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Anatomical aspects of the liver and angiorchitecture of the hepatic portal vein of *Bradypus variegatus* SCHINZ, 1825 (MAMMALIA: PILOSA)

Aspectos anatômicos do fígado e angiorquitetura da veia porta hepática de *Bradypus variegatus* SCHINZ, 1825 (MAMMALIA: PILOSA)

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ABSTRACT: Sloths are placental mammals known for their slow movements and peculiar morphophysiological characteristics that need to be elucidated. In this context, the present study aimed to describe the morphological aspects of the liver and the distribution of the hepatic vein of *Bradypus variegatus*. Eleven animals were used for angiotechniques and dissections to describe the lobes, morphometry, and topography of the liver, as well as the vascular arrangement of the hepatic portal vein. Of the eleven, four specimens were dissected and used for specific morphometric analyses. Meanwhile, six animals were used for an angiotechnique with stained latex and one was used for an angiotechnique with stained vinylite and corrosion in 33% hydrochloric acid (HCL). The results indicated that the liver of *B. variegatus* is located in the cranial portion of the abdominal cavity, situated entirely in the right antimere, positioned cranially between the 7th and 9th ribs, and caudally between the 12th and 14th ribs. The organ has measurements directly related to the size of the individual, with the length representing approximately 18.8% of the animal's length. The liver has the following lobar divisions: left, quadrate, right, and caudate lobes, with caudate and papillary processes. Falciform, triangular, round, venous, hepatoduodenal, and hepatogastric ligaments were also evidenced. When dissecting the liver parenchyma, it was found that the hepatic portal vein emits two main branches, one right and one left, and these are distributed between the lobes, so that the left branch has a larger area of privacy than the right.

Keywords: wild animals; morphology; angiotechniques; Xenarthra; sloth.

RESUMO: Os bichos-preguiça são mamíferos placentários, conhecidos por seus movimentos lentos e características morfofisiológicas peculiares que precisam ser elucidadas. Neste contexto, o presente trabalho teve como objetivo descrever os aspectos morfológicos do fígado e a distribuição da veia porta hepática de *Bradypus variegatus*.Para realização das análises foram utilizados 11 animais destinados a angiotécnicas e dissecações para a descrição dos lobos, morfometria e topografia do fígado, bem como o arranjo vascular da veia porta hepática. Destes, quatro exemplares foram dissecados e utilizados para descrições morfométricas. Enquanto que, seis animais foram destinados a angiotécnica com látex corado e um foi destinado a angiotécnica com vinilite corado e corrosão em ácido clorídrico (HCL) a 33%. Os resultados indicaram que, o fígado de *B. variegatus* está localizado na porção cranial da cavidade abdominal, situado em sua totalidade no antímero direito, posicionado cranialmente entre a 7ª e 9ª costelas, e caudalmente entre a 12ª e 14ª. O órgão possui medidas diretamente proporcionais ao tamanho do indivíduo, com o comprimento representando cerca de 18,8% do comprimento do animal e apresentou as seguintes divisões lobares: lobo hepático esquerdo, quadrado, direito e caudado, constituído pelos processos, caudado e papilar. Foram também evidenciados os ligamentos: falciforme, triangular, redondo, venoso, hepatoduodenal e hepatogástrico. Ao dissecar o parênquima do fígado constatou-se que, a veia porta hepática emite dois ramos principais, um direito e outro esquerdo e estes se distribuem entre os lobos, de modo que, o ramo esquerdo possui uma área de irrigação maior que o direito.

Palavras-chave: animais silvestres; morfologia; angiotécnicas; Xenarthra; bicho-preguiça.

INTRODUCTION

Bradypus variegatus sloths Schinz, 1825, known as common sloths, are arboreal animals with a diet restricted to leaves with low energy content and some toxic substances. To reduce the collection of substances, the liver, an important organ of the digestive system, acts in a fundamental way, performing functions such as: metabolization, storage, synthesis, and elimination of absorbed substances that are harmful to the individual. It is a large gland, vascularized by the hepatic arteries, hepatic veins, and the portal vein (Pough *et al.*, 2003; Pereira Júnior, 2007; Medri *et al.*, 2011; Bosso, 2012).

