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Spontaneous pathology of the common marmoset (*Callithrix jacchus*) and tamarins (*Saguinus oedipus*, *Saguinus mystax*)

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Abstract

Background—Marmosets and tamarins are increasingly used in research, but their pathology remains poorly defined compared to old world primates.

Methods—Necropsy records of 129 marmosets and 52 tamarins were reviewed; none were used experimentally.

Results—The most common marmoset lesions were dehydration, emaciation, nephritis, colitis and inanition. The most common tamarin lesions were dehydration, ascites, emaciation and congestive heart failure. Colitis and heart disease were the most common cause of death in marmosets and tamarins, respectively. Immature marmoset and tamarin deaths often occurred within the first month of life. Immature marmosets usually died from inanition, stillbirth and colitis; immature tamarins from atelectasis, stillbirth, heart failure and colitis. Lymphoma was the most common neoplasm for both marmosets and tamarins.

Conclusion—The findings were similar to prior reports with differences in frequency and severity. We report the first case of endometriosis in a marmoset.

Keywords

nonhuman primate; *Callitrichidae*; disease; epidemiology; cancer

Introduction

The new world primate family *Callitrichidae*, including marmosets (*Callithrix sp*) and tamarins (*Saguinus sp*), are the smallest NHP. This family is arboreal with claws, and possesses the highest fertility rate of any primate with average litters of two to three offspring [34].

The common marmoset (*Callithrix jacchus*) has become a popular research model in virology, viral oncology, reproductive physiology, bacterial infectious disease, transplantation immunology, pharmacology, endocrinology, teratology, metabolism, behavior, osteology, autoimmune encephalomyelitis models of multiple sclerosis, stroke, and toxicology [2,9,17,20,21,25,28,36,38]. This increase usage is reflected in the literature as there were over 40 times the number of publications involving marmosets in the 1990's

than in the 1960's¹. In part, their increased use has been attributed to well-established breeding colonies, small size, relatively rapid generational turnover, abundance in the wild (compared to other species of *Callitrichidae*) [1], and low zoonotic risk [34]. The common marmoset has been suggested for genome mapping [15]. Marmosets reach maturity at approximately 18 months of age [1,40].

In contrast, tamarins are not used as commonly as marmosets, partially due to the presence of less-established breeding colonies and declining wild populations. However, tamarins have played key research roles in vaccine trials, colon cancer, ulcerative colitis, inflammatory bowel disease, and Crohn's disease [18,19,23,33]. Tamarins reach maturity at approximately 16 months of age [3].

The spontaneous pathology of these species, which can impact study results, remains poorly defined in comparison to old world primates. There are two reviews of marmoset pathology [8,35] from the early 1980s and one recent review of marmoset pathology performed in animals utilized in viral studies [18]. Understanding the spontaneous pathology of these species can aid in interpreting pathological findings in research and in their husbandry. We documented the spontaneous pathology seen at necropsy for 129 common marmosets (*Callithrix jacchus*) and 52 cotton-top (*Saguinus oedipus*, SOT) and moustached tamarins (*Saguinus mystax*, SMT) from 1987 to 2008 housed at the Southwest National Primate Center at the Southwest Foundation for Biomedical Research (SFBR).

Materials and Methods

Animals

The marmosets and tamarins were housed in indoor, conventional wire caging, fed a commercial diet (Mazuri Callitrichid diet, Richmond, Indiana, USA) supplemented with grains, vegetables, and fruits and provided water *ad libitum*. All animals in this report were part of a breeding colony and were not used experimentally. The marmosets and tamarins were cared for in compliance with the Guide for the Care and Use of Laboratory Animals. All procedures were approved by the SFBR Institutional Animal Care and Use Committee. The SFBR is accredited by the Association for Assessment and Accreditation of Laboratory Animal Care, International.

Pathology

A full necropsy with histological evaluation was performed for each *Callitrichidae* primate. Tissues were fixed in 10% neutral buffered formalin, processed conventionally, embedded in paraffin, cut at 5 µm, stained with hematoxylin and eosin, and reviewed by light microscopy. Necropsies were performed and histopathologic diagnoses were made by two board-certified veterinary pathologists (EJD and GBH). Special stains, cultures or other specialized tests or consultations were utilized as needed. All results were stored in an internal anatomic pathology database program (apath).

Records Review

We performed a search of apath for all pathology diagnoses from *Callitrichidae* primates from 1987 to 2008; NHP used experimentally were excluded. We identified 129 marmosets (56 male, 69 female, and 4 fetuses of undetermined gender) and 52 tamarins (18 male, 29 female, and 5 fetuses of undetermined gender). A definitive cause of death was identified for 122 of the marmosets and 42 of the tamarins.

Data Analysis

Individual records were assembled into a Microsoft Office Excel 2003 (Microsoft, 2003) spreadsheet to be sorted to generate tables organized by species, morphological diagnosis, organ systems, and cause of death, to include indications for euthanasia. The number of male, female mature, immature (<18 months old, marmosets [1]; <16 months old, tamarins [3]) and total NHP was identified for each morphologic diagnosis; the tamarin results were also counted by species (SMT, SOT).

Results

The morphologic lesions, body systems affected, and cause of death for the 129 common marmosets are summarized in Tables 1, 2 and 3. The most common marmoset lesions were dehydration, emaciation, nephritis, colitis, and inanition. The average age of all, mature, and immature common marmosets at necropsy was 3.9 +/- SD 3.1, 5.32 +/- SD 2.66, and 0.45 +/- SD 0.46 years. Three cases of colitis were cultured, yielding one isolate each of *Escherichia coli* (*E. coli*), *Klebsiella pneumoniae*, and *Psuedomonas aeruginosa* (*P. aeruginosa*). The case of nematodiosis was caused by the parasite *Trichospirura leptostoma* (*T. leptostoma*). Three cases of pneumonia were cultured: two yielded *Bordetella bronchiseptica* and one *E. coli*. Three cases of hepatitis were cultured: all yielded *P. aeruginosa*.

The morphologic lesions, body systems affected, and cause of death for the 52 tamarins are summarized in Tables 4, 5 and 6. The most common tamarin lesions were dehydration, ascites, emaciation, congestive heart failure, cardiomegaly, and colitis. The average age of all, mature, and immature tamarins at necropsy was 3.09 +/- SD 3.50, 5.21 +/- SD 3.39 and 0.01 +/- SD .00 years. Four cases of nematodiosis were caused by *T. leptostoma* and two were suspected to be caused by filaroides. One case of pneumonia was cultured, yielding *E. coli*. *Klebsiella pneumoniae* was cultured from a case of peritonitis.

Discussion

In both species, dehydration and emaciation were generally considered secondary to other chronic diseases processes, such as colitis, heart failure, lymphosarcoma, and amyloidosis. This explains their high frequency as a morphological diagnosis and their infrequent listing as a cause of death.

We identified two prior surveys of marmoset pathology conducted approximately 25 years ago. A survey of marmosets from a breeding colony [8] identified Heinz body haemolytic anemia, skeletal muscle myopathy, inflammatory disease of the intestinal tract and chronic colitis, and bacterial infections as the most frequent findings. A similar survey of marmosets used in experimental studies [35] identified chronic colitis, chronic thyroiditis and interstitial mononuclear infiltrates in the kidney as the most frequent findings. Similar to those surveys, nephritis, colitis and enteritis were commonly observed in our colony.

Heinz body haemolytic anemia and skeletal muscle myopathy were uncommon in our animals. This may reflect improvements in diet and husbandry practices over the last 25 years, as these lesions were thought to be a result of a nutritional deficiency involving vitamin E, selenium, and protein [8]. Interestingly, hemosiderosis was still commonly encountered in our marmosets suggesting further dietary modifications are still required. It is likely that the decreased frequency of bacterial infections in our animals is also related to changes in housing and husbandry procedures over the last 25 years.

Amyloidosis only accounted for 3% of marmoset diagnoses, however it was diagnosed in 15 of the 128 animals (12%). This is consistent with a prior study reporting a 17% incidence [26]. As in that study, affected animals in our colony included both immature and mature marmosets.

Extramedullary hematopoiesis (EMH) in marmosets has been reported in the liver, adrenal glands, liver, kidney, spleen and mesenteric lymph nodes [17,24,28]. Although we did not find EMH in the mesenteric lymph nodes, we believe this is the first report of EMH in the lungs.

Although endometriosis has been experimentally induced in marmosets [16], to the best of our knowledge, no spontaneous case has ever been reported in a marmoset.

