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Pathological features of gastrointestinal and hepatobiliary parasitosis in neotropical primates in Northeast Brazil[1]

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ABSTRACT.- Silva R.A.F., Lima T.S., Dias R.F.F., Santos N.T.A., Oliveira R.L., Oliveira J.B., Araújo J.L. & Lucena R.B. 2024. **Pathological features of gastrointestinal and hepatobiliary parasitosis in neotropical primates in Northeast Brazil.** *Pesquisa Veterinária Brasileira 44:e07301, 2024*. Hospital Veterinário, Departamento de Ciências Veterinárias, Centro de Ciências Agrárias, Universidade Federal da Paraíba, Campus II, 12 Rodovia PB-079, Areia, PB 58397-000, Brazil. E-mail: raquel_fagundesvet@hotmail.com

Understanding primate helminth fauna through the characterization of the associated diseases and parasitism, clinicopathological behavior, and parasite-host relationship is crucial in determining the impact of parasitic infections on free-living and captive species. The present study aimed to describe the primary clinical and anatomopathological aspects of parasitism in non-human primates (NHP). Necropsy records of NHPs diagnosed with endoparasitosis at the Veterinary Pathology Laboratory of the "Universidade Federal da Paraíba" were reviewed to obtain epidemiological, clinical, and pathological data, while samples were collected for parasitological identification at the time of necropsy. All animals were obtained from the cities of Cabedelo and João Pessoa, Paraíba, Brazil, from screening and monitoring centers for animals seized from illegal trafficking in this state. Twenty-four cases of gastrointestinal and hepatobiliary parasites affecting primate species belonging to species of the *Sapajus* and *Callithrix* genera were identified. In contrast, *Molineus torulosus* was identified in the intestinal serosa of 16 animals. Further, there were five cases of *Trypanoxyuris callithrix*, two cases of *Platynosomum illiciens* infection, and one case of *Dipetalonema gracile*. The clinical and pathological behaviors of these diseases ranged from asymptomatic infections, considered based on necropsy findings in 14 cases, to cases with characteristic clinical manifestations associated with the cause of death of the animals in 10 of the 24 cases. Identification of the clinical behavior and pattern of pathological lesions can contribute to a better understanding of the parasite-host relationship and aid in the adequate diagnosis of these diseases.

INDEX TERMS: Gastrointestinal tract, wildlife, *Molineus torulosus*, *Trypanoxyuris callithrix*, *Platynosomum illiciens, Dipetalonema gracile*.

RESUMO.- [**Aspectos patológicos das parasitoses gastrointestinais e hepatobiliares diagnosticadas em primatas não humanos.**] Compreender a helmintofauna de primatas através da caracterização dessas enfermidades/parasitismos, conhecendo o comportamento clínico-patológico, bem como a relação parasito-hospedeiro é crucial para a determinação do

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impacto das infecções parasitárias em espécies de vida livre e de cativeiro. Diante disso, o objetivo deste trabalho é descrever os principais aspectos clínicos e anatomopatológicos em casos de parasitismos em primatas não humanos (PNH). Foram revisados os registos de necropsias de primatas diagnosticados com endoparasitoses no Laboratório de Patologia Veterinária da Universidade Federal da Paraíba, para obtenção de dados epidemiológicos, clínicos e patológicos, bem como coletado amostras para identificação parasitológica no momento da necropsia. Os animais vieram dos municípios de Cabedelo e João Pessoa, Paraíba, Brasil, de centros de triagem e monitoramento de animais apreendidos no tráfico ilegal no estado. São relatados 24 casos de parasitoses gastrointestinais e hepatobiliares acometendo espécies de primatas pertencentes aos gêneros *Sapajus* sp. e *Callithrix* sp., nos quais foram identificados *Molineus torulosus* na serosa intestinal de 16 animais. Cinco casos de infecção por *Trypanoxyuris callithrix,* dois casos de infecção por *Platynosomum illiciens* e um caso de *Dipetalonema gracile.* O comportamento clínico e patológico dessas enfermidades variou de infecções assintomáticas sendo considerados achados de necropsia em 14 casos, a casos com manifestações clínicas características associada a causa morte dos animais, representando 10 dos 24 casos totalizados. A identificação do comportamento clínico e padrão de lesões patológicas podem colaborar para melhor entendimento da relação parasito e hospedeiro, além de ajudar no diagnóstico adequado dessas enfermidades.

TERMOS DE INDEXAÇÃO: Trato gastrointestinal, animais selvagens, *Molineus torulosus*, *Trypanoxyuris callithrix*, *Platynosomum illiciens, Dipetalonema gracile*.

INTRODUCTION

Endoparasitosis is a clinicopathological condition that shows considerable variability in wild animals, with many non-specific clinical manifestations that may lead to death (Silva et al. 2012, Mattioli et al. 2016). Several studies conducted in Brazil have aimed to identify the helminth fauna of non-human primates (NHP), reporting approximately 50 parasitic helminth species (Corrêa et al. 2016, Figueiredo et al. 2020). However, this number is believed to be underestimated, as the helminth fauna of most Brazilian NHP remains unknown (Corrêa et al. 2016), particularly in the Northeast region of Brazil.