Sloths belong to the Eutheria subclass and

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Xenarthra superorder (Larrázabal, 2004). The *Bradypus* genus is represented by five species. Brazil is the country with most of them, except for the pygmaeus (*Bradypus pygmaeus*), whose occurrence is limited to the Escudo de Veráguas Island located in Panama (Medri *et al.*, 2011). Therefore, Brazil stands out for having a larger natural reserve of sloths, favoring the study of these mammals (Amorim, 2000; Santos *et al.*, 2023).

Bradypodids are sensitive animals and suffer damage by human actions which lead to the destruction of natural ecosystems and cause major environmental changes, making these xenarthrans more susceptible to predation and disease (Azarias *et al.,* 2006). According to the IUCN (2024a and b), species of the *Bradypus* genus are already on the red list of threatened animals, so that *B. pygmaeus* is critically endangered (IUCN, 2024a) and *Bradypus torquartus* is considered a vulnerable species (IUCN, 2024b). These mammals exhibit peculiar and poorly described anatomy and physiology, which makes it difficult to keep specimens in captivity (Nowak, 1999; Dickman, 2001). Therefore, this study aims to describe and document the anatomy of the liver and the angioarchitecture of the hepatic portal vein of *B. variegatus*, help to reduce knowledge gaps about the morphology of this species, and contribute with information that can be used in clinical practice.

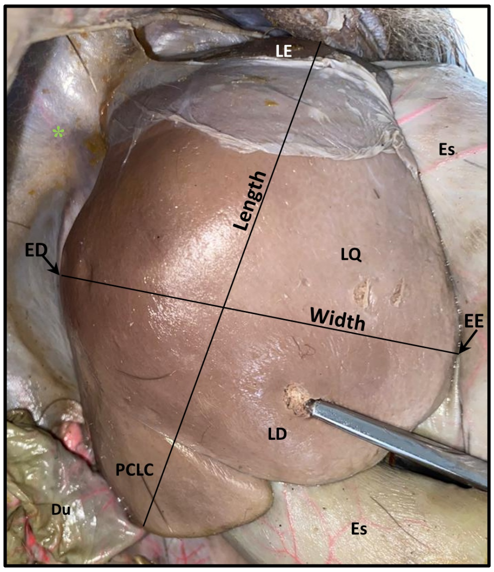
MATERIAL AND METHODS

The research was carried out in the Anatomy Area of the Department of Animal Morphology and Physiology of the Federal Rural University of Pernambuco (DMFA/UFRPE), with authorization from the Ethics Committee on the Use of Animals of the Federal Rural University of Pernambuco (CEUA/UFRPE) Number 128/2019, from the Biodiversity Authorization and Information System of the Chico Mendes Institute (SisBio/ICMBio) Number 46655-11 and the National System for the Management of Genetic Heritage and Associated Traditional Knowledge (SisGen) Number A7A29C5. In this study, 11 specimens of *B. variegatus* were used, originating from the Center for Triage and Rehabilitation of Wild Animals in Recife, Pernambuco (CETRAS-TANGARÁ), after natural death.

Four specimens, one adult male and one juvenile, one adult female and one juvenile, were fixed with 20% formaldehyde from cannulation of the left common carotid artery and preserved in a hyper-saturated aqueous solution of 30% sodium chloride. A median incision was made in the abdomen of these animals and subsequent reflection of the skin and muscles in order to observe topographic relationships such as skeletopia, syntopia, and idiotopia of the liver. These rules were made considering the abdominal limits and their subdivisions proposed by Lima *et al.* (2022). The authors described the abdominal quadrants based on the existing literature of other species and on the anatomical characteristics of the sloth, thus, through parasagittal, oblique and transverse planes to the median plane, cranially, the xiphoid, right and left hypochondriac regions; in the middle portion, umbilical, right and left lateral abdominal regions; and caudally, right and left pubic and inguinal regions.

