Case Report

Lung Lobe Torsion in an Adult Male Common Marmoset (*Callithrix jacchus*)

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A 6-y-old, intact, pair-housed male common marmoset (*Callithrix jacchus*) presented with acute onset dyspnea and tachypnea immediately after sedation with alfaxalone; a history of gradual weight loss initiated the examination under sedation. Thoracic radiographs revealed significant right-lung consolidation, with a vesicular gas pattern in the right caudodorsal lung field, pleural effusion, and dorsal displacement of the heart. The marmoset was euthanized due to his unstable condition and poor prognosis. At necropsy, the cranial and middle lobes of the right lung were homogenously dark red-brown, enlarged, edematous, and twisted around the longitudinal axis at the hilus. The left lung lobes were pale pink and slightly edematous. In light of the clinical and gross necropsy findings, acute torsion of the right cranial and middle lung lobes was diagnosed. Predisposing conditions for lung lobe torsion include trauma, neoplasia, pulmonary disease, previous thoracic surgery, and diaphragmatic hernia, but none of these applied to this case. Initial therapy for lung lobe torsion is to stabilize the patient and treat for underlying conditions, with prompt surgical resection as the treatment of choice. To our knowledge, this report is the first description of lung lobe torsion in an experimentally unmanipulated New World NHP.

Abbreviation: LLT, lung lobe torsion

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Lung lobe torsion (LLT) is a rare and life-threatening condition in mammals, including humans, that occurs when a lung lobe rotates on its longitudinal axis, usually at the level of the hilus. This torsion causes occlusion of the bronchus and pulmonary veins, but arterial circulation is maintained and can lead to congestion, edema, and necrosis if the torsion remains unresolved.²⁰ LLT can occur spontaneously; underlying conditions, such as respiratory disease, history of thoracic surgery, pneumothorax, and trauma, which can change the spatial relationship among lung lobes, are associated with increased risk of developing LLT.^{8,13} Although multiple cases of LLT in companion dogs and cats have been published,^{12,14,19} the occurrence of LLT in an experimentally unmanipulated laboratory animal has not previously been reported. Here we describe the clinical progression of spontaneous LLT in a laboratory-reared adult male common marmoset. To our knowledge, this report is the first description of LLT in a New World primate. Because small NHPs like marmosets are increasingly used in pulmonary disease research because of their homologous parenchymal and bronchial architecture to humans,⁴ knowledge of their respiratory pathology is exceptionally important.

Case Report

A 6-y-old, 331-g, pair-housed male common marmoset with a history of declining body weight (approximately 10% over a 3-mo period) presented for sedated physical examination,

weight measurement, and blood collection. The animal was part of a breeding colony ($n = 12$ breeding pairs) housed in an AAALAC-accredited institution on an animal use protocol approved by the MIT Committee on Animal Care and was housed and maintained according to the standards in the Animal Welfare Act and Regulations and the *Guide for the Care and Use of Laboratory Animals*.^{1,2,9} This marmoset was used exclusively for breeding, without experimental manipulation, and was housed in an enriched stainless steel and polycarbonate cage (57.9 in. $\times$ 30.5 in. $\times$ 30.5 in.) in a housing room maintained at 74.0 ± 2.0 °F (23.3 ± 1.0 °C), with a relative humidity of 30% to 70% and a 12:12-h light:dark cycle. Diet consisted of extruded biscuits (Teklad New World Primate Diet 8794, Envigo, Madison, WI) soaked lightly in water and supplemented with washed fruits and vegetables, yogurt, eggs, beans, cottage cheese, canned diet (ZuPreem, Premium Nutritional Products, Shawnee, KS), and mealworms. Reverse-osmosis-purified dechlorinated water was provided without restriction. Health monitoring for marmosets in the colony consists of a complete annual physical, hematologic, and biochemical evaluation. In addition, the colony is monitored semiannually for the presence of pathogenic bacteria and parasites. Animals were seronegative for squirrel monkey cytomegalovirus, *Saimiriine herpesvirus 1*, *Saimiriine herpesvirus 2*, and measles virus on arrival to the facility (C panel, VRL Laboratories, San Antonio, TX). At least twice daily, veterinary staff examine marmosets for injuries and for changes in behavior and fecal output. Daily health records are maintained for each animal, with clinical signs necessitating veterinary attention.

To further evaluate the marmoset for chronic weight loss, a sedated examination was scheduled. However, lethargy and

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Figure 1. (A) Right lateral, (B) left lateral, and (C) ventrodorsal thoracic radiographs demonstrating right middle and cranial LLT. A vesicular emphysema pattern (circles) is evident in the affected lung lobes. Pleural effusion is noted bilaterally, with the heart displaced dorsally in the ventrodorsal view.

increased respiratory effort were noted when the animal was removed from his cage to weigh him before sedation. Immediately after sedation (6 mg/kg IM alfaxalone; Alfaxan, Jurox, Kansas City, MO), the animal's dyspnea worsened, and flow-by oxygen (2 L/min) through a facemask was initiated. On physical exam, the marmoset had pale mucous membranes, reduced body condition (body condition score, 2 of 5) and increased respiratory effort and rate (60 to 80 breaths per minute). Decreased bronchovesicular sounds and muffled heart sounds were auscultated over the right thorax. No external lesions or evidence of trauma were present.

Thoracic radiographs, performed in right and left lateral and ventrodorsal views (Toshiba Rotanode at 40 kVp and 3.75 mAs), revealed significant right lung consolidation with a vesicular emphysema pattern in the right caudodorsal lung field (Figure 1). In addition, the costophrenic angle appeared blunted, suggesting mild pleural effusion within the pleural space. The heart was dorsally displaced. The marmoset received furosemide (4 mg/kg IM; Lasix, Merck Animal Health, Madison, NJ) and dexamethasone sodium phosphate (2 mg/kg IM; MWI, Boise, ID), was intubated with a 1.5-mm endotracheal tube, and was supplemented with 100% O₂ (300 mL/min). The animal's heart rate, pulse rate, temperature, and oxygen saturation were monitored continuously (SystemVET Vet Trends Series 6400 monitor configured with Covidien Nellcor SpO₂ monitor, Ivy Biomedical Systems, Branford, CT). Persistent hypoxemia was noted (SpO₂, 75% to 77%). Ultrasonography (Sonoscape S9, Universal Solutions, Bedford Hills, NY) by using a 4- to 16-MHz 52-mm linear T probe revealed consolidated lung fields with fibrin tags and pleural fluid. Differential diagnoses included pneumonia with severe

Table 1. Serum chemistry results from a 6-y-old male common marmoset with lung lobe torsion

	This animal	Reference range ^{a,b}
ALP (U/L)	34	125 ± 64
AST (U/L)	82	112 ± 112
ALT (U/L)	21	13 ± 24
Creatine kinase (U/L)	1036	543 ± 0
Total protein (g/dL)	4.2	5.1 ± 0.6
Albumin (g/dL)	2.8	6.8 ± 1.0
Globulin (g/dL)	1.4	1.7 ± 0.5
BUN (mg/dL)	31.0	19.5 ± 5.0
Creatinine (mg/dL)	0.4	0.7 ± 0.2
Cholesterol (mg/dL)	92	176 ± 73
Glucose (mg/dL)	660	177 ± 65
Calcium (mg/dL)	8.3	9.5 ± 1.1
Phosphorus (mg/dL)	12.2	5.3 ± 1.9
Chloride (mEq/L)	101	103 ± 11
Potassium (mEq/L)	3.0	4.9 ± 2.6
Albumin:globulin ratio	2.0	
Sodium (mEq/L)	144	147 ± 8
Na:K ratio	48.0	
Anion gap (mEq/L)	26.0	5.0 ± 1.5

^aData for adult common marmosets (*Callithrix jacchus*) were obtained from reference 16.

^bData from the MIT marmoset colony (adults [older than 2 y] housed indoors; n = 41).

Figure 2. Evidence of right cranial and middle lung lobe torsion (A) in situ and (B) after removal of the pluck. The cranial and middle lobes of the right lung are homogeneously dark red-brown, enlarged, and edematous (arrows). The left (unaffected) lung lobes are pale pink, noncollapsible, and edematous.