Colitis was the most common cause of death in marmosets, accounting for 22% and 23% of overall and mature marmoset deaths, respectively. Our results were significantly less than the 96% incidence rate reported in a 1998 study [13]. Environmental and dietary changes have been shown to radically alter the rates of colitis in marmoset colonies [23]. Although genetic differences between the colonies can not be excluded, it is possible that marmoset husbandry changes over the last 20 years could account for this difference.

Lymphosarcoma has been previously reported in marmosets [30] and was the most common neoplasm and the second most common cause of death in mature marmosets in our colony.

Inanition, stillbirths and colitis were the most common reasons for death in immature marmosets in our study, accounting for 61% of immature marmoset deaths. Forty percent of immature marmoset deaths occurred at under one month of age. Our results confirm a prior report that most deaths occur during the first month of life and the most common causes of death are reproductive failures (e.g. abortion, stillbirth) and rearing failure (inanition/starvation) [21].

Heart failure was by far the most common cause of death, accounting for 29% and 36% of overall and mature tamarin deaths, respectively. A high incidence of cardiac disease was reported in tamarins exposed to hepatitis A and GB viruses [7,9,18]. The authors in those studies believed the lesions were unrelated to the experimental study. Our findings of a high incidence of heart failure in naive tamarins supports their hypothesis. However the characteristic of the heart lesion was different; instead of myocardial fibrosis, we typically encountered a dilated heart (Cardiomegaly) with minimal histologic changes. Interestingly, heart failure in our colony was restricted to SMT, the same species used in these studies. Although fewer numbers of SOT were evaluated in our colony, the only cardiac lesion identified in these animals was one case of hemorrhage.

Colitis only accounted for 5% of tamarin diagnoses, however it was diagnosed in 11 of the 52 animals (21%). This was still significantly less than the 73% incidence of colitis cystica profunda reported in a previous survey [18]. Additionally, while there were occasional lesions consistent with colitis cystica profunda, the majority of the colitis diagnoses we observed lacked the herniation through the basement membrane and the mucus-filled cysts characteristic of that condition.

Atelectasis, stillbirth, heart failure and colitis were the most common reasons for death in immature tamarins in our study, accounting for 64% of immature tamarin deaths. Forty five percent of immature tamarin deaths occurred at under one month of age. Tamarin infant pathology is poorly documented, leaving little published data for comparison.

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Table 1

Marmoset morphological diagnoses in descending order of occurrence.

Morphology	Total	Percentage	Male	Female	Immature	Mature
Dehydration	55	10.00	20	35	15	40
Emaciation	49	8.91	21	28	14	35
Nephritis	40	7.27	20	20	2	38
Colitis	39	7.09	16	23	7	32
Inanition	32	5.82	16	16	13	19
Enteritis	30	5.45	10	20	1	29
Constipation	21	3.82	8	13	2	19
Amyloidosis	17	3.09	7	10	4	13
Hemosiderosis	17	3.09	8	9	0	17
Hyperplasia	15	2.73	5	10	4	11
Hepatitis	13	2.36	6	7	1	12
Typhlitis	13	2.36	8	5	0	13
Peritonitis	10	1.82	4	6	0	10
Ascites	9	1.64	5	4	3	5
Pneumonia	9	1.64	4	5	2	7
Cholecystitis	8	1.45	6	2	0	8
Lymphosarcoma	8	1.45	4	4	1	7
Necrosis	8	1.45	3	5	0	8
Cardiomyopathy	7	1.27	5	2	1	6
Extramedullary Hematopoiesis	7	1.27	5	2	0	7
Glomerulonephritis	7	1.27	1	6	0	7
Impaction	7	1.27	3	4	1	6
Stillborn/	7	1.27	3	3	7	0
Edema	6	1.09	3	3	3	3
Hemochromatosis	6	1.09	1	5	0	6
Hemorrhage	6	1.09	1	5	2	4
Mineralization	6	1.09	4	2	0	6
Fracture	5	0.91	1	4	0	5
Atrophy	4	0.73	3	1	0	4