The liver of each specimen was dissected separating the adjacent structures, and then it was removed from the abdominal cavity for morphometric analysis by using a steel caliper (150 mm/0.2 mm). The right and left thickness measurements were obtained from the right lateral end of the caudate process of the caudate lobe and the left lateral end of the quadrate lobe, respectively; the width was measured from the left lateral end of the quadrate lobe to the right lateral end of the caudate process of the caudate lobe; and the length was measured from the most cranial area of the left lobe to the most caudal area of the caudate process of the caudate lobe (Figure 1). The length of the specimens was also measured from the apex of the skull to the tail, by using a tape measure.

Figure 1 – Image of the abdominal cavity and liver in situ of the adult *Bradypus variegatus* sloth, establishing the points of measurements taken on the organ. Stomach (S). Duodenum (Du). Diaphragm (*). Left lobe (LE). Quadrate lobe (LQ). Right lobe (RL). Caudate process of the caudate lobe (PCLC). Left end of the quadrate lobe (EE). Right end of the caudate process of the caudate lobe (ED).



Six animals (one adult and three young males, and two adult females) underwent latex angiography, based on the methodology proposed by Oxley *et al.* (2021). Five of these were cannulated through the hepatic vein, where they received a latex solution (Siquiplás) added with blue checkerboard dye (Sherwin Williams). One of them, an adult male, was also cannulated through the hepatic artery, receiving a small amount of red-stained latex, in order to highlight the differentiation of the vessels in the hepatic hilum. A young male, in turn, received exclusively the latex stained with red checkerboard dye (Sherwin Williams), through the hepatic artery, in order to determine the location of the right hepatic lobe through the arterial branches, given that its external limits are not very clear. Dyce *et al.* (2019) indicated the importance of the internal branches of the vessels for determining the hepatic lobation as an alternative to the external fissures.

The latex was stirred for homogenization and diluted with ammonium hydroxide P.A. until it assumed a fluid consistency, then it was mixed with the dye. Once injected, glacial acetic acid P.A. was used to accelerate coagulation and prevent latex extravasation at the place of cannulation. In the remaining animal, an adult male, angiography with vinylite was performed, based on what was proposed by Viana and Barbosa (2022). The vinylite solution was prepared so that the powder was homogenized with acetone P.A. until it acquired the consistency of honey. The mixture was left in a glass container for 48 hours. After this time, blue oil paint (Acrilex) was added, and it was then injected into the previously cannulated animal from the hepatic vein. Vinylite added with red oil paint (Acrilex) was also injected into the hepatic arteries and yellow oil paint into the common bile duct, in small quantities, just to highlight the differentiation of the structures of the hepatic hilum. After injection, the organ was removed and immediately immersed in water for 24 hours. It was then submerged in a solution containing two liters of 33% hydrochloric acid (HCL) for five days. After this period, the specimen was washed in running water for cleaning and subsequent analysis. After the angiotechniques were performed and before being removed from the abdominal cavity, the livers were analyzed for topography.

All steps were photo-documented. The anatomical terminology used in the petitions follows the determinations of the International Committee on Veterinary Gross Anatomical Nomenclature, Nomina Anatômica Veterinária (2017).

RESULTS

Based on the analyses of the examples, the liver of *B. variegatus* has four lobes: left, quadrate, right, and caudate, the latter consisting of the caudate and papillary processes (Figure 2). The organ is located to the right of the median sagittal plane between the topographic regions, xiphoid, close to the xiphoid cartilage, and right hypochondriac. Thus, the left lobe is located in the xiphoid region, while the quadrate, right, and caudate lobes are located in the right hypochondriac region, in all evident specimens.

