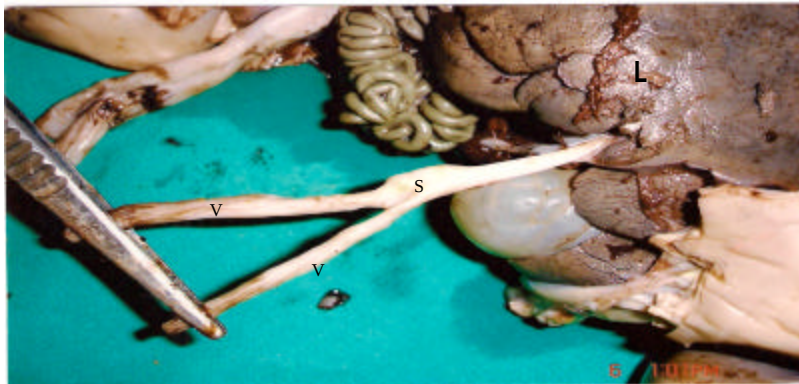


Fig. 3: Photograph showing two V: Umbilical veins uniting in a venous sinus (S), before entering the liver (L) during second trimester

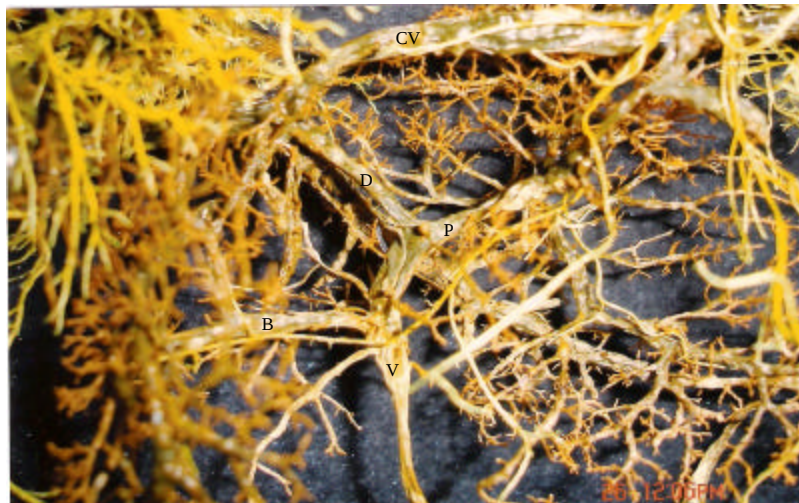


Fig. 4: Photograph of a cast of foetus during second trimester illustrating umbilical vein (V) uniting with the portal vein (P) to form the ductus venosus (D). Note the caudal vena cava (CV) and a branch from the umbilical vein (B)

Ductus venosus: The ductus venosus is a straight tubular duct that begins from the union of the left main portal and umbilical veins. The duct passes between the left lateral liver lobe and the papillary process of the caudate lobe and joins the vena cava caudalis at its ventral surface, caudal to the left hepatic vein. The ductus venosus is devoid of branches; it forms an acute angle with the hepatic vein and vena cava caudalis and is almost perpendicular to the portal vein (Fig. 4). The ductus venosus is located opposite the portal vein, caudal to the right hepatic vein and parallel to the umbilical cord. The length and diameter of the ductus venosus increase progressively with advancing age (gestation).

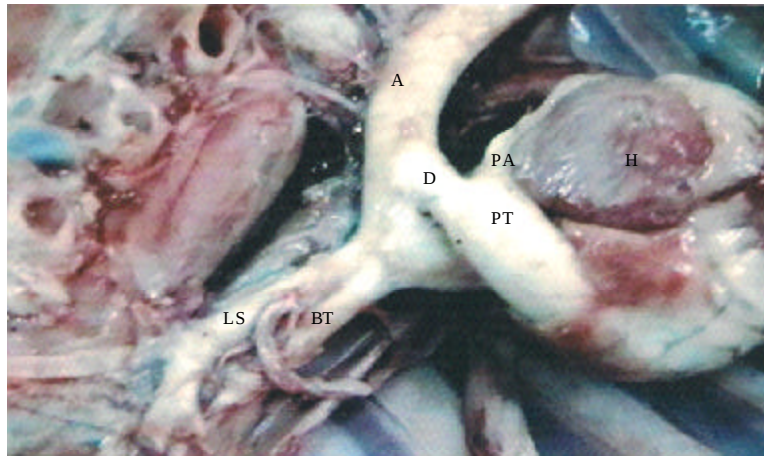


Fig. 5: Photograph showing the D: Ductus arteriosus, PT: Pulmonary trunk, PA: Pulmonary artery, A: Aorta, H: Heart, LS: Left subclavian artery and BT: Brachiocephalic trunk



Fig. 6: Photograph a cast of foetus during second trimester demonstrating PT: Pulmonary trunk, PA: Pulmonary artery, DA: Ductus arteriosus, A: Aorta, LS: Left subclavian artery and BT: Brachiocephalic trunk

Ductus arteriosus: The ductus arteriosus connects the pulmonary trunk to the left side of the aortic arch (Fig. 5). It is a straight conduit devoid of branches; it is perpendicular to the pulmonary trunk and forms an acute angle with the aorta. The origin of the ductus arteriosus at the pulmonary trunk projects as a cone-shaped tip toward the aorta. The ductus arteriosus then passes within the wall of the aorta before they become confluent (Fig. 6).

DISCUSSION

In most mammals, blood passes from the placenta and enters the fetus via a single large umbilical vein embedded in the umbilical cord (Kent and Carr, 2000). In the camel fetus, we found that blood from the placenta is carried to the fetus by 2 large umbilical veins that empty into a venous sinus; a single vein subsequently emerges and enters the liver. The umbilical vein is joined by the portal vein and empties into the ductus venosus. In this respect, the camel is similar to the lion and hippopotamus (Benirschke and Miller, 1982). The remaining part of the fetal circulation of the camel is similar to that of the other mammalian species including ruminants, carnivores, pigs and equines (Kent and Carr, 2000; McGeady *et al.*, 2006) as well as humans (Sadler, 1995). In the present study, we found that blood in the aorta is returned to the placenta of the camel via 2 large umbilical arteries that arise from the aorta abdominalis after giving rise to the external iliac arteries; this finding corroborates the findings reported by Smuts and Benzuiden Hout (1987) in the dromedary camel. However, in equines, bovines, dogs, pigs and goats, blood is returned to the placenta via 2 large umbilical arteries that are branches of the internal iliac arteries (Getty, 1975).

Umbilical cord and its vessels: The umbilical cord of the dromedary camel is long and contains 4 blood vessels (2 arteries and 2 veins) as well as a large allantoic duct similar to those of some wild animals such as the African lion, Speke's gazelle, the alpine ibex (Benirschke and Miller, 1982) and the Bactrian camel (Tibary and Anouassi, 1997). In the horse, the cord contains 2 arteries: a vein and the allantoic duct (Whitwell, 1975; Hong *et al.*, 1993). However, McGeady *et al.* (2006) reported that the body of the cord comprised 2 fused umbilical arteries and veins each in the mare and sow. In the present study, the umbilical cord was completely covered with the amnion except at the navel which was covered by skin; this finding corroborates those reported by Morton (1961), Ghazi *et al.* (1994) and Mohammed (2008) in the same species. In horses, dogs and cats, the umbilical cord is divided into amniotic and allantoic portions (Noden and Lahunta, 1985; McGeady *et al.*, 2006). In the present study, the amniotic portion of the umbilical cord of the dromedary camel was longer than the allantoic portion; this finding is similar to that reported by Whitwell (1975) in the horse. Wild animals (e.g., Speke's gazelle, the alpine ibex, the Nile hippopotamus) and the camel all have numerous bracteolae amnioticae of squamous metaplasia on the surface of their umbilical cord (Morton, 1961; Benirschke and Miller, 1982). We observed that bracteolae amnioticae cover the surface of the umbilical cord. Malas *et al.* (2003) reported a positive correlation between gestation age and umbilical vessel measurements; this also holds true for the dromedary camel in the present study. Tibary and Anouassi (1997) stated that the umbilical cord is up to 110 cm long in the Bactrian camel while that of the llama is 30-50 cm long and 2-3 cm in diameter (Fowler and Olander, 1990). In this study, the length of the cord in the dromedary camel was up to 70 cm long (Table 1). The length of the cord increases with fetus weight and gestational age up to the time of delivery (Fowler and Olander, 1990). Tibary and Anouassi (1997) reported that there are usually many clockwise spirals in the umbilical cord of the camel which is corroborated by the findings reported in the present study. The immature llama fetus has a few cord spirals (Fowler and Olander, 1990). Two umbilical veins pass through most of the length of the umbilical cords of carnivores and ruminants and subsequently join to form the left umbilical vein before entering the body of the embryo (Noden and Lahunta, 1985). We noted 2 umbilical veins in the dromedary camel along the entire length of the umbilical cord. The 2 veins merged and united after entering the abdominal cavity in the venous sinus. This finding is corroborated by the findings reported by Hediger (1962) and Benirschke and Miller (1982), in the hippopotamus,

Table 1: Age of the foetus and measurements of the umbilical cord, ductus venosus and ductus arteriosus of dromedary camel during the three trimesters (trimester = 4 months) of pregnancy