Morphology	Total	Percentage	Male	Female	Immature	Mature
Cardiomegaly	4	0.73	1	3	0	4
Cholangiohepatitis	4	0.73	3	1	1	3
Congestion	4	0.73	0	4	0	4
Esophagitis	4	0.73	2	2	0	4
Fibrosis	4	0.73	2	2	0	4
Hydrothorax	3	0.55	2	1	1	3
Nephrocalcinosis	3	0.55	1	2	1	2
Obstipation	3	0.55	2	1	1	2
Osteopenia	3	0.55	1	2	0	3
Adenoma	2	0.36	1	1	0	2
Arteriosclerosis	2	0.36	1	1	1	1
Congestive heart failure	2	0.36	0	2	0	2
Degeneration	2	0.36	1	1	0	2
Dermatitis	2	0.36	1	1	0	2
Erythrophagocytosis	2	0.36	0	2	0	2
Gastritis	2	0.36	1	1	0	2
Hepatomegaly	2	0.36	1	1	0	2
Hypoplasia	2	0.36	2	0	0	2
Infarct	2	0.36	1	1	0	2
Myelofibrosis	2	0.36	0	2	0	2
Pancreatitis	2	0.36	2	0	0	2
Prostatitis	2	0.36	2	0	0	2
Steatosis	2	0.36	1	1	0	2
Urinary Stasis	2	0.36	1	1	0	2
Abrasion	1	0.18	1	0	0	1
Atelectasis/	1	0.18	0	0	1	0
Cannibalism	1	0.18	0	1	1	0
Cellulitis	1	0.18	1	0	0	1
Cyst	1	0.18	0	1	0	1
Depletion	1	0.18	1	0	1	0
Endometritis	1	0.18	0	1	0	1

Morphology	Total	Percentage	Male	Female	Immature	Mature
Hematoma	1	0.18	1	0	0	1
Hepatopathy	1	0.18	1	0	0	1
Histiocytosis	1	0.18	0	1	0	1
Hypertrophy	1	0.18	0	1	0	1
Kyphosis	1	0.18	0	1	0	1
Lipidosis	1	0.18	1	0	0	1
Luxation	1	0.18	0	1	0	1
Lymphadenitis	1	0.18	1	0	0	1
Megacosophagus	1	0.18	0	1	0	1
Myopathy	1	0.18	1	0	0	1
Nematodiasis	1	0.18	1	0	0	1
Nephrosis	1	0.18	1	0	0	1
Obese	1	0.18	1	0	0	1
Prostatitis	1	0.18	1	0	0	1
Septicemia	1	0.18	0	1	0	1
Splenitis	1	0.18	0	1	0	1
Strangulation	1	0.18	1	0	0	1
Thrombus	1	0.18	0	1	0	1
Ulcer	1	0.18	1	0	0	1
Vaginitis	1	0.18	0	1	0	1

J Includes animals of unknown sex

Table 2

Marmoset lesions by organ system in descending order of occurrence.

System	Organ	Morphology	Total	Male	Female
TOTAL	Total	Total ¹	597	280	315
Digestive	Total	Total	278	148	130
	Colon	Total	83	39	44
		Colitis	37	15	22
		Constipation	22	9	13
		Amyloidosis	9	6	3
		Lymphosarcoma	6	2	4
		Impaction	4	3	1
		Obstipation	4	3	1
		Edema	1	1	0
	Liver	Total	49	29	20
		Hemosiderosis	14	8	6
		Hepatitis	13	6	7
		Hemochromatosis	5	4	1
		Cholangiohepatitis	4	3	1
		Amyloidosis	2	1	1
		Extramedullary hematopoiesis	2	1	1
		Hepatomegaly	2	1	1
		Hepatopathy	1	1	0
		Lipidosis	1	1	0
		Lymphosarcoma	1	0	1
		Necrosis	1	1	0
Small intestine		Nephritis	1	0	1
		Peritonitis	1	1	0
		Steatosis	1	1	0
	Total	Total	38	23	15
	Enteritis	Enteritis	30	21	9
	Amyloidosis	Amyloidosis	6	2	4
	Edema	Edema	2	0	2

System	Organ	Morphology	Total	Male	Female
	Stomach	Total	37	18	19
		Inanition	32	16	16
		Amyloidosis	2	0	2
		Gastritis	2	1	1
		Impaction	1	1	0
		Total	24	14	10
		Typhlitis	13	8	5
		Impaction	5	2	3
		Amyloidosis	3	1	2
		Hemorrhage	1	1	0
		Lymphosarcoma	1	1	0
		Ulcer	1	1	0
	Peritoneal cavity	Total	20	9	11
		Ascites	12	7	5
		Peritonitis	8	2	6
		Cholecystitis	8	2	6
	Gall bladder	Total	8	8	0
		Lymphosarcoma	2	2	0
		Pancreatitis	2	2	0
		Adenoma	1	1	0
	Pancreas	Fibrosis	1	1	0
		Hemosiderosis	1	1	0
		Nematodiasis	1	1	0
		Total	5	2	3
	Esophagus	Esophagitis	4	2	2
		Megaesophagus	1	0	1
		Total	4	3	1
		Amyloidosis	2	1	1
	Rectum	Proctitis	2	2	0
		Total	2	1	1
		Lymphosarcoma	1	0	1

System	Organ	Morphology	Total	Male	Female
Hematopoietic Lymphatic	Total	Peritonitis	1	1	0
		Total	104	38	66
	Blood	Total	56	20	36
		Dehydration	55	20	35
	Lymph node	Septicemia	1	0	1
		Total	28	12	16
		Hyperplasia	10	5	5
		Lymphosarcoma	6	2	4
		Edema	3	2	1
		Erythrophagocytosis	2	0	2
Spleen	Total	Hemorrhage	2	0	2
		Atrophy	1	0	1
	Total	Depletion	1	1	0
		Histiocytosis	1	0	1
	Total	Hypoplasia	1	1	0
		Lymphadenitis	1	1	0
	Total	Total	16	6	10
		Amyloidosis	10	4	6
	Total	Lymphosarcoma	2	1	1
		Extramedullary hematopoiesis	1	0	1
Bone marrow	Total	Hemosiderosis	1	0	1
		Hypoplasia	1	1	0
	Total	Splenitis	1	0	1
		Myelofibrosis	2	0	2
	Total	Total	2	0	2
		Congestion	1	0	1
	Total	Hemorrhage	1	0	1
		Total ¹	83	39	43
	Total	Total	63	29	34
		Nephritis	40	20	20
Urogenital	Total	Glomerulonephritis	6	1	5

System	Organ	Morphology	Total	Male	Female
		Amyloidosis	5	3	2
		Nephrocalcinosis	3	1	2
		Infarct	2	1	1
		Necrosis	2	1	1
		Hemosiderosis	1	0	1
		Lymphosarcoma	1	0	1
		Mineralization	1	0	1
		Nephrosis	1	1	0
		Sleatosis	1	1	0
		Total ¹	10	3	6
	Uterus	Stillborn ¹	7	3	3
		Endometriosis	1	0	1
		Hemorrhage	1	0	1
		Necrosis	1	0	1
		Atrophy	3	3	0
		Total	3	1	2
		Urinary stasis	2	1	1
		Congestion	1	0	1
		Total	2	2	0
		Degeneration	1	1	0
	Prostate	Prostatitis	1	1	0
		Impaction	1	1	0
		Vaginitis	1	0	1
		Total	62	26	36
		Total	50	22	28
		Emaciation	49	21	28
		Obesity	1	1	0
		Total	8	2	6
		Fracture	4	1	3
		Osteopenia	3	1	2
Musculoskeletal	Bone	Kyphosis	1	0	1
	Seminal vesicle				
	Vagina				
	Total				
	Adipose tissue				

System	Organ	Morphology	Total	Male	Female
Cardiovascular	Skeletal muscle	Total	3	1	2
		Cannibalism	1	0	1
		Myopathy	1	1	0
		Necrosis	1	0	1
	Leg	Hematoma	1	1	0
		Total	25	12	13
	Heart	Total	20	9	11
		Cardiomyopathy	7	5	2
		Cardiomegaly	5	1	4
		Fibrosis	3	2	1
		Congestive heart failure	2	0	2
		Necrosis	2	1	1
		Congestion	1	0	1
Endocrine	Artery	Total	4	2	2
		Mineralization	3	2	1
		Thrombus	1	0	1
		Arteriosclerosis	1	1	0
	Aorta	Total	18	6	12
		Total	10	6	4
	Adrenal	Extramedullary hematopoiesis	6	4	2
		Amyloidosis	3	2	1
		Hyperplasia	1	0	1
	Thyroid	Total	5	0	5
		Hyperplasia	3	0	3
		Adenoma	1	0	1
		Cyst	1	0	1
Respiratory	Parathyroid	Total	2	0	2
		Hyperplasia	1	0	1
		Hypertrophy	1	0	1
		Mineralization	1	0	1
	Pituitary	Total	16	6	9
		Total ¹			

