

Diagnosis and Repair of Familial Diaphragmatic Defects in Golden Lion Tamarins

Mitchell Bush, DVM; Richard J. Montali, DVM; D. G. Kleiman, PhD; Judson Randolph, MD;
Michael D. Abramowitz, MD; Ronald F. Evans, BA

SUMMARY

Diaphragmatic defects were identified in 11 of 130 golden lion tamarins. Seven of the cases were found at necropsy (52 tamarins) and 4 were diagnosed by radiography (78 tamarins). When screening radiography revealed a thoracic mass, a barium series was indicated and either demonstrated loops of bowel within the thorax or suggested liver displacement by the cranial location of the intestine. In 1 case, pneumoperitoneum aided in the diagnosis, by showing liver displacement cranially in an eventration of the diaphragm.

The 4 defects diagnosed clinically were successfully corrected surgically. The defects mainly involved the ventromedial to lateral aspect of the costal and sternal muscular portions of the diaphragms. Either a thin pleuroperitoneal sac remained or wide gaps were associated with herniation of abdominal contents into the thorax.

Of the 11 affected tamarins, 10 were closely related and the other had no direct consanguinity. An autosomal recessive mode of inheritance was suggested, but other genetic factors may have been involved.

GOLDEN LION tamarins (*Leontopithecus rosalia*) are rare and endangered primates indigenous to the coastal rain forest in Brazil. Their decreasing numbers in the wild are due mainly to habitat destruction. The studbook for this species identifies only 197 individuals in captivity. Current estimates suggest that approximately 20 to 30 may be left in their native habitat.¹ This provides only a limited breeding nucleus to establish a self-sustaining captive population. If any genetic defect were in a population with a limited gene pool, identification and elimination of it would be desirable.

From the Department of Animal Health (Bush), the Department of Pathology (Montali), and the Department of Zoological Research (Kleiman, Evans), National Zoological Park, Smithsonian Institution, Washington, DC 20008, and the Department of Surgery (Randolph) and the Department of Anesthesiology (Abramowitz), Children's Hospital, National Medical Center, Washington, DC 20010.

The authors thank Ms. Brenda Clymire of the Office of Graphics and Exhibits, National Zoological Park, for the photographic reproductions of the radiographs.

Birth defects are not commonly reported in simian primates.² Though familial diaphragmatic defects are not uncommon in human beings,³ none has been recorded in simian primates; however, a diaphragmatic hernia attributed to trauma was reported in a Rhesus monkey (*Macaca mulatta*).⁴ One congenital diaphragmatic hernia, with the left hemidiaphragm absent, was reported in a 16-week baboon fetus (*Papio* sp).² Another diaphragmatic hernia was one of many congenital defects found in a chimpanzee (*Pan troglodytes*) with Down's syndrome.⁵

In this report, a diaphragmatic defect, believed to be congenital, was diagnosed at necropsy and radiographically in a group of golden lion tamarins. In the 4 cases diagnosed clinically, the defect was corrected surgically. The description of those cases follows.

Clinical Case Reports

Case 1—A 9½-year-old, 700-g, female golden lion tamarin developed progressive facial edema during a 1-week period. She had given birth to twins 5 weeks earlier. On close examination, the edema was also noted in her forelimbs and inguinal areas. Radiography revealed a large mass in the thorax (Fig 1A). The tamarin showed no respiratory distress while on exhibit or during the diagnostic procedures. She appeared alert and active and ate well. Hematologic values were within the normal limits for golden lion tamarins in our collection. Treatment consisted of a corticosteroid and antibiotic combination,^a and the edema was gone in about 1 week.

A barium series showed no stomach or bowel within the thoracic cavity, but the cranial displacement of these structures into the area of the liver suggested that liver was in the thorax (Fig 1B). The tamarin was returned to the collection and went through 1 normal pregnancy. An abortion terminated a 2nd pregnancy. At 22 months after the episode of facial edema, surgery was performed to explore and correct the suspected defect.

Anesthesia was induced with 1–1½% halothane^b and oxygen delivered by a face mask to the tamarin, which had been fasted for 12 hours and had received

^aAzimidin, Schering Corp, Bloomfield, NJ.

^bFluothane, Ayerst Laboratories, Inc, New York, NY.

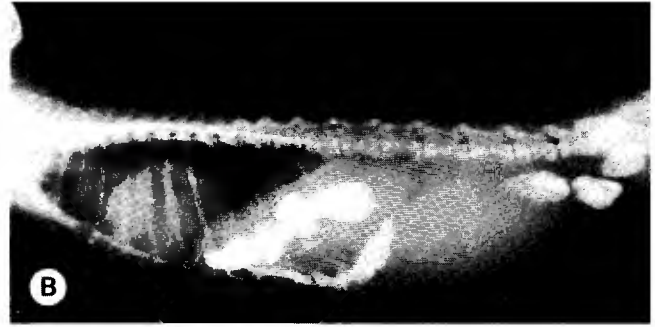


Fig 1A—Lateral radiograph of tamarin 1, showing a large mass in the thorax.
B—Lateral radiograph following barium ingestion, showing the cranial location of the large intestine, suggesting the liver is within the thorax.