CVR. L. (cm)	Age (days)	Um.co.L (cm)	Circum (cm)	D.V.L (mm)	D.A.L (mm)
13	101	-	-	-	2
16	109	5	3.0	5	3
17	111	7	3.5	5	3
19	117	11	3.5	-	4
28	142	14	4.0	13	6
31	150	20	4.5	12	6
33	155	22	5.0	11	-
40	174	22	7.0	14	-
43	183	27	7.0	17	5
44	185	27	7	-	-
51	204	30	7.5	-	-
52	207	30	7.5	17	10
53	210	30	7.5	15	11
57	221	28	7.5	17	10
62	234	31	8.0	20	12
68	254	40	8.0	-	-
72	262	47	8.0	-	14
81	286	-	-	-	14
82	289	58	8.0	30	18
84	295	55	8.0	-	18
102	344	70	8.0	-	-
120	393	72	8.0	-	-

CVR. L.: Curved crown-rump length, Um. co. L: Length of the umbilical cord, Circum: Circumference of the umbilical cord, D.V.L: Ductus venosus length, D.A.L: Ductus arteriosus length

in which the 2 veins join immediately after entering the abdomen forming a single vein. The hippopotamus has an epitheliochorial placenta with diffuse villi (Benirschke and Miller, 1982), similar to the camel placenta; this type of placenta may be related to this particular pattern of umbilical veins and their fusion. Although the African lion has an endotheliochorial placenta (Benirschke and Miller, 1982; Dantzer, 1999), these 2 veins in the abdomen: 1 to the right of the liver hilus and the other to the left of the vena cava caudalis (Benirschke and Miller, 1982). In the horse and pig, the umbilical veins fuse within the amniotic part of the cord while they fuse upon entering the abdominal cavity in other species (McGeady *et al.*, 2006). In the present study, we report 2 veins in the dromedary camel; this may be related to the type of the camel placenta which is represented by the endometrium and 2 bilaminar membranes in the fetal side (the chorioamniotic and chorioallantoic membranes), as reported by Mohammed (2008). Morton (1961) and Fowler and Olander (1990) reported similar findings in 3 species of Camelidae and llamas. In this study, the left uterine horn was observed to have received large vessels (umbilical veins and arteries) which may be due to the fact that all foetus were found in the left uterine horn.

Allantoic duct: In the umbilical cord, the allantoic duct is a sac-like structure webbed with blood vessels that is primarily involved in nutrition and excretion. It collects liquid waste from the embryo and is involved in the exchange of gases used by the embryo (Downs, 1998). Mohammed (2008) reported that the amniotic membrane of the dromedary camel covers the allantois and that the 2 membranes fuse together to form the allantoamniotic membrane at the distal end of the umbilical

cord. The results of the present study corroborate the findings reported by Mohammed (2008). In the present study, the allantoic duct in the dromedary camel was larger in caliber at the distal part of the cord and gradually decreased in caliber toward the navel.

Ductus venosus: In pups, the ductus venosus is a straight vessel that arises from the left main portal vein and terminates in an ampulla into which the left hepatic and phrenic veins drain. The ampulla finally joins the vena cava caudalis (Burton and White, 1999). In the present study, the ductus venosus in the dromedary camel was observed to be a straight tubular duct that begins from the union of the left main portal vein and the umbilical vein and joins the vena cava caudalis caudal to the left hepatic vein.

Ductus arteriosus: During fetal development, the ductus arteriosus shunt protects the lungs from being overworked and strengthens the right ventricle (Zahaka and Patel, 2002). In the present study, the dromedary camel ductus arteriosus was a muscular shunt that connected the pulmonary trunk to the aortic arch similar to that observed in other domesticated mammals.

CONCLUSION

In the camel fetus, we found that blood from the placenta is carried to the fetus by 2 large umbilical veins that empty into a venous sinus; a single vein subsequently emerges and enters the liver (In this respect, the camel is similar to the lion and hippopotamus) and this may be related to the type of the camel placenta which is represented by the endometrium and 2 bilaminar membranes in the fetal side (the chorioamniotic and chorioallantoic membranes). The amniotic portion of the umbilical cord of the dromedary camel was longer than the allantoic portion.

ACKNOWLEDGMENTS

I would like to express my cordial thanks and sincere gratitude to Prof. Dafalla. I. Osman for his continuous advises criticism, stimulating supervision and unfailing help which made this study possible.

Also I would like to express my deepest gratitude and thanks to Prof. Ali. A. M. Taha, staff members, my colleagues, senior technicians and all employees in the Anatomy Department, Faculty of Veterinary Medicine, University of Khartoum. I really appreciate the financial support provided by the International Centre for Faith Research, Khartoum, Sudan.

The financial support provided by the University of Khartoum enabled me to carry out this study.

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