System	Organ	Morphology	Total	Male	Female
Nervous	Lung	Total [/]	12	4	7
		Pneumonia	9	4	5
		Atelectasis [/]	1	0	0
		Extramedullary hematopoiesis	1	0	1
		Lymphosarcoma	1	0	1
	Thoracic cavity	Hydrothorax	3	1	2
	Trachea	Strangulation	1	1	0
	Total	Total	8	3	5
	Brain	Total	5	2	3
		Mineralization	3	2	1
Integument		Arteriosclerosis	1	0	1
		Necrosis	1	0	1
	Cerebellum	Mineralization	1	1	0
	Meninges	Hemorrhage	1	0	1
	Spinal cord	Degeneration	1	0	1
	Total	Total	3	2	1
	Subcutaneous	Total	2	2	0
		Cellulitis	1	1	0
		Dermatitis	1	1	0
	Skin	Dermatitis	1	0	1

[/] Includes animals of unknown sex

Table 3

Marmoset causes of death in descending order of occurrence.

Cause of Death	Total	Percentage	Male	Female	Immature	Mature
Colitis	27	22.13	11	16	6	21
Inanition	10	8.20	5	5	8	2
Lymphosarcoma	9	7.38	4	5	1	8
Amyloidosis	7	5.74	3	4	3	4
Constipation	6	4.92	3	3	2	4
Nephritis	6	4.92	4	2	0	6
Stillbirth ¹	6	4.92	3	2	6	0
Cholecystitis	5	4.10	4	1	0	5
Enteritis	5	4.10	1	4	0	5
Glomerulonephritis	4	3.28	1	3	0	4
Fracture	3	2.46	1	2	0	3
Heart Failure	3	2.46	1	2	0	3
Hemorrhage	3	2.46	1	2	2	1
Impaction	3	2.46	1	2	0	3
Pneumonia	3	2.46	2	1	1	2
Cardiomyopathy	2	1.64	1	1	0	2
Hepatitis	2	1.64	1	1	0	2
Atelectasis ¹	1	0.82	0	0	1	0
Arteriosclerosis	1	0.82	0	1	1	0
Dystocia	1	0.82	0	1	0	1
Endometritis	1	0.82	0	1	0	1
Gastroenterocolitis	1	0.82	1	0	0	1
Hung	1	0.82	1	0	1	0
Necrosis, heart	1	0.82	1	0	0	1
Necrosis, kidney	1	0.82	1	0	0	1
Necrosis, liver	1	0.82	1	0	0	1
Nephrocalcinosis	1	0.82	0	1	0	1
Nephrosis	1	0.82	1	0	0	1

Cause of Death	Total	Percentage	Male	Female	Immature	Mature
Osteopenia	1	0.82	0	1	0	1
Pancreatitis	1	0.82	1	0	0	1
Placenta abrupta	1	0.82	0	1	0	1
Proctitis	1	0.82	1	0	1	0
Pulmonary edema	1	0.82	0	1	0	1
Self Mutilation	1	0.82	1	0	0	1
Septicemia	1	0.82	0	1	0	1

¹ Includes animals of unknown sex

Table 4

Tamarin morphological diagnoses in descending order of occurrence.

Morphology	Total	Percentage	Male	Female	Immature	Mature	SOT	SMT
Dehydration [/]	21	9.01	5	13	5	16	15	6
Ascites	16	6.87	6	10	5	11	0	16
Emaciation	16	6.87	4	12	1	15	6	10
Congestive heart failure	13	5.58	7	6	3	10	0	13
Cardiomegaly	11	4.72	6	5	4	7	0	11
Colitis [/]	11	4.72	3	7	3	8	2	9
Hydrothorax	11	4.72	4	7	2	9	0	11
Hepatomegaly	10	4.29	4	6	3	7	0	10
Edema	9	3.86	4	5	2	7	1	8
Nephritis	9	3.86	4	5	7	2	1	8
Atelectasis [/]	8	3.43	2	2	5	3	0	8
Congestion	6	2.58	3	3	4	2	5	1
Hemorrhage	6	2.58	5	1	0	6	3	3
Hemosiderosis	6	2.58	4	2	0	6	0	6
Inanition [/]	6	2.58	4	1	3	3	2	4
Necrosis [/]	6	2.58	0	5	5	1	0	6
Cardiomyopathy	5	2.15	3	2	0	5	0	5
Hydropericardium	5	2.15	3	2	1	4	0	5
Hepatopathy	4	1.72	2	2	0	4	0	4
Nematodiasis	4	1.72	1	3	0	4	2	2
Peritonitis	4	1.72	2	2	2	2	0	4
Typhlitis	4	1.72	3	1	0	4	0	4
Amyloidosis	3	1.29	0	3	0	3	2	1
Splenomegaly	3	1.29	1	2	0	3	0	3
Telangiectasia	3	1.29	2	1	0	3	0	3
Thrombus	3	1.29	1	2	3	0	0	3
Extramedullary hematopoiesis	2	0.86	1	1	1	1	0	2
Filariasis	2	0.86	1	1	0	2	0	2

Morphology	Total	Percentage	Male	Female	Immature	Mature	SOT	SMT
Glomerulonephritis	2	0.86	0	2	1	1	0	2
Hepatitis	2	0.86	1	1	0	2	0	2
Hyperplasia	2	0.86	0	2	1	1	1	1
Intussusception	2	0.86	0	2	1	1	0	2
Adenocarcinoma	1	0.43	0	1	0	1	1	0
Bronchopneumonia	1	0.43	1	0	0	1	0	1
Carcinoma	1	0.43	0	1	0	1	0	1
Enteritis	1	0.43	1	0	1	0	0	1
Fibrosis	1	0.43	1	0	0	1	0	1
Hemochromatosis	1	0.43	0	1	0	1	1	0
Icterus	1	0.43	0	1	0	1	1	0
Infarct	1	0.43	0	1	0	1	0	1
Lipidosis	1	0.43	0	1	1	0	0	1
Lymphosarcoma	1	0.43	0	1	0	1	0	1
Myodegeneration	1	0.43	1	0	0	1	0	1
Obese	1	0.43	0	1	1	0	0	1
Pancreatitis	1	0.43	1	0	0	1	0	1
Pericarditis	1	0.43	1	0	0	1	0	1
Pneumonia	1	0.43	1	0	0	1	0	1
Pyelonephritis	1	0.43	0	1	0	1	1	0
Stillborn	1	0.43	1	0	1	0	0	1
Vasculitis	1	0.43	1	0	0	1	1	0

¹ Includes animals of unknown sex

Table 5

Tamarin lesions by organ system in descending order of occurrence.

System	Organ	Morphology	Total	Male	Female	SOT	SMT
TOTAL	Total	Total [/]	235	93	131	39	196
Digestive	Total	Total [/]	86	31	51	12	74
	Liver	Total [/]	35	11	23	1	34
		Hepatomegaly	10	3	7	0	10
		Necrosis [/]	6	0	5	0	6
		Hepatopathy	4	2	2	0	4
		Congestion	3	1	2	0	3
		Telangiectasia	3	2	1	0	3
		Hemosiderosis	2	1	1	0	2
		Hepatitis	2	1	1	0	2
		Amyloidosis	1	0	1	0	1
		Hemochromatosis	1	0	1	1	0
		Lipidosis	1	0	1	0	1
		Thrombus	1	0	1	0	1
		Vasculitis	1	1	0	0	1
Abdominal cavity	Total	Total	20	8	12	0	20
		Ascites	15	6	9	0	15
		Peritonitis	4	2	2	0	4
Colon		Filariasis	1	0	1	0	1
	Total [/]	Total	14	4	8	5	9
		Colitis [/]	11	3	6	4	7
		Adenocarcinoma	1	0	1	1	0
		Carcinoma	1	0	1	0	1
		Intussusception	1	1	0	0	1
Cecum	Total	Total	6	2	4	1	5
		Typhlitis	4	1	3	0	4
		Hyperplasia	1	0	1	1	0
		Intussusception	1	1	0	0	1

System	Organ	Morphology	Total	Male	Female	SOT	SMT
Cardiovascular	Stomach	Inanition [/]	6	4	1	2	4
	Pancreas	Total	3	1	2	2	1
		Nematodiasis	2	0	2	2	0
		Pancreatitis	1	1	0	0	1
	Small intestine	Total	2	1	1	1	1
		Amyloidosis	1	0	1	1	0
		Enteritis	1	1	0	0	1
	Total		41	24	17	1	40
	Heart	Total	36	21	15	1	35
		Congestive heart failure	13	6	7	0	13
Respiratory		Cardiomegaly	12	7	5	0	12
		Cardiomyopathy	5	3	2	0	5
		Thrombus	2	1	1	0	2
		Hemorrhage	1	1	0	1	0
		Myodegeneration	1	1	0	0	1
		Nematodiasis	1	1	0	0	1
		Pericarditis	1	1	0	0	1
	Pericardial sac	Hydropericardium	5	3	2	0	5
	Total		39	16	19	1	38
	Lung	Total [/]	28	10	14	1	27
Blood-lymph		Atelectasis [/]	8	2	2	0	8
		Edema	8	4	4	1	7
		Hemosiderosis	6	2	4	0	6
		Congestion	3	0	3	0	3
		Bronchopneumonia	1	1	0	0	1
		Nematodiasis	1	0	1	0	1
		Pneumonia	1	1	0	0	1
	Total		31	9	19	16	15
	Blood	Total [/]	22	6	13	15	7
		Dehydration [/]	21	5	13	15	6

System	Organ	Morphology	Total	Male	Female	SOT	SMT	
	Spleen	Filariasis	1	1	0	0	1	
		Total	6	2	4	1	5	
		Splenomegaly	3	1	2	0	3	
		Amyloidosis	1	0	1	1	0	
		Hemosiderosis	1	1	0	0	1	
		Necrosis	1	0	1	0	1	
	Lymph node	Total	3	1	2	0	3	
		Extramedullary hematopoiesis	1	0	1	0	1	
		Hemosiderosis	1	1	0	0	1	
	Musculoskeletal		Lymphosarcoma	1	0	1	0	1
Total			19	6	13	6	13	
Adipose tissue		Total	17	4	13	6	11	
		Emaciation	16	4	12	6	10	
Head		Obese	1	0	1	0	1	
		Hemorrhage	1	1	0	0	1	
		Leg	Hematoma	1	1	0	0	1
			Thoracic cavity	Hydrothorax	11	6	5	0
Urogenital		Total	16	6	10	2	14	
		Kidney	Total	15	5	10	2	13
		Nephritis	9	4	5	1	8	
		Glomerulonephritis	2	0	2	0	2	
		Amyloidosis	1	0	1	0	1	
		Fibrosis	1	1	0	0	1	
		Infarct	1	0	1	0	1	
		Pyelonephritis	1	0	1	1	0	
	Uterus	Stillborn	1	1	0	0	1	
		Total	2	0	2	1	1	
	Integument	Skin	Hyperplasia	1	0	1	0	1
			Icterus	1	0	1	1	0
Endocrine	Adrenal	Necrosis	1	0	1	0	1	
		Nervous	Brain	Hemorrhage	1	1	0	1

Includes animals of unknown sex
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Table 6

Tamarin causes of death in descending order occurrence.

Cause of Death	Total	Percentage	Male	Female	Immature	Mature	SOT	SMT
Heart Failure	12	28.57	5	7	2	10	0	12
Colitis	6	14.29	2	4	2	4	2	4
Atelectasis [/]	3	7.14	0	0	3	0	0	3
Amyloidosis	2	4.76	0	2	0	2	0	2
Stillbirth [/]	2	4.76	1	0	2	0	0	2
Pneumonia	2	4.76	2	0	0	2	0	2
Peritonitis	2	4.76	1	1	0	2	0	2
Typhlitis	2	4.76	0	2	0	2	0	2
Adenocarcinoma	1	2.38	0	1	0	1	1	0
Dehydration	1	2.38	0	1	1	0	0	1
Enteritis	1	2.38	1	0	1	0	0	1
Hemorrhage	1	2.38	1	0	1	0	0	1
Hyperplasia, smooth muscle	1	2.38	0	1	0	1	1	0
Intussusception	1	2.38	1	0	1	0	0	1
Lymphosarcoma	1	2.38	0	1	0	1	0	1
Nephropathy	1	2.38	0	1	0	1	1	0
Pulmonary edema	1	2.38	1	0	1	0	0	1
Pyelonephritis	1	2.38	0	1	0	1	1	0
Rectal prolapse	1	2.38	1	0	0	1	0	1

[/] Includes animals of unknown sex