consolidation, neoplasia, pulmonary hemorrhage from trauma or coagulopathy, pyothorax, and foreign body. The marmoset was euthanized due to poor prognosis. Prior to euthanasia, blood (approximately 1 mL) was collected from the femoral vein for inhouse CBC analysis into an EDTA tube and into a serum separator tube for clinical chemistry (IDEXX Bioresearch, North Grafton, MA; Table 1). Pertinent serum chemistry findings included an elevated creatinine kinase (1036 U/L), hypoalbuminemia (2.8 g/dL), and hypoglobulinemia (1.4 g/dL). BUN and creatinine were mildly elevated (31 mg/dL and 0.4 mg/dL, respectively). The animal was hyperglycemic (660 mg/dL) and hyperphosphatemic (12.2 mg/dL), with an elevated anion gap (26 mEq/L). All other values were within published reference intervals.¹⁶ CBC analysis (HemaVet 950FS, Drew Scientific, Oxford, CT) revealed a mild microcytic normochromic anemia (RBC, 3.71 M/ μ L; Hgb, 8.5 g/dL; MCV, 65.1 fL; MCHC, 35.1 g/dL; and RDW, 14.4%) and thrombocytosis ($458 \times 10^3/\mu$ L).

Thoracocentesis in the left 7th intercostal space obtained approximately 0.2 mL of dark red-brown serous fluid. The fluid was moderately proteinaceous (4.2 g/dL), with few (0 to 3) RBC per high-power field and 1800 WBC per microliter (40% neutrophils, 38.5% lymphocytes), consistent with a modified transudate. Bacterial aerobic and anaerobic cultures of the fluid were negative. Directly after intubation, the marmoset was kept anesthetized on sevoflurane (maximum, 2%), extubated, and then given ketamine hydrochloride (7 mg/kg IM; Putney, Portland, ME) and midazolam (0.2 mg/kg IM; Fresenius Kaba, Lake Zurich, IL). The animal was euthanized approximately 2 h after presentation through terminal perfusion with 4% paraformaldehyde, followed by immediate necropsy.

On gross necropsy, the cranial and middle lobes of the right lung were homogeneously dark red-brown, enlarged, edematous, and twisted around its longitudinal axis at the hilus (Figure 2). The left lung lobes were pale pink and slightly edematous. There was an associated left-lateral displacement of the heart. The liver was enlarged and compressed against the diaphragm, but no diaphragmatic herniation was present. Tissue samples were fixed in 10% neutral buffered formalin, embedded in paraffin, sectioned at 5 μ m, and stained with hematoxylin

and eosin. On histopathologic examination, the right cranial and medial lung lobes were compressed and coiled around the bronchial bifurcation, with clear separation between unaffected and severely affected pulmonary parenchyma (Figure 3 A). In addition, moderate pleural thickening with reactive mesothelial proliferation was noted (Figure 3 B). The affected infarcted parenchyma was characterized by severe effacement of normal architecture by massive hemorrhage, alveolar septal necrosis, proteinaceous fibrinous material, and scattered degenerate cellular debris (Figure 3 C). Comparatively, the left lung lobes were atelectatic but otherwise normal in appearance (Figure 3 D). Additional histologic findings included mild bilateral progressive glomerulonephropathy with associated minimal multifocal tubular degeneration, regeneration and hyperplasia of tubular epithelia, and occasional proteinaceous casts in the tubules. In light of the clinical presentation, gross necropsy, and histopathologic findings, acute torsion of the right cranial and middle lung lobes with lobar infarction was diagnosed.

Discussion

This report is the first to detail LLT in an adult male common marmoset. This animal developed right cranial and middle LLT without any history of chest disease or experimental manipulation. Except for the acute onset of tachypnea and dyspnea, the animal had no relevant medical history other than chronic weight loss. Routine preventative health testing performed prior to the event, including fecal examination, rectal culture, and bloodwork, revealed no significant findings. In humans and animals, LLT presents similarly, with the predominant clinical signs being lethargy, progressive dyspnea, coughing, anorexia, and vomiting.^{8,15} Physical examination frequently reveals pale mucous membranes, dull cardiopulmonary sounds on auscultation, pain on abdominal palpation, pyrexia, and cyanosis.⁸ CBC and chemistry findings are often nonspecific and can include mild anemia, hypoproteinemia, and elevated creatinine, as seen the case we describe here.⁸ The physical exam and laboratory test findings of the marmoset here suggest that this species presents similarly to other mammals, including humans.

Figure 3. Histology, lung. (A) Demarcation between infarcted (arrowhead) and noninfarcted (asterisk) lung parenchyma, with kinking of the main bronchial stem to the right (affected) cranial lobe and mild bronchial epithelial thickening (arrow). Hematoxylin and eosin stain; magnification, 2 $\times$. (B) Subcapsular distention of the affected lung, filled with hemorrhage and moderate amounts of fibrin and showing pleural thickening. Hematoxylin and eosin stain; magnification, 10 $\times$. (C) Pulmonary necrosis with acute diffuse hemorrhage of the right cranial lung lobe. Numerous RBC are present in the disrupted alveoli and interstitium with proteinaceous fluid (edema), and in some areas, there is moderate fibrin formation. Hematoxylin and eosin stain; magnification, 200 $\times$. (D) The left lung lobe parenchyma has diffuse atelectasis but is otherwise normal. Hematoxylin and eosin stain; magnification, 200 $\times$.

Imaging results were consistent with typical findings in other mammals presenting with LLT and included pleural effusion, lung consolidation, and an emphysematous vesicular pattern in the affected lung lobe.^{5,7} The modified transudate obtained from thoracocentesis is consistent with some reports in domestic species, although suppurative inflammation and hemorrhage have been noted also; therefore the type of effusion generally does not help identify the cause.⁵ Although radiographic and ultrasonographic techniques are used to aid diagnosis of LLT, the findings can be nonspecific. Although unavailable at our institution during the current case, CT and bronchoscopy can be informative in cases of LLT.¹⁷ In particular, CT is a critical diagnostic tool in cases of LLT; an abruptly ending bronchus and enlargement and consolidation of the torsed lobe are the most common diagnostic findings.^{3,5,17} LLT is definitively diagnosed through either exploratory thoracotomy or at necropsy.

Initial therapy for LLT is symptomatic and involves relieving respiratory distress by removing pleural fluid, if necessary, and providing supplemental oxygen; these measures are followed immediately by treatment of any concurrent respiratory disease and subsequently with prompt surgical resection of the

affected lobe(s) as the treatment of choice. In canines, a thoracotomy approach is recommended to best visualize and remove the affected lobe, although resection by using thoracoscopy has been reported as well.^{6,11} Reported postoperative complications include recurrence of LLT, pneumonia, infection, and chylothorax.^{8,18} In companion-animal patients, the prognosis is fair for spontaneous LLT to guarded when LLT is associated with other intrathoracic pathology and prolonged time to lung lobe resection.¹⁴

Histopathologically, the lung lesions in our marmoset were consistent with acute intra- and extrapulmonary hemorrhage and lobar infarction, supporting the right and cranial middle lobar infarction seen grossly. The reactive changes in the pleura and surrounding mediastinal adventitial tissue in the thoracic cavity are consistent with leakage of blood and protein contents from affected lung lobes, causing reactive mesenchymal early fibroplasia and de novo hematopoiesis. This pathology is consistent with the observed clinical signs of respiratory distress that necessitated immediate action in this case. These findings are consistent with previous histologic analyses of dogs and cats with LLT.⁵ Interestingly, both the right cranial and middle lobes

were torsed in our marmoset. In dogs and cats, the most common affected lobes are the right middle and left cranial lobes, and torsion of multiple lobes rarely occurs.^{5,12,19} No characteristically affected lobe in humans has been reported.¹³ The most common presentation in marmosets remains unclear, given that this report is the first description of this morbidity in a NHP. The progressive bilateral glomerulonephropathy noted on histopathology was likely spontaneous and is commonly reported in marmosets; we therefore considered it an incidental finding.¹⁰

The cause of the lung lobe torsion in our marmoset remains unclear but most likely was spontaneous, given the lack of history of chronic respiratory disease, experimental manipulation, and injury and the acute onset of clinical signs. Animal movement during capture for sedation may have been an inciting factor. A fight between cagemates is unlikely to have instigated pathology, given the lack of injuries and absence of noted incompatibility between the pair. Published information on this condition is sparse, given that it is exceptionally rare and has not previously been reported in captive primates.

In conclusion, we report a case of spontaneous LLT in a common marmoset. The primary clinical signs were acute onset tachypnea and persistent dyspnea, with similar radiographic and ultrasonographic findings as reported in other species. Although this condition is rare in all mammals, LLT should be included in the differential diagnoses for marmosets with acute dyspnea, despite a lack of history of respiratory disease. We recommend including chest radiographs to screen for underlying causes of respiratory distress and disease as part of preventative health exams. Although subtle, the clinical presentation and radiographic findings can suggest LLT and direct case evaluation, including CT scans and prompt surgical intervention.

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