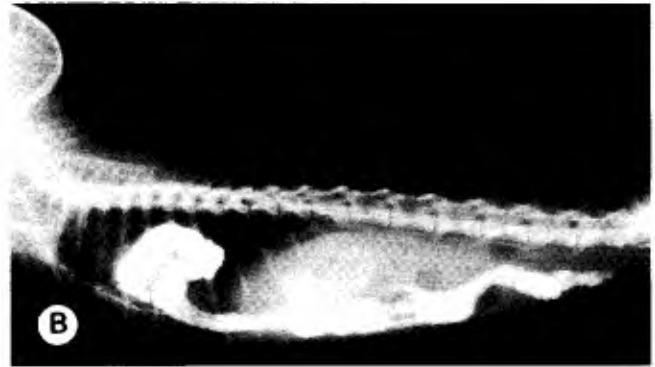
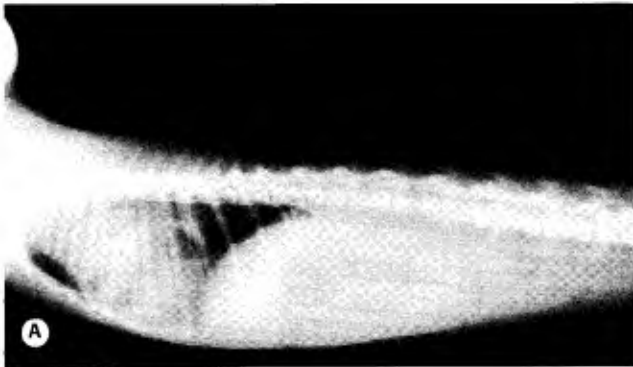


Fig 2A—Lateral radiograph of thorax of tamarin 2, showing a large mass containing air pockets, suggesting the presence of bowel.
B—Lateral radiograph following barium ingestion, showing the cecum and colon within the thorax.

50 μ g of atropine sulfate IM 15 minutes prior to anesthesia. Once anesthetized, a modified No. 5 French feeding tube was used for tracheal intubation because the smallest commercial Murphy eye (2-mm internal diameter) tracheal tube was too large. The larynx and epiglottis looked relatively large, compared with the actual size of the tracheal lumen, giving the illusion of a trachea that would accommodate a larger tracheal tube. A pediatric laryngoscope with a Miller 0 blade aided intubation. The modified tracheal tube did not contain a cuff but the fit was adequate to allow proper ventilation and expansion of the lungs by positive pressure ventilation during the time when the thoracic cavity was open, despite some leakage around the tube. Anesthesia was maintained by means of controlled respirations and by titrating the halothane and oxygen concentration from 0.5–1.5% while monitoring included heart rate and tone by esophageal stethoscope; a doppler was used to measure systolic blood pressure. The surgery lasted about 50 minutes. Supportive care included lactated Ringer's solution IV and an antibiotic given subcutaneously.

Surgery was performed through a ventral midline abdominal incision. The hernia involved the right hemidiaphragm, which was pushed to the lateral thoracic wall, with 70% of the liver in the thorax. Repair was accomplished with interrupted sutures of 000 silk, and the right hemidiaphragm was

sutured to the mediastinum and the xiphoid. Closure of the abdominal incision was routine.

Following recovery from anesthesia, the tamarin was placed in an incubator at 30 C, with supplemental oxygen for about 24 hours. Small amounts of water, banana, and marmoset diet were offered 6 to 8 hours after recovery from the anesthesia. After 24 hours, the animal was then transferred to a small cage. The prophylactic antibiotic was continued for 5 days. Skin sutures were removed at 7 days following surgery. The tamarin recovered without complications.

Case 2—A 425-g, 1½-year-old daughter of tamarin 1 was radiographed and found to have a mass in her thorax (Fig 2A). This animal had a history of failure to grow, as compared with her brother. She had had repeated infection with the nematode of the *Rictularia* sp, which had caused diarrhea, vomiting, and anemia.⁶ The parasitism was treated with mebendazole,⁶ and she also received supportive therapy, which led to some clinical improvement. However, she was prone to reinfection, due to her habit of eating cockroaches, which are believed to be the intermediate host for this parasite.⁶

Contrast radiography showed part of the cecum and colon within the thorax (Fig 2B).

The anesthesia and surgical approach were as

⁶Telmin, Pitman-Moore, Washington Crossing, