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ABDOMINAL SPLANCHNIC ARTERIAL MAPPING OF *Cerdocyon thous:* HELPING IN SURGICAL PLANNING

MAPEAMENTO ARTERIAL ESPLÂNCNICO ABDOMINAL DE Cerdocyon thous: AUXILIANDO NO PLANEJAMENTO CIRÚRGICO

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ABSTRACT. Detailed knowledge of the anatomy of wild animals is essential for effective clinical and surgical procedures, especially given the growing number of specialists in wild animals and interventions carried out on these species. Thus, we mapped the abdominal splanchnic arterial vasculature of *Cerdocyon thous*, with the aim of contributing to professionals who work directly with wild animal surgery. In specimens whose arterial system was evidenced by stained latex, we identified anatomical variations when compared to other species. The jejunal arteries issued nine branches, and the caudal abdominal phrenic and cranial arteries arose from the common branch of the abdominal aorta. The left renal artery was bifurcated in one specimen, in another, the left renal artery was double and penetrated the renal pelvis. One specimen had the right kidney more caudally in relation to the left kidney, similar to the corresponding renal artery. The left renal artery originated from the left adrenal artery, and the right internal iliac artery was bifurcated. Given these findings, we understand such knowledge is crucial in the clinical and surgical care of this species, as it will allow for the greatest success of the professionals involved.

Keywords: Anatomy; abdominal aorta; arteries; grab eating fox; canids

RESUMO. O conhecimento detalhado da anatomia de animais silvestres é essencial para procedimentos clínicos e cirúrgicos eficazes, especialmente devido ao crescente número de especialistas em animais silvestres e intervenções realizadas nessas espécies. Assim, mapeamos a vasculatura arterial esplâncnica abdominal de *Cerdocyon thous*, com o intuito de contribuir com os profissionais que trabalham diretamente com a cirurgia de animais silvestres. Nos espécimes cujo sistema arterial foi evidenciado pelo látex corado, identificamos variações anatômicas quando comparados a outras espécies. As artérias jejunais emitiram nove ramos, e as artérias frênicas abdominais caudais e craniais originaram-se do tronco comum da aorta abdominal. A artéria renal esquerda era bifurcada num espécime, em outro, a artéria renal esquerda era dupla e penetrava na pelve renal. Um espécime apresentava o rim direito mais caudalmente em relação ao rim esquerdo, à semelhança da artéria renal correspondente. A artéria renal esquerda originava a artéria adrenal esquerda e a artéria ilíaca interna direita era bifurcada. Diante desses achados, entendemos que tal conhecimento é fundamental no atendimento clínico e cirúrgico dessa espécie, pois permitirá o maior sucesso dos profissionais envolvidos.

Palavras-chave: Anatomia; aorta abdominal; artérias; cachorro-do-mato; canídeos

INTRODUCTION

Cerdocyon thous, popularly known as the bush dog, belongs to the Phylum Chordata, Class Mammalia, Family Canidae, Order Carnivora, and has five subspecies, of which three are found in Brazil: *C. thous thous*, in the North and Northeast, *C. thous entrerianus*, in the South and Southeast, and *C. thous azarae*, in the Southeast, Midwest, North, and Northeast (BERTA, 1982).

This carnivore is an omnivorous animal with robust dimensions, measuring 1 m in length and weighing between 3.7 kg and 11 kg. It has a coloration ranging from gray to yellowish and a spot darker than the fur all over the back and tail, while it weighs between 5 kg and 8 kg (PEÇANHA et al., 2020).

Cerdocyon thous is one of the mammalian species victims of roadkill, indiscriminate devastation, poaching, and diseases (JUSI et al., 2011) owing to urbanization. Such factors risk the survival of the species, thereby causing concern and a possible inclusion of these animals in the list of threatened species (WEBER et al., 2020).

The abdominal aorta is the continuation of the thoracic aorta, which in turn comes from the aortic arch. It becomes known as the abdominal aorta when it crosses the aortic hiatus, located in the most dorsal portion of the diaphragm, through which the thoracic duct also passes (DYCE et al., 2019). The organs in both the abdominal and pelvic cavities are irrigated by collateral branches originating from the abdominal aorta, and sometimes some of these branches can irrigate more than one organ or part of a given organ (KÖNIG; LIEBICH, 2021).

The arterial system, the target of this study, is of paramount importance in the performance of clinical procedures, some specific examinations, and surgical approaches, especially in situations of transplantation, trauma, embolism, angioplasty, and total or partial organ removal (SILVA et al., 2014).

Thus, we consider that the more accurate the information about the topographic relationship between organs and the branches of the abdominal aorta, the better the welfare and survival of the poorly investigated species that require medical intervention.

METHODOLOGY

We studied 12 adult cadavers of *Cerdocyon thous* (grab eating fox), three males and nine females, all victims of trampling in a mining area (Bauxita Mine, Paragominas, Pará, Brazil), belonging to the collection of the Animal Morphology Research Laboratory (LaPMA) of the Federal Rural University of Amazonia - UFRA, Pará, Brazil, under the authorization of SISBIO No. 23401-8.

The animals were appropriately catalogued by the laboratory and kept frozen. After thawing the specimens in running water to map the arteries, we performed neoprene latex perfusion, directly into the left common carotid artery, after prior dissection, followed by the fixation of the cadavers with 10% formaldehyde. After one week, the viscera were exteriorized to map the entire splanchnic arterial vasculature of each individual.

The nomenclature used was based on International Committee on Veterinary Gross Anatomical Nomenclature (2017).

RESULTS AND DISCUSSION

As the available literature on abdominal splanchnic arterial vascularization in wild carnivores is scarce, it is important to make comparisons with species of other orders, thereby promoting a better level of comparison and enriching the literature.

We realized that it is not possible to simply extrapolate previous knowledge on the abdominal splanchnic arterial arrangement of domestic dogs to *Cerdocyon thous*, considering that we found such variations, which may influence decision-making and approaches to operative sites during surgical procedures in the abdominal cavity of this species.

In general, immediately dorsal to and after the aortic hiatus, the abdominal aorta emerged in the craniocaudal direction. It presented as collateral branches and derivations: the celiac artery, left gastric artery, splenic artery, hepatic artery, right gastric artery, gastroduodenal artery, cranial pancreatic-duodenal artery, right gastroepiploic artery, splenic branches, caudal pancreatic-duodenal artery, cranial mesenteric artery, ileal artery, jejunal arteries, mesenteric ileal branches, cecal artery, ileocolic artery, right colic artery, middle colic artery, left colic artery, common colic artery, caudal phrenic artery, cranial abdominal artery, right renal artery, left renal artery, right adrenal artery, left adrenal artery, right gonadal artery, left gonadal artery, caudal mesenteric artery, cranial rectal artery, right deep iliac circumflex artery, left deep iliac circumflex artery, right external iliac artery, left external iliac artery, right internal iliac artery, left internal iliac artery, and median sacral artery (Figure 1).

The arrangement and sequence of the abdominal splanchnic arteries found in *Cerdocyon thous* is also supported by what is described in the literature for domestic dogs (SILVA et al., 2009; DYCE et al., 2019) and in *Lycalopex vetulus* (SILVA et al., 2018). However, there are some variations, as shown in the illustrative diagram (Figure 1).

As in many animals studied to date, in *Cerdocyon thous* the abdominal aorta begins by crossing the aortic hiatus dorsal to the abdominal cavity, with the caudal vena cava arranged to the right (PINHEIRO et al., 2014; FARIA et al., 2016; DYCE et al., 2019; CASTANO et al., 2022).

The celiac artery of *Cerdocyon thous*, caudal to the diaphragm, gave rise to the left gastric, splenic, and hepatic arteries (Figure 2B and 2C). The left gastric artery gave off the esophageal branches that irrigated a part of the lesser curvature.