In Brazil, infections by nematodes belonging to the families Molineidae, Oxyuridae, and Onchocercidae, as well as trematodes of the family Dicrocoeliidae, can infect neotropical primates. Particular species include *Molineus torulosus*, *Trypanoxyuris callithrix*, *Platynosomum illiciens*, and *Dipetalonema gracile*. These species parasitize the intestine, liver, and abdominal cavity and can cause severe gastrointestinal disorders and/or act as susceptibility factors for other diseases (Miguel et al. 2013, Pinto et al. 2013, Mati et al. 2021, Ramalho et al. 2022).

In this context, the study of parasitic infections in wild species is crucial for understanding aspects of the parasite-host interactions, such as transmission routes and zoonotic potential, particularly among NHP in contact with domestic communities (Daszak et al. 2000, Thompson et al. 2010, Klaus et al. 2017). Therefore, this study aimed to describe the pathological aspects of gastrointestinal and hepatobiliary parasites in primates collected from the state of Paraíba in Northeast Brazil.

MATERIALS AND METHODS

Ethical approval. This study did not involve any animal experiments, as all data were obtained from a review of necropsy record. As such, this manuscript did not need to be submitted to an Animal Ethics Committee (CEUA).

The necropsy records of non-human primates diagnosed with endoparasitosis at the "Laboratório de Patologia Veterinária" of the "Universidade Federal da Paraíba" (LPV/UFPB) from January 2013 to December 2019 were reviewed. Information related to the species, sex, age, and provenance of the animals was subsequently extracted from records. In addition to epidemiological data, information related to the clinical presentation of the affected animals, necropsy findings, and microscopic findings were collected. Furthermore, new necropsy cases in NHP were monitored to identify diseases caused by parasites and parasitism in these animals. New histological slides were prepared from tissues embedded in paraffin or materials preserved in 10% buffered formalin and routinely stained with hematoxylin and eosin (HE) when necessary.

Parasites were collected from the affected anatomical sites, photographed, preserved in a solution of alcohol, formalin, and glacial acetic acid (AFA), and subsequently sent for identification to the "Laboratório de Parasitologia" of the "Universidade Federal Rural de Pernambuco" (LAPAR/UFRPE). According to Anderson et al. (2009), nematodes can be identified at the genus level. In the case of older samples, when buffered formalin material is unavailable, parasite identification can be performed based on photographic records, along with the descriptions in the reports and reference to more current cases.

RESULTS

Throughout the study period, 70 necropsy cases of neotropical non-human primates were recorded at the LPV/UFPB, of which 24 (34.3%) were recorded as having endoparasitism of the gastrointestinal and hepatobiliary tracts. These animals had disparate origins, ranging from captive animals in zoos to animals rescued by wildlife trafficking. In some cases, the animals were found sick in the wild and referred for treatment to a Veterinary Hospital. Of the 24 identified cases, 17 were diagnosed with *Sapajus libidinosus*, *Sapajus flavius*, and *Sapajus apella* (70.8%), and seven with *Callithrix jacchus* (29.2%). Overall, endoparasitism occurred predominantly in adults (20/24) and females (11/24). From some records, it was not possible to extract information regarding sex or age.

After parasite identification, 16 cases were attributed to *Molineus torulosus* infection (66.7%), five to *Trypanoxyuris callithrix* (20.8%), two to *Platynosomum illiciens* (8.3%), and one to *Dipetalonema gracile* (4.2%). The species of affected animals, parasite species, anatomical location, and macroscopic and microscopic alterations are presented in Table 1.

Molineus torulosus

Overall, 16 cases of parasitosis were attributed to infection by *Molineus torulosus*, many of which were from individuals from the Cebidae family. Among these, 11 were reported by Bacalhao et al. (2016). Ten cases occurred in *S. libidinosus* (yellow-breasted capuchin monkeys), four in *S. flavius* (golden capuchin monkeys), and two in *S. apella* (Guianan capuchin monkeys), with nine cases in males and seven in females, with animals ranging in age from juveniles (two cases) to adults (14 cases). All animals came from the municipalities

of Cabedelo and João Pessoa, Paraíba, Brazil, originating from screening and monitoring centers for animals seized from illegal trafficking in the state. Clinically, parasitized animals exhibit weight loss that progresses to severe cachexia, apathy, and dehydration.

Macroscopic observations included pronounced emaciation and multifocal to coalescing firm, brownish-gray nodules ranging in diameter from 0.5 to 2.0cm, located in the serosa of the duodenum, proximal third of the jejunum, and pancreas (Fig.1). Upon sectioning, the walls of these nodules were found to be thick and firm, with an irregular and friable central area characteristic of necrosis and mineralization. Occasionally, they were associated with numerous yellowish-white fine cylindrical structures, morphologically suggestive of nematodes such as *M. torulosus* (Fig.2 and 3). In some sections of the intestine, continuity between these nodules and the intestinal lumen was observed, which was associated with mucosal ulcers. In all cases, respiratory system involvement was observed to varying degrees of severity. The lesions comprised shiny lungs characterized by the presence of amorphous and hyaline material within the alveoli, both macroscopically and microscopically, compatible with pulmonary edema. Irregular and multifocal reddened areas were further distributed throughout the cranial and caudal lobes.