The liver has cranial syntopy with the diaphragm; caudal with the small intestine and abdominal wall; ventral with the small intestine and stomach; dorsal with the diaphragm and abdominal wall; left lateral with the stomach and abdominal wall; and right lateral with the abdominal wall. The organ is fixed to the abdominal cavity by the falciform ligament, which originates on the diaphragmatic surface, between the left and quadrate hepatic lobes and continues towards the diaphragm. The round and venous ligaments were also shown, and are located on the visceral surface, so that the round ligament is located between the left and quadrate lobes, inserted into the abdominal wall, while the venous ligament is located in the quadrate, right, and caudate lobes. The triangular ligaments, which emerge between the quadrate hepatic lobes and the caudate process of the caudate lobe and are inserted into the diaphragm and abdominal wall, also participate in maintaining the liver's statics. The hepatoduodenal ligament extends from the hepatic hilum to the duodenum, and the hepatogastric ligament, from the papillary process of the caudate hepatic lobe to the stomach (Figure 2).

The liver is positioned cranially between the 7th and 8th ribs in 100% of females and 57% of males. In the remaining animals, the organ was distributed between the 8th and 9th ribs in 29% of males, and in 14% of them at the level of the 8th rib.

Caudally, the liver is located between the 12th and 13th ribs in 90% of females and 43% of males. However, in 10% of females and 43% of males, the organ presented its caudal portion between the 13th and 14th ribs, and in 14% of males at the level of the 14th rib. Therefore, the liver of *B. variegatus* presented a variable skeletopia.

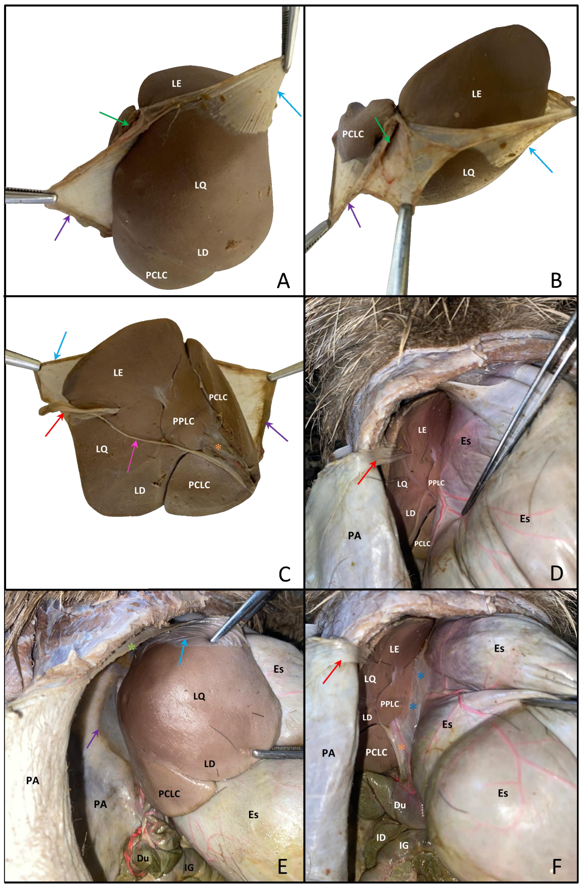


Figure 2 – Images of the abdominal cavity and liver in situ of the adult *Bradypus variegatus* sloth, demonstrating its lobes and ligaments. A and B- Diaphragmatic surface of the liver. C- Visceral surface of the liver. D and F- Abdominal cavity showing the visceral surface of the liver. E- Abdominal cavity showing the diaphragmatic surface of the liver. Left lobe (LE). Quadrate lobe (LQ). Right lobe (RL). Caudate process of the caudate lobe (PCLC). Papillary process of the caudate lobe (PPLC). Stomach (Es). Abdominal wall (PA). Duodenum (Du). Small intestine (SI). Large intestine (SI). Caudal vena cava (→). Triangular ligament (→). Falciform ligament (→). Round ligament (→). Venous ligament (→). Hepatoduodenal ligament (*). Hepatogastric ligament (*). Diaphragm (*).

By analyzing the liver in situ, we observed that the left hepatic lobe presented symptomatology and/or cranial idiopy with the diaphragm; caudal with the square and right lobes; ventral with the stomach and papillary process of the caudate lobe; dorsal with the diaphragm and abdominal wall; left lateral with the stomach; and right lateral with the square lobe.

Whereas cranial syntopia and/or idiopy were observed in the quadrate lobe with the left hepatic lobe; caudal with the right; ventral with the stomach; dorsal with the abdominal wall; left lateral with the left hepatic lobe and the papillary process of the caudate hepatic lobe; and right lateral with the abdominal wall.

As to the right lobe, cranial syntopia and/or idiopy occurred with the left and quadrate lobes; caudal with the caudate process of the caudate hepatic lobe; ventral with the papillary process of the caudate hepatic lobe and stomach; dorsal with the right hepatic lobe and abdominal wall; left lateral with the caudate process of the caudate hepatic lobe; and right lateral with the abdominal wall.

In the caudate hepatic lobe, the caudate process presented cranial syntopia and/or idiopy with the left and right hepatic lobes; caudal with the small intestine and abdominal wall; ventral with the stomach and small intestine; dorsal with the right hepatic lobe and abdominal wall; left lateral with the abdominal wall; and right lateral with the right hepatic lobe and extends to the left antimere (Konig and Liebich, 2021).

In *B. variegatus*, the liver presented cranial syntopy with the diaphragm, caudal syntopy with the small intestine and abdominal wall, ventral syntopy with the stomach and small intestine, and dorsal syntopy with the diaphragm and abdominal wall. Regarding the liver of *B. tridactylus*, Vidal *et al.* (2018) described that the organ is related to the lungs, cranially, with the heart, craniomedially, with the stomach, oviducts, and

Table 1 – Median (minimum - maximum) of livers of sloths *Bradypus variegatus*, in both sexes and different age groups.

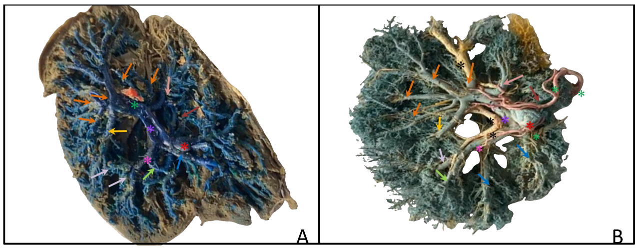
Animal	Body Measurement (cm)	Liver Length (cm)	Liver Width (cm)	Thickness Right Margin of the Liver (cm)	Thickness Left Margin of the Liver (cm)
Adult Male	42 (39 a 45)	8,1 (7,6 a 8,5)	5,7 (4,8 a 6,6)	2,5 (2,3 a 2,7)	3 (2,5 a 3,4)
Adult Female	45 (44 a 46)	7,8 (7,4 a 8,2)	5,5 (4,6 a 6,3)	2,4 (2,2 a 2,5)	2,8 (2,3 a 3,2)
Young Male	39,5 (39 a 40)	7,3 (6,5 a 8,1)	5,5 (5,1 a 5,8)	2 (1,8 a 2,2)	2,7 (2,2 a 3,1)
Young Female	35 (34 a 36)	7,2 (6,5 a 7,9)	5,4 (5,1 a 5,6)	2,2 (2,0 a 2,4)	2,6 (2,2 a 3,0)

papillary process. This process, in turn, has cranial syntopy and/or idiotopy with the left hepatic lobe; caudal with the caudate process; ventral with the stomach; dorsal and right lateral with the left, quadrate, and right hepatic lobes; and left lateral with the caudate process.

Regarding the morphometric data of the liver of the specimens measured, it was possible to observe that in both sexes, the size of the organ increased proportionally to the length of the animal for all measurements performed (Table 1).