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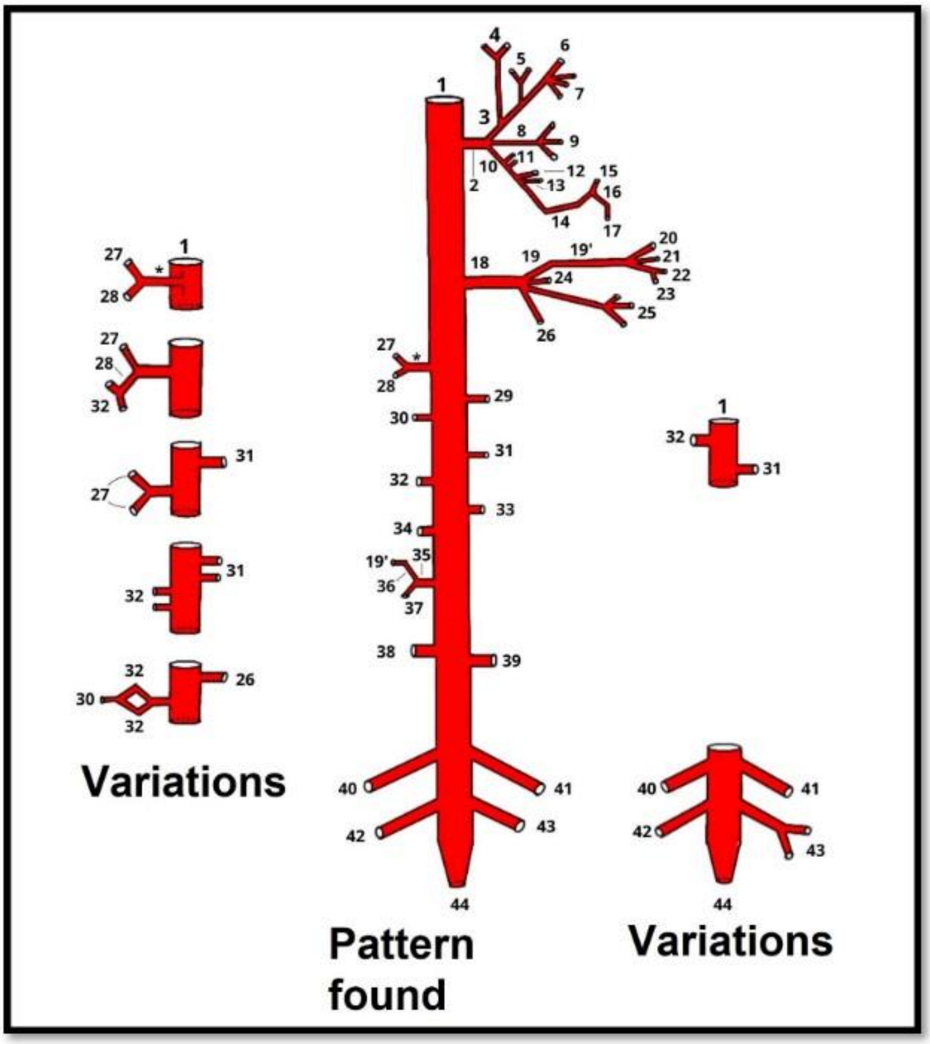
Figure 1 - Schematic mapping of the splanchnic vasculature of *Cerdocyon thous*. 1. Abdominal aorta, 2. celiac artery, 3. splenic artery, 4. splenic branches, 5. pancreatic branches, 6. left gastroepiploic artery, 7. short gastric arteries, 8. left gastric artery, 9. esophageal branches, 10. hepatic artery, 11. hepatic branches, 12 - 13. right gastric artery, 14. gastroduodenal artery, 15. cranial pancreaticoduodenal artery, 16. right gastroepiploic artery, 17. splenic branch, 18. cranial mesenteric artery, 19. ileocolic artery, 19. middle colic artery, 20. right colic artery, 21. colic branch, 22. ileal mesenteric artery, 23. cecal artery, 24. caudal pancreaticoduodenal artery, 25. jejunal arteries (nine in each animal studied), 26. ileal artery, *common branch, 27. caudal phrenic artery, 28. abdominal artery, 29. right adrenal artery, 30. left adrenal artery, 31. right renal artery, 32. left renal artery, 33. right gonadal artery, 34. left gonadal artery, 35. cranial mesenteric artery, 36. left colic artery, 37. cranial rectal artery, 38. left deep iliac circumflex artery, 39. right deep iliac circumflex artery, 40. left external iliac artery, 41. right external iliac artery, 42. left internal iliac artery, 43. right internal iliac artery, and 44. median sacral artery.



Source: Author.

The splenic artery emitted its branches as well as short gastric arteries. The hepatic artery had the following branches: hepatic branches, right and left gastric artery, gastroduodenal artery, pancreaticoduodenal artery (Figure 2A-C).

The celiac artery is the first branch of the abdominal aorta localized in *Cerdocyon thous*, as has also been described in domestic dogs (ABIDU-FIGUEIR et al., 2005), *Leopardus pardalis* (PINHEIRO et al., 2014), *Aotus azarae infulatus* (FARIA et al., 2016), *Sapajus apella*

(FURTADO et al., 2017), *Lycalopex vetulus* (SILVA et al., 2018) and *Puma concolor* (CASTANO et al., 2022).

Corroborating the findings in domestic dogs (ABIDU-FIGUEIR et al., 2005, DYCE et al., 2019), *Galea spixii* (OLIVEIRA et al., 2017), *Tamandua tetradactyla* (MACEDO et al., 2013), rabbits (BAVARESCO et al., 2013), *Myocastor coypus* (CULAU et al., 2010) and *Puma concolor* (CASTANO et al., 2022), in *Cerdocyon thous* the celiac artery originated the left gastric artery, generating an esophageal branch; the splenic artery, which issued splenic, the left gastroepiploic artery, and the short gastric arteries, and the hepatic artery from which the hepatic branches, right gastric artery, and gastroduodenal artery emerged; the latter bifurcated into the cranial pancreatic duodenal artery and right gastroepiploic artery, which anastomosed with the left gastroepiploic artery (Figure 2A-D).

In this sense, we emphasize that careful observation of the vascularization of these branchs is an essential surgical approach in the stomach, spleen, and liver (KONIG; LIEBICH, 2021), because improper ligation can cause ischemia and/or necrosis in the aforementioned organs.

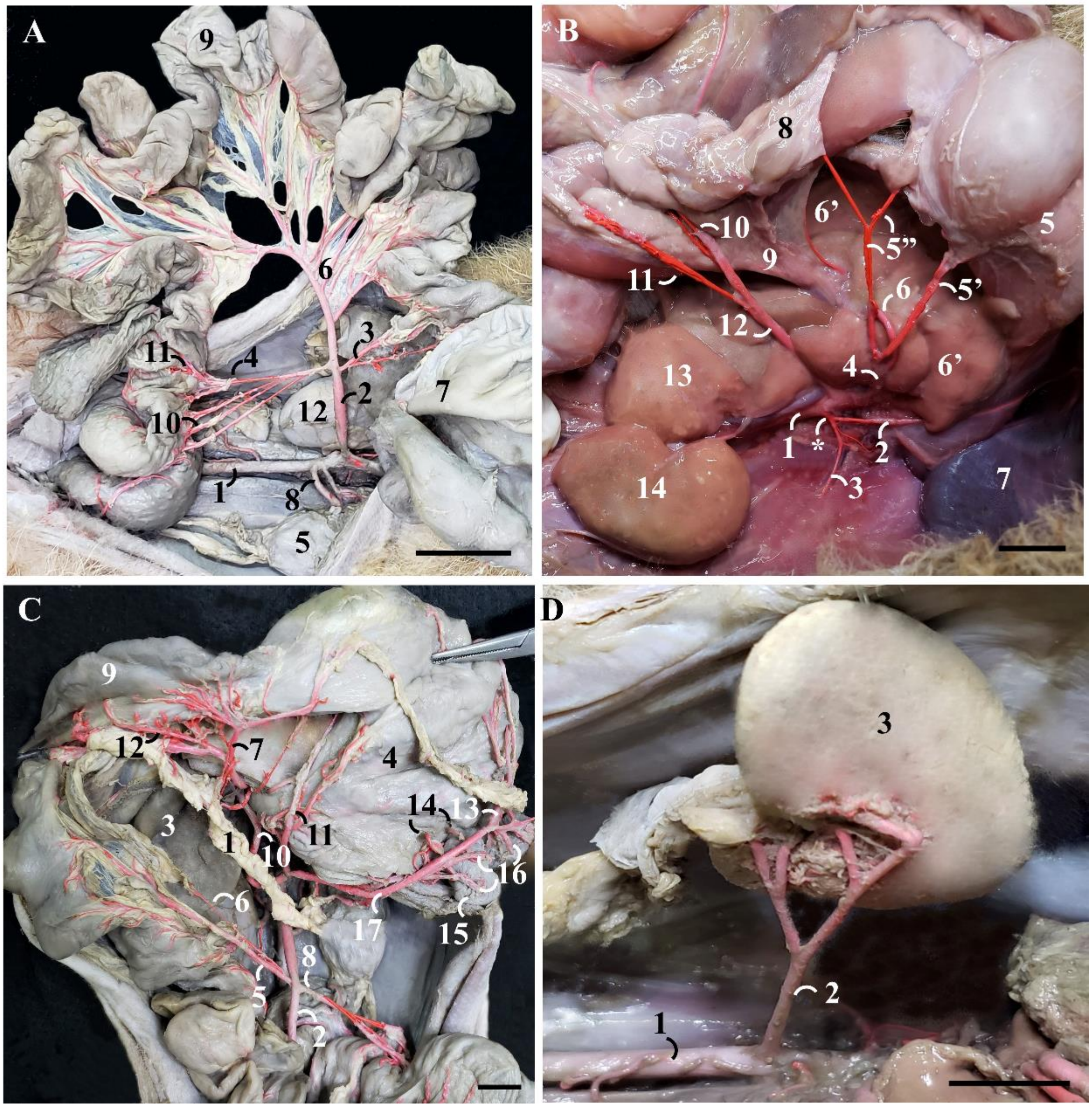
Then, we identified the cranial mesenteric artery, located caudally to the celiac artery, as has been described in domestic animals (DYCE et al., 2019), *Myocastor coypus* (CULAU et al., 2010) and *Aotus azarae infulatus* (FARIA et al., 2016), originating from the ileocolic, caudal pancreatic duodenal, jejunal (nine in all subjects), and ileal arteries (Figure 2A and 2B). Apparently, *Cerdocyon thous* have fewer jejunal arteries than domestic dogs (11 to 17 branches) (DYCE et al., 2019). However, although the cranial mesenteric artery is expected to be immediately caudal to the celiac artery, it is possible for there to be an anatomical variation, in which both are united in a common branch called the celiac-mesenteric branch, as described in a domestic dog (SCHMIDT; SCHOENAU, 2007; MAGNO et al., 2009). In only one of the animals studied, the common branch was disposed on the dorsal face of the abdominal aorta (Figure 2A).

Similar to domestic carnivores (DYCE et al., 2019), in *Cerdocyon thous*, caudal to the cranial mesenteric artery, a common branch arises from the lateral aspect of the abdominal aorta (Figure 2B), that bifurcates, giving rise to caudal phrenic and cranial abdominal arteries. However, in *Myocastor coypus*, Culau et al. (2008) called this arterial branch the phrenic-abdominal branch. We highlight only one specimen with a common phrenic-abdominal branch, which also originated from the caudal phrenic and cranial abdominal arteries (Figure 2B).

As for the renal arteries, as described in the classical literature for domestic carnivores (KÖNIG; LIEBICH, 2021) and some wild animals such as *Myocastor coypus* (CULAU et al., 2008), *Procyon cancrivorus* (BARCELOS et al., 2012), *Aotus azarae infulatus* (FARIA et al., 2016) and *Lycalopex vetulus* (SILVA et al., 2018), penetrate the renal hilum in the unpaired condition. In *Cerdocyon thous* in one specimen, the left renal artery divided into two (bifurcation), and each one subdivided into two more (Figure 2D).

While in 11 Cerdocyon thous analyzed, the renal arteries also behaved in the same way as the kidneys, i.e., the right was more cranial than the left, in one specimen, in addition to being double (both right and left), the left renal artery was arranged more cranial than the right, following the positioning of the corresponding kidneys (Figure 3A), as described by Silva et al., (2009) in domestic dogs, Abidu-Figueiredo et al., (2009) in goats, Romagnolli et al., (2010) in pigs, Pestana et al., (2011) in domestic cats, Barcelos et al. (2012) in *Procyon cancrivorus* and Almeida et al., (2013) in rabbits, Pinheiro et al., (2014) in *Leopardus pardalis*.

Figure 2 - Photomacrograph of the abdomen of *Cerdocyon thous*, ventral view. **A**: 1- abdominal aorta; 2- cranial mesenteric artery; 3- caudal pancreatic duodenal artery; 4- cecal artery; 5- left kidney; 6- jejunal arteries; 7- stomach; 8- left renal artery; 9- jejunum; 10- middle colic artery; 11- ileocolic artery; 12- right kidney. **B**: 1- abdominal aorta; 2- caudal phrenic artery; 3- cranial abdominal artery; *- phrenic-abdominal branch 4- celiac artery; 5- stomach; 5'- left gastric artery; 5"- right gastric artery; 6- liver; 6'- hepatic artery; 7- spleen; 8- duodenum; 9- pancreas; 10- cranial pancreatic duodenal artery; 11- right colic artery; 12- cranial mesenteric artery; 13- right kidney; 14- left kidney. **C**: 1- pancreas; 2- celiac artery; 3- liver; 4- stomach; 5- right colic artery; 6- cecal artery; 7- cranial pancreatic duodenal artery; 8- caudal pancreatic duodenal artery; 9- duodenum; 10- right gastric artery; 11- left gastric artery, 11- left gastric artery, 12- right gastroepiploic artery, 13- left gastroepiploic artery, 14- short gastric arteries, 15- spleen, 16- lienal arteries, 17- lienal artery. **D**: 1- abdominal aorta; 2- left renal artery with bifurcation; 3- left kidney. Scale bars A-D: 1 cm.



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As in other domestic animals, in *Cerdocyon thous* the adrenal glands are located next to the cranial pole of the kidneys. The adrenal arteries in domestic dogs can emerge from the celiac, phrenic, cranial mesenteric, renal, and lumbar arteries as well as the adrenal branches, which are more common in the renal artery (DYCE et al., 2019).

In the animals studied, the adrenal arterieswere arranged cranially to the kidneys and arose from the renal arteries. Some authors have already described this feature in other species, such as *Myocastor coypus* (CULAU et al., 2008), rabbits (BAVARESCO et al., 2013), *Tamandua tetradactyla* (MACEDO et al., 2013), *Nasua nasua* (BIIHRER et al., 2015), and *Aotus azarae infulatus* (FARIA et al., 2016), as it is not common only in carnivores. In *Leopardus pardalis*, Pinheiro *et al.*, (2014) described the origin of the adrenal artery solely from the abdominal aorta.

In one *Cerdocyon thous* the left adrenal artery originated from the renal artery, starting as a double branch and continuing to the adrenal gland as a single branch (Figure 3B).

In view of the above, the surgical approach of nephrectomy, when necessary, should be well-planned if the adrenal arteries emerge from the renal artery of the same antimere.

In the study specimens, the gonadal arteries were caudal to the renal artery, emerging from the abdominal aorta (Figure 3C), as described in domestic carnivores (DYCE et al., 2019) and in *Myocastor coypus* reported by Culau et al., (2008), whose gonadal arteries originate from the umbilical arteries, which, in turn, emerge from the external iliac arteries.

The caudal mesenteric artery de *Cerdocyon thous* started with a common part and then branched into two arteries: the left colic artery (which anastomosed with the middle colic artery supplying the descending colon) and the cranial rectal artery (supplying the rectum), and arranged cranially to the deep circumflex iliac arteries (Figure 3C). This vascular arrangement is also described in domestic carnivores (FIRMINO et al., 2011), *Mazama gouazoubira* (AMADORI et al., 2012), *Leopardus pardalis* (PINHEIRO et al., 2014), *Aotus azarae infulatus* (FARIA et al., 2016), *Nasua nasua* (FELIPE et al., 2017) and *Lycalopex vetulus* (SILVA et al., 2018).

This information reveals the importance of surgical intervention in the large intestine in cases of trauma with active bleeding, intussusception (evolving to ischemia), and/or neoplasia, in which it is necessary to quickly locate the artery and check for possible anastomoses as reported here in *Cerdocyon thous*, thereby avoiding undue ligatures that will generate necrosis in other intestinal portions.

About the deep circumflex iliac arteries (right and left), the origin, course, and distribution, in *Cerdocyon thous* is consistent with that reported in other carnivores such as domestic dogs (DYCE et al., 2019), *Leopardus pardalis* (PINHEIRO et al., 2014), and *Nasua nasua* (FELIPE et al., 2017), emerging from the abdominal aorta (Figura 3C-D).