Microscopically, a neutrophilic inflammatory infiltrate associated with myriad bacteria, characteristic of bacterial pneumonia, was observed. Microscopically, parasitic granulomas were observed in the duodenum, between the serosal and muscular layers, occasionally extending to the other layers (transmural). The granulomas were characterized by a necrotic center associated with an inflammatory infiltrate comprising numerous epithelioid macrophages, eosinophils, and neutrophils, as well as multiple cross-sections and longitudinal sections of nematodes compatible with *M. torulosus*. The nematodes measured up to 120µm and had a cuticle 5µm thick, with uniformly spaced longitudinal cuticular ridges, pseudocoelom, platyhelminth/coelomate musculature, and a prominent digestive tract lined by few multinucleated cells with a brush border (Fig.4). Inside, eggs measuring 30-50µm in diameter with a thin shell were also observed. Lymphocytes and plasma cells surrounded by discontinuous fibrous capsules were further identified.

Small openings communicating with the granulomas and extending to the ulcerated areas in the intestinal mucosa were observed. Neutrophilic and lymphocytic periductal pancreatitis was observed in the pancreases of four animals, with intraductal nematodes and eggs associated with mild desquamation and necrosis of the pancreatic ductal epithelium. Lymphocytes and plasma cells were further observed in the mesentery, with lymphadenitis and invasion of the mesenteric vessels inducing fibrin thrombi in some cases.

Trypanoxyuris callithrix

Five specimens of *C. jacchus* (white-tufted marmosets) were diagnosed with *T. callithrix*. All were adults, and three of five were females. All specimens originated from the municipalities of João Pessoa and Areia, Paraíba, Brazil. Clinically, the animals appeared cachectic, with pale mucous membranes, dull and brittle fur, and pronounced eyeball retraction, indicative of severe dehydration (Fig.5). Necropsy findings included distended intestinal loops in the cecum and colon segments, with multiple whitish nematodes present in the intestinal lumen, measuring 2 to 6mm in length; upon opening the segments, moderate reddening of the mucosa was noted (Fig.6).

The histopathological findings were characterized by diffuse and moderate inflammatory infiltrates in the mucosal layer of the cecum and colon, comprising lymphocytes, plasma cells, and eosinophils, in addition to moderate edema. Parasites were not observed in histological sections.

Platynosomum illiciens

Two not previously reported cases of platinosomiasis (*P. illiciens*) affecting white-tufted marmosets (*C. jacchus*) from the municipalities of João Pessoa and Belém, Paraíba, Brazil, one male and one female, were also assessed. Clinically, pronounced cachexia was observed in both animals; however, only one further presented with diffuse and severe jaundice (Fig.7). On necropsy, parasites were observed in both animals, but with different parasitic loads. In severely parasitized animals, in addition to a pronounced decrease in adipose tissue and muscle mass, the liver exhibited moderately rounded edges with irregular brownish areas across the entire capsular surface. Sectioning revealed numerous parasites with ellipsoid, flattened, and brownish bodies inside the gallbladder (Fig.8 and 9).

Histopathological findings included moderate periportal lymphoplasmacytic inflammatory infiltrates with proliferation of the bile ducts, fibrous tissue, and cholestasis (Fig.10), with no parasite sections observed within the bile ducts.

Table 1. Characterization of affected animals, parasites, anatomical location, and morphological description of parasitic infections diagnosed in non-human primates at LPV/UFPB, Paraíba, Brazil

Host	Parasite	Anatomical location	Macroscopic description	Description microscopic/ Morphological diagnosis
Sapajus libidinosus *Sapajus flavius* *Sapajus apella*	*Molineus torulosus*	Small intestine (duodenum, jejunum and pancreas)	Multiple, firm, grayish-brown nodules and ulcers	Granulomas in the muscular layer of the intestine
Callithrix jacchus	*Trypanoxyuris callithrix*	Large intestine (cecum and colon)	Dilation of intestinal loops and mucosal hyperemia	Lymphocytic and eosinophilic typhlocolitis
Callithrix jacchus	*Platynosomum illiciens*	Liver and gallbladder	Marked emaciation and jaundice	Periportal lymphoplasmacytic infiltrate, cholestasis and fibrosis in the liver
Sapajus flavius	*Dipetalonema gracile*	Abdominal cavity	Fibrinous exudate and fibrous adhesions in the peritoneum and serosa of organs	Polymorphonuclear infiltrate and rare giant cells in lymph nodes and spleen

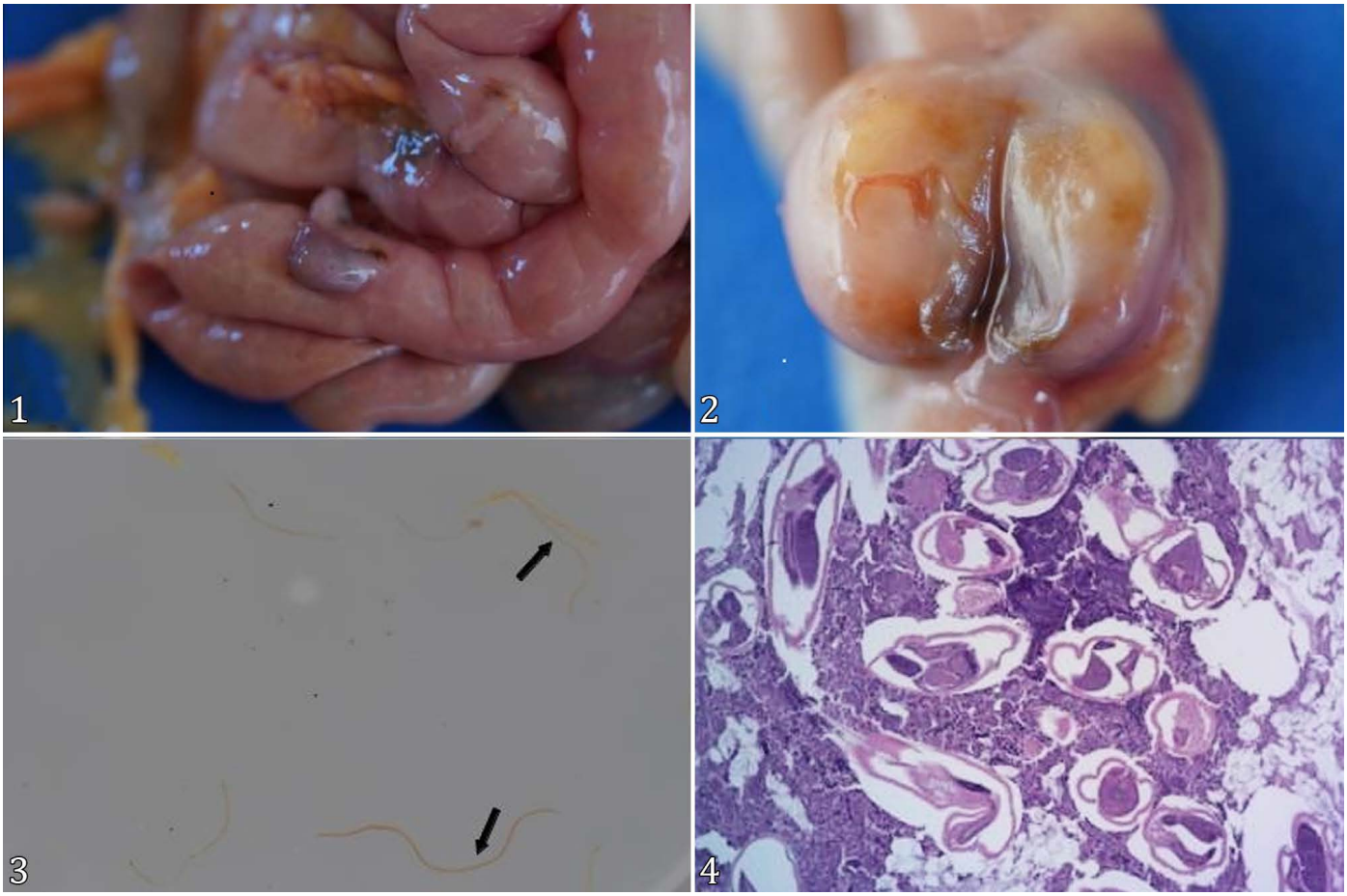

Fig.1-4. *Molineus torulosus* infection in *Sapajus flavius* (golden saguis) and *Sapajus apella* (Guiana saguis). (**1**) In the small intestine, the presence of firm, reddish nodules varying in diameter from 0.5 to 2cm. (**2**) The cut surface of these nodules was thick and firm, with an irregular and friable central area, indicative of necrosis and mineralization. Occasionally, these lesions were associated with numerous filamentous, yellowish-white structures indicative of *M. torulosus*. (**3**) Macroscopically visualization of *M. torulosus* specimens. (**4**) In the small intestine, longitudinal and transverse sections of the nematodes reveal a thick cuticle (5µm), uniformly spaced longitudinal cuticular ridges, as well as a pseudocoelom, platyhelminth/celomic musculature, and a prominent digestive tract, lined with few multinucleated cells with a brush border. HE, bar = 50µm.

Fig.5-6. *Trypanoxyuris callithrix* in *Callithrix jacchus* (white-tufted-ear marmosets). (**5**) A cachectic animal. (**6**) Segments of the cecum and colon show marked distension of the loops associated with multiple whitish nematodes in the intestinal lumen, measuring 2-6mm in length, with moderately reddened mucosa.

Dipetalonema gracile

A case of infection by *D. gracile* was identified in an adult male *S. flavius* (golden capuchin monkey) from the municipality of Cabedelo, Paraíba, Brazil. Clinically, the animal appeared cachectic, with pronounced eyeball retraction. Macroscopic findings revealed microfilariae in the peritoneal cavity, along with exudate, yellowish fibrin filaments, and fibrous adhesions in the abdominal cavity (Fig.11), which further involved the mesentery and capsular surface of the spleen. Hyperemia and enlargement of the mesenteric lymph nodes were also observed, along with multifocal pinpoint-whitish areas in the splenic parenchyma.

Microscopically, pronounced and diffuse inflammatory infiltrate was observed in the spleen and liver, comprising plasma cells, eosinophils, histiocytes, lymphocytes, and rare multinucleated giant cells, associated with microfilariae approximately 125µm in length (Fig.12). Morphologically, filarial nematodes have long, tapered tails with different sexual dimorphisms. Males have four pairs of preanal papillae and unequal slender spicules, whereas females have a vulva near the esophagus's glandular portion.

DISCUSSION

In the present study, the diagnosis of endoparasitosis in neotropical non-human primates was established based on necropsy, histopathological, and parasitological findings. Endoparasites commonly infect domestic animals; however, most cases can be treated quickly and efficiently, thanks to the wide range of anti-helminthic protocols available on the market (Jones & Garcia 2018). In contrast, in wild animals, whether living freely or maintained under human care, there is still a lack of information complementing the clinical and pathological profiles of helminthoses, which are often diagnosed at the time of necropsy (Pinto et al. 2013), as observed in the present study.

In general, among the predisposing factors for endoparasitosis, age tends to be an important factor, given the greater susceptibility of young animals to debilitating conditions triggered by a high parasitic load (Miguel et al. 2013). In this study, no age- or sex-linked predisposition was observed, which may be related to the small number of animals evaluated and the lack of information in the record sheets. Furthermore, relatively little information was recorded owing to a lack of knowledge regarding the origin of animals. However, in the study by Kumar et al. (2018), a higher prevalence of gastrointestinal parasitic infections was noted in young animals and females.

In the present study, the exact etiopathogenesis of endoparasitosis was not clear; however, it is believed that its