From the analysis of the distribution of the branches of the hepatic vein, it was found that upon entering the liver, this vein undergoes a bifurcation, creating a right and a left main branch. The right branch gives off branches to the quadrate, right lobes, and to the caudate process of the caudate lobe. While the left branch gives off branches to the left, quadrate, and caudate lobes, reaching both the caudate and papillary processes. The number of branches coming from the main branches that go to the declared lobes varied between the specimens (Figure 3).

Figure 3 – Images of the livers of adult *Bradypus variegatus* sloths, showing the angioarchitecture of the hepatic portal vein. A- Visceral surface of the liver, with latex angiography. B- Visceral surface of the liver, with vinylite angiography and acid corrosion. Hepatic portal vein (*). Right main branch (*). Left main branch (*). Branches emitted from the right main branch to the quadrate (→), right (→), and caudate (→) lobes. Branches emitted from the left main branch to the hepatic lobes, left (→), quadrate (→), caudate process of the caudate lobe (→), and papillary process of the caudate lobe (→). Branches of the hepatic artery (*). Bile ducts (*).



DISCUSSION

The liver of the common sloth was observed in the cranial portion of the abdominal cavity, to the right of the median sagittal plane, in a vertical position, corroborating the findings of Vidal *et al.* (2018) for the common sloth (*Bradypus tridactylus*). This position appears to be related to the size and arrangement of the stomach in these species, which occupies almost the entire abdominal cavity, resembling that found in ruminants such as the brown brocket deer (*Mazama gouazoubira*) (Ulsenheimer *et al.*, 2018) and the marsh deer (*Blastocerus dichotomus*) (Borges *et al.*, 2002), which, like sloths, have the liver predominantly to the right of the median plane, in their case displaced by the size of the rumen. This characteristic is different from that described for domestic animals whose liver ovaries, caudally, and with the small intestine, caudomedially. This differs drastically from the relationships observed in the common sloth, considering the description of the syntopy of the liver with thoracic organs and gonads. In *M. gouazoubira,* it was found that the left hepatic lobe was located to the left of the umbilical notch, while the quadrate and right hepatic lobes were located to the right of the notch in question. The caudate process of the caudate hepatic lobe and the right hepatic lobe delimit the renal fossa, descending the relationship between the liver and the right kidney (Ulsenheimer *et al.*, 2018). According to Martins *et al.* (2012), in the paca (*Cuniculus paca*), the renal impression is located in the caudate process of the caudate hepatic lobe and in part of the right lateral lobe. Relationships between the hepatic lobes and the right kidney were not evidenced in the common sloth, which indicates the more cranial position of the liver of bradypodids in relation to other quadrupeds, which is similar to that observed in pigs (*Sus scrofa domesticus*) (Konig and Liebich, 2021).

Regarding hepatic lobation, findings by Vidal *et al.* (2018) for *B. tridactylus* showed similarities with the results obtained in *B. variegatus*, with the presence of four lobes. However, the sloth only has the caudate process, while in the common sloth, in addition to this, the papillary process was also present integrating the caudate hepatic lobe. Regarding armadillos, Silva *et al.* (2014) found that in the six-banded armadillo (*Euphractus sexcinctus*) and in the blue-winged armadillo (*Dasypus novemcinctus*) the liver is divided into four lobes, as in the findings of this study, including the caudate and papillary processes forming the caudate hepatic lobe. This was also observed in ruminants, such as in the brown brocket deer (Ulsenheimer *et al.*, 2018) and the marsh deer (Borges *et al.*, 2002).

In relation to domestic animals such as dogs and cats, a greater number of hepatic lobes are described, with the presence of lateral and medial left and right lobes, in addition to quadrate and caudate lobes (Dyce *et al.*, 2019). According to Konig and Liebichi (2021), most species have the liver divided into four main lobes, however this division pattern presents great anatomical variation. In species whose spine develops great mobility, the liver exposes deeper fissures, resulting in a greater number of hepatic lobes compared to species with more excavated spines, such as herbivores. However, this is not a rule, since, in pigs, the liver has a greater number of evident lobes and fissures, but they do not present significant spinal motility (Konig and Liebich, 2021).

Studies carried out on representatives of the Xenarthra superorder indicate that three-toed sloths do not have a gallbladder (Vital *et al*., 2018), allowing the products of the bile ducts to go directly to the duodenum through the common bile duct. Meanwhile, in two-toed sloths, the presence of the gallbladder was observed, which allows the storage of bile (Albuquerque *et al.*, 2015). This organ was also present in the six-banded armadillo and the blue-banded armadillo (Silva *et al*., 2014). According to Konig and Liebich (2021), the presence or absence of a gallbladder must be related to the type of diet of the animals. However, studies indicate that it is not considered essential to the organism, and is absent in equines as well as in bradypodids.

Sloths are predominantly herbivorous mammals that consume mainly leaves and fruits (Urbani and Bosque, 2007). However, two-toed sloths also feed on eggs and insects, presenting greater plasticity in their diet (Chiarello, 2008; Reis *et al*., 2011), which is associated with the fact that they have a gallbladder.

Based on the dissection of the hepatic vein of the common sloth, it was found that, when crossing the hepatic hilum, it divided into two main branches, a right branch and a left branch, which presented a larger area of clarity, emitting branches that reach the two processes of the caudate hepatic lobe.

In the capybara (*Hydrochoerus hydrochaeris*) (Souza *et al.*, 2007) and in the cavy (*Galea spixii*) (Oliveira *et al.*, 2012), the hepatic portal vein showed the same arrangement as in sloths, upon entering the liver parenchyma, emitting a right and a left branch. However, these branches covered distinct supervision areas, in relation to bradypodids. For the hepatic vein in H. hydrochaeris, the right branch was divided, emitting branches to the right medial and right lateral hepatic lobes and the caudate process of the caudate lobe, while the left branch emitted branches to the quadrate, left medial, and right lateral hepatic lobes. When studying the intraparenchymal distribution of the portal vein in the cavy, Oliveira *et al.* (2012) observed that the main right branch irrigates the right lateral hepatic lobe and the caudate process of the caudate hepatic lobe. While on the left side, a larger safety area was observed, with branches covering the hepatic lobes, left lateral, left medial, quadrate, and papillary process.

In studies carried out with the opossum (*Didelphis albiventris*) (Fragoso Neto, 2000), with the paca (Bosso, 2012), and with the rabbit (*Oryctolagus cuniculus*) (Birck *et al.*, 2012), upon entering the parenchyma, the hepatic portal vein presents three main branches, differing from the results found for *B. variegatus*. According to Konig and Liebiche (2021), these vessels create alternatives for blood in the intrahepatic circulation in the event of any impediment.

CONCLUSION

In *B. variegatus*, the liver is divided into four lobes: left, quadrate, right, and caudate lobes, which are formed by the caudate and papillary processes. Upon entering the liver, the hepatic portal vein bifurcates into two branches, one right and one left, heading towards the right quadrate lobes and the caudate process of the caudate lobe; and the left quadrate and caudate lobes, in their two processes, respectively.

The presenter was located to the right of the median sagittal plane, in the topographic regions, xiphoid, and right hypochondriac, positioned cranially between the 7th and 9th ribs, and caudally between the 12th and 14th rib. It is fixed by the falciform, triangular, round, venous, hepatoduodenal, and hepatogastric ligaments.

In general, the liver of the common sloth was similar to that of ruminants in terms of lobation. However, in terms of ligaments, it was found that it does not have a coronary ligament and has a single triangular ligament. The more vertical position assumed by the liver of *B. variegatus* appears to be strongly related to the size and positioning of the stomach of these animals, which occupies most of the abdominal cavity.

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