The external iliac arteries were caudal to the deep circumflex iliac artery, whereas the internal iliac arteries were caudal to the external arteries. The median sacral artery was located at the end of the abdominal aorta and positioned caudally to the internal iliac arteries (Figure 3C-D).

The iliac arteries (external and internal) can emerge from a common trunk arising from the abdominal aorta, as previously described in *Myocastor coypus* (CULAU et al., 2008), *Didelphis albiventris* (CULAU et al., 2010) and *Hydrochoerus hydrochaeris* (SILVEIRA et al., 2018). In *Sapajus apella* (FURTADO et al., 2017) the external iliac artery bifurcates, resulting in the emergence of the internal iliac artery. However, these arteries can also arise individually from the lateral surface of the abdominal aorta, as already described in domestic animals (DYCE et al., 2019), *Leopardus pardalis* (PINHEIRO et al., 2014), and in *Cerdocyon thous*, as observed in this study.

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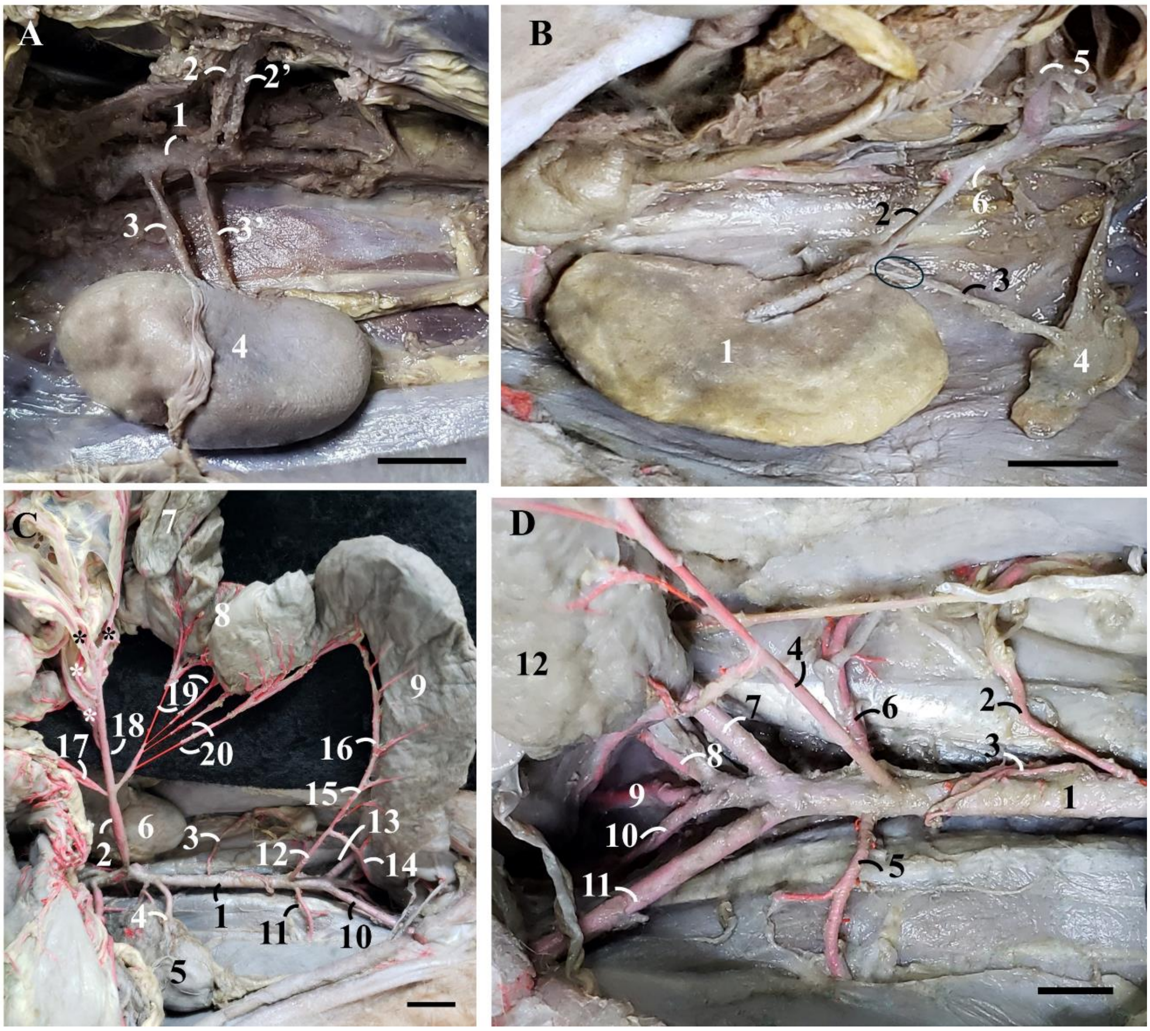
Figure 3 - Photomacrograph of the abdomen of *Cerdocyon thous*, ventral view. **A**: 1- abdominal aorta; 2- cranial left renal artery; 2'- caudal left renal artery (left kidney not apparent, covered by part of the abdominal wall.; 3- cranial right renal artery; 3'- caudal right renal artery; 4- right kidney with part of the fibrous renal capsule removed. **B**: 1- left kidney; 2- left renal artery; 3- left adrenal artery bifurcation (circle); 4- left adrenal gland, 5- cranial mesenteric artery; 6- abdominal aorta. **C**: 1- abdominal aorta; 2- cranial mesenteric artery; 3- right ovarian artery; 4- left renal artery; 5 - left kidney; 6- right kidney; 7- part of the ilium, 8- caecum; 9- colon; 10- left external iliac artery; 11- left deep iliac circumflex artery; 12- caudal mesenteric artery; 13- right external iliac artery; 14- cranial rectal artery; 15- left colic artery; 16- middle colic artery; 17- caudal pancreatic duodenal artery; 18- jejunal arteries (*); 19- cecal artery; 20- right colic arteries. **D**: - 1- abdominal aorta; 2- right ovarian artery; 3- left ovarian artery; 4- caudal mesenteric artery; 5- left deep iliac circumflex artery; 6- right deep iliac circumflex artery; 7- right external iliac artery; 8- right internal iliac artery; 9- median sacral artery; 10- left internal iliac artery; 11- left external iliac artery; 12- colon. Scale bars A-D: 1 cm.



Source: Author.

Finally, but no less importantly, the median sacral artery was found caudal to the internal iliac arteries originating from the abdominal aorta in *Cerdocyon thous*; similar discoveries were made in domestic animals (DYCE et al., 2019, KÖNIG; LIEBICH, 2021), rabbits (BAVARESCO et al., 2013), *Leopardus pardalis* (PINHEIRO et al., 2014), *Nasua nasua* (FELIPE et al., 2017) and *Hydrochoerus hydrochaeris* (SILVEIRA et al., 2018). However, in *Myocastor coypus* (CULAU et al., 2008) and *Tamandua tetradactyla* (MACEDO et al., 2013) the median sacral artery emerged as a collateral branch of the left internal iliac artery.

CONCLUSION

Run over animals do not always allow us to investigate all the segments of certain areas of the animal's body, due to severe lacerations or amputations. Although the animals studied were victims of being run over in an extractive area, there was no abdominal visceral involvement and its correlated arterial vascularization. This shows that, despite the damage to fauna, it should be exploited as much as possible in order to contribute to the survival of the species.

Although we observed that many of the studied splanchnic arterial branches were similar to those described in the literature for carnivores in general as well as for species of other orders, we cannot ignore the differences found and mapped, which may lead to differences in the scope of abdominal surgical approaches.

With the advancement of basic research, there is no justification for veterinary surgeons to surgically approach wild or exotic patients based on extrapolations of what is described in the literature for domestic animals. However, it is of the highest importance that veterinarians do not forget the possible anatomical variations, which occur not only in the *Cerdocyon thous*, but also in other species of animals, both wild and domestic.

Recording variations can be crucial, impacting on the surgical outcome when a certain vascular pattern is expected. This shows that basic science is not static, and as the name suggests, it serves as a basis for new investigations, allowing for the standardization of each anatomical reference to mitigate therapeutic failures and malpractice.

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