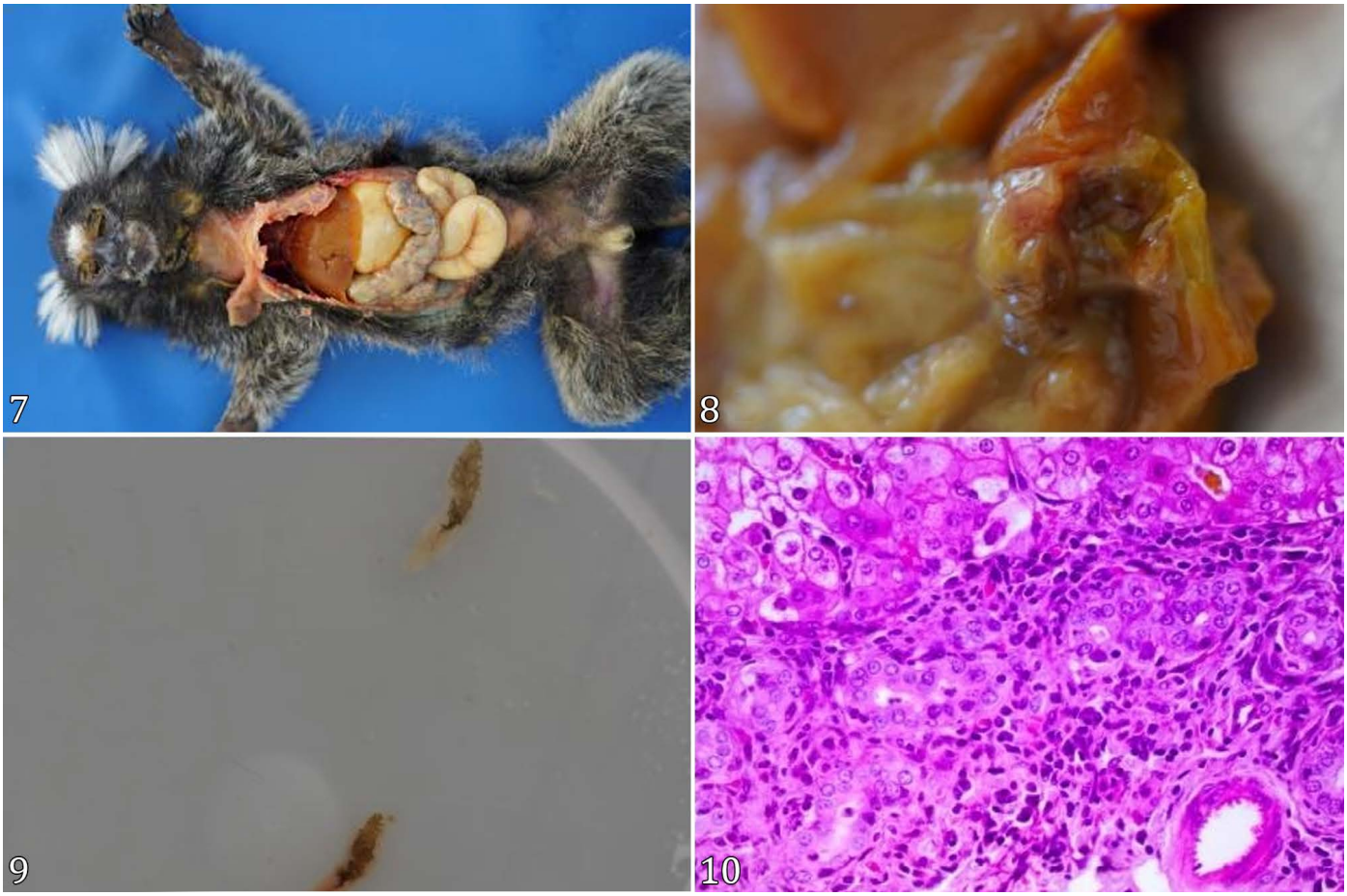

Fig.7-10. *Platynosomum illiciens* in *Callithrix jacchus* (white-tufted-ear marmosets). (**7**) An example animal showing severe cachexia and jaundice. (**8**) Numerous parasites with ellipsoid, flattened, and brownish bodies can be observed in the opening of the gallbladder. (**9**) Morphology of the parasites observed at higher magnification. (**10**) In the liver, there is moderate periportal lymphoplasmacytic inflammatory infiltrate with bile duct proliferation, fibrous tissue, and cholestasis. HE, bar = 20µm.

occurrence was associated with a history of capture. Animals taken from their habitats are generally placed in small, overcrowded enclosures with scarce food and inadequate nutrition (Freitas et al. 2014). These conditions trigger stress and result in weakness in the animals. Consequently, symbiotic microorganisms may begin to proliferate, causing severe clinical and pathological conditions, or new infections may develop.

This situation poses a challenge not only from a clinical but also from a pathological standpoint, as the determination of the severity of pathological findings is associated with the clinical profile of animals. However, in cases of debilitating conditions and sudden death, the collection of accurate information is impossible. In the present study, necroscopic evaluation allowed the determination of endoparasitosis as a cause of death in at least seven animals, with infections caused by the studied parasites, while endoparasitosis was only a potential necropsy finding in 17 cases, representing a low percentage. However, parasitic infections can also weaken these animals and predispose them to infection with other pathogens, highlighting the importance of cadaveric evaluation (Miguel et al. 2013).

In studies conducted by Siqueira et al. (2016), animals seized from trafficking operations commonly exhibited a low body score, showing emaciation, apathy, and dry, brittle, and dull skin and fur, similar to observations in the present study. However, this condition is more commonly described in avian species, which represent a higher percentage of trafficked animals (Siqueira et al. 2017).

Molineus torulosus

Four species of the genus *Molineus* have been identified as being commonly involved in parasitism of neotropical primates*: M. elegans, M. midas, M. torulosus,* and *M. vexillarius*. However, *M. torulosus* is the only species found within granulomas (Durette-Desset et al. 2001), reinforcing the diagnosis in the relevant case in this study. Unlike the present case, where a high parasite load was accompanied by severe emaciation, in most cases, free-living animals are more resistant to this parasitosis and rarely develop severe clinical symptoms (Miguel et al. 2013).

The loss of muscle mass observed in these cases may be associated with granulomatous enteritis and ulcerative enteritis, consequently resulting in malabsorption, emaciation, and debilitation (Bacalhao et al. 2016), similar to our observations in the present study. The formation of granulomas in the intestine is related to chronic persistent inflammation, in which the host is unable to destroy or eliminate the parasite, leading to the progressive release of chemical mediators. As lesions evolve, they become nodules/granulomas (Snyder 2013). Ulcerated areas in the gastrointestinal tract can favor secondary infections by opportunistic agents, such as bacteria that can disseminate hematogenously, posing a risk for the development of systemic conditions.

The involvement of the pancreas may also contribute to the progressive emaciation observed in our cases, owing to the endocrine role of this organ in the digestion and absorption of nutrients. The respiratory changes observed in these cases may further be associated with alterations in the osmotic balance caused by the significant emaciation observed in the animals, thus leading to the formation of pulmonary edema. Edema is associated with the progressive development of purulent inflammation and secondary bacterial infections.

Observation of the anatomical site and macro-and histopathological characteristics are sufficient for pathological diagnosis, allowing for the identification of the parasite at the genus level. However, the identification of the causative parasite based on its morphological characteristics is essential for the evaluation and confirmation of diagnosis (Kafle et al. 2017). It is also important to emphasize that coproparasitological diagnostics should be routinely performed in clinical settings for wild animals, particularly when selecting appropriate antiparasitics. In the differential diagnosis, other parasites that cause nodule formation and granulomatous inflammation in the intestinal serosa should be listed, such as in cases of infections caused by *Oesophagostomum* sp. and *Prosthenorchis*

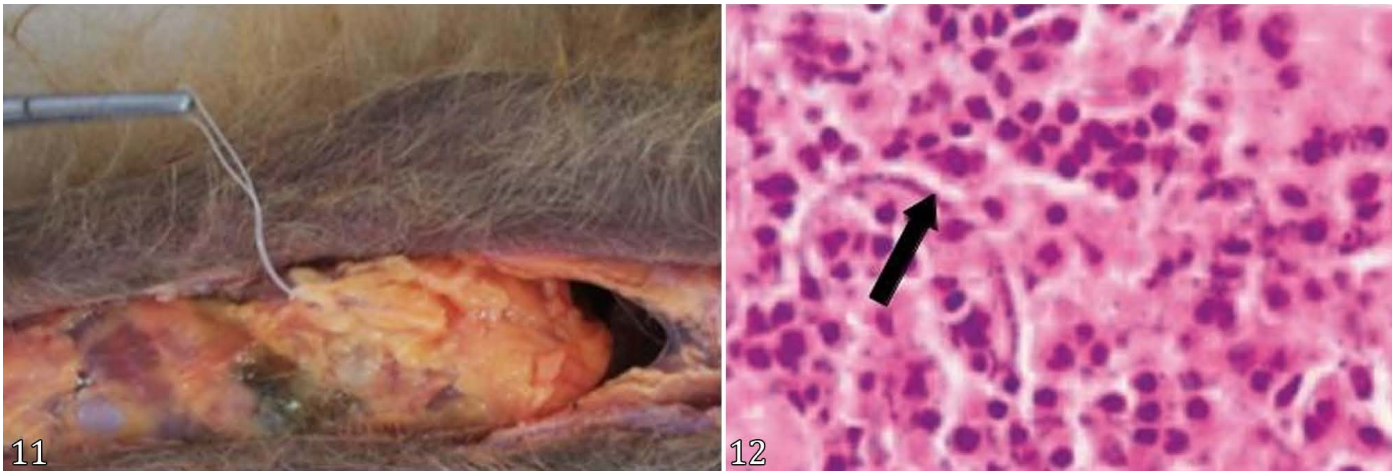

Fig.11-12. *Dipetalonema gracile* in *Sapajus flavius* (golden-handed capuchin monkeys). (**11**) In the abdominal cavity, a filarial nematode can be observed amidst the fibrinous exudate, yellowish fibrin filaments and fibrous adhesions between the abdominal organs. (**12**) In the spleen, a pronounced and diffuse inflammatory infiltrate composed of plasmocytes, eosinophils, histiocytes, lymphocytes, and rare multinucleated giant cells can be microscopically observed, associated with microfilariae approximately 125µm in length (arrow). HE, bar = 20µm.

sp. (Oliveira et al. 2017, Terio et al. 2018). For example, in one study, reddened nodules were observed on the serosa, along with large adult parasites that strongly adhered to the mucosa (Strait et al. 2012). Furthermore, parasites can be differentiated based on the morphological characteristics observed under a microscope.

Trypanoxyuris callithrix

The genus *Trypanoxyuris* encompasses parasites that inhabit the large intestine of neotropical primates; this genus is currently recognized as encompassing 18 species, which are further divided into four subgenera. Among these, three have been described to infect NHPs: *Trypanoxyuris* (*Trypanoxyuris*) in Cebinae, Aotidae, Atelidae, and Pitheciidae; *Trypanoxyuris* (*Hapaloxyuris*) in Callitrichidae; and *Trypanoxyuris* (*Paraoxyuronema*) in Atelidae (Pinto et al. 2013). These parasites have also been reported as incidental findings during necropsy in *Alouatta guariba clamitans* and *Lagothrix cana* (Souza et al. 2010, Pinto et al. 2013). However, in the present study, it is believed that the high parasitic load contributed to fatalities.

Despite the lack of clinical information in the present study, animals infected with *Trypanoxyuris* spp. may exhibit perianal pruritus, anorexia, restlessness, irritability, and progressive weight loss (Amato et al. 2002, Rietschel et al. 2003). Although these signs are non-specific, once such behavioral changes are observed, the possibility of parasitosis should be considered before the condition progresses significantly.

In the present study, parasite sections were not observed using intestinal microscopy as they were not firmly attached to the mucosa, which is believed to have contributed to their detachment during histochemical processing. Although histopathological descriptions of these parasites are infrequent, a similar description observed by Yaguchi et al. (2014) could be used to describe the morphology of the histopathological findings of parasites from the Oxyuridae family.

Because this is often an incidental finding during necropsy, few studies have addressed the characteristics of lesions resulting from *Trypanoxyuris* sp. However, there are some reports of lymphoplasmacytic and eosinophilic colitis involvement with edema, similar to that observed in the present case and described in the literature (Rietschel et al. 2003).

Other possible microscopic findings include intestinal wall fibrosis and nodular and necrotic lesions (Rietschel et al. 2003). However, such findings were not observed in the present study, which may be related to the duration of the lesion and/or intensity of the infection (Pinto et al. 2013). In the presence of lymphoplasmacytic and eosinophilic inflammation, it is important to consider parasitism by *Trypanoxyuris* sp. in the differential diagnosis; however, other causes should also be investigated.

Platynosomum illiciens

The genus *Platynosomum* comprises several species that parasitize mammals worldwide, notably *P. fastosum*, *P. illiciens*, and *P. concinnum*, with *P. illiciens* being the most commonly described species in neotropical primates (Salomão et al. 2005, Mati et al. 2021). Parasitosis caused by *Platynosomum* sp. in domestic species also results from the dietary habits of the parasitized lizards (Jesus et al. 2015), which perpetuate the lifecycle of the parasite in the environment (Pinto et al. 2014). In primates of the genus *Callithrix*, the occurrence of this parasite may similarly be linked to the consumption of insects and small reptiles (Pereira et al. 2021), indicating that this could be an important source of infection, including in the present study. However, this has not yet been confirmed.

The cases of infection by *P. illiciens* in the present study displayed distinct clinical presentations, possibly related to the intensity of the infection. This disease can range from absent or mild signs, as observed in one animal, to severe hepatopathy, which may lead to death (Silva et al. 2012, Mattioli et al. 2016). In the present study, only one patient showed clinical manifestations, which include the yellowish discoloration of tissues, indicating severe jaundice. In addition to jaundice, other symptoms, including anorexia, dehydration, lethargy, reduced adiposity of the panniculus, weight loss, and abdominal sensitivity leading to death, have also been reported in infections of species of the genus *Callithrix* sp. (Mati et al. 2021).

The icterus in these animals is obstructive and associated with the presence of the parasite in the biliary canaliculi, similar to that observed in domestic felines (Marques et al. 2020). However, in the present case, it was not possible to observe parasites in the histological sections, which may be related to the large number of parasites in the gallbladder, preventing their migration to the intrahepatic ducts. Weight loss appears to occur as a consequence of cholestasis, resulting from impaired bile canalicular secretion or alterations in bile flow due to the mechanical action of these parasites, which hinders lipid digestion and the absorption of fat-soluble vitamins (Araújo et al. 2002).

Clinical cases of infection by *Platynosomum* sp. in *C. jacchus* can lead to acute clinical disease, characterized by chronic active cholangitis with hyperplasia and proliferation of the bile ducts, occasionally accompanied by periportal fibrosis (Sousa et al. 2008, Gomes et al. 2018), similar to that observed in the present study. A diagnosis can be made based on the identification of a parasite associated with characteristic clinical signs (Mati et al. 2021, Pereira et al. 2021). However, additional complementary tests may differentiate it from other diseases that present with liver impairment and jaundice (Wilson et al. 2021, Bakker & Bomzon 2022).

It is necessary to investigate lesions secondary to inflammation due to this disease's chronic nature, such as cholangiocarcinoma, which has been reported in cats (Andrade et al. 2012). Tumors associated with lesions caused by hepatic parasites have also been reported in humans (Van Tong et al. 2017). Other diseases that can present with jaundice and should be considered as differential diagnoses include infections by bacteria of the genera *Erysipelothrix* and *Leptospira*, as well as hemoprotozoa, such as *Plasmodium* and *Entopolypoides* (Strait et al. 2012).

Dipetalonema gracile

Infections caused by microfilariae of the species *D. gracile* are commonly found in the peritoneal cavity or mesentery of neotropical NHPs and may be associated with the development of clinical diseases, including the potential death of infected animals (Zhang et al. 2018). The parasite is vectored by the mosquito *Culicoides hollensis*, which facilitates its easy dissemination and infection among susceptible hosts (Ramalho et al. 2022). Deforestation has also been highlighted as an

important environmental factor predisposing individuals to the occurrence of infection due to the increased density of hosts and contact with vector insects (Notarnicola et al. 2007).

Zárate-Rendón et al. (2022) previously reported the first phylogenetic analysis of *D. yatesi* in *Ateles chamek* (the Peruvian spider monkey), thus confirming the occurrence of various circulating species in Latin America. There is also a significant need for surveillance associated with the description of this disease affecting neotropical NHP species, as highlighted by Strait et al. (2012). This will enable the tracking of new hosts and areas of parasite occurrence.

CONCLUSIONS

Endoparasitosis was described in primate species of the genera *Sapajus* and *Callithrix*, including specimens raised under human care and captured from the wild. These parasitic infections were linked to the cause of death in 10 of the analyzed cases and were discovered as incidental necropsy findings in 14 cases.

Recognition of clinical pathological behavior, including the anatomical location and characterization of macroscopic lesions, could contribute to a better understanding of the relationship and dynamics between the parasite and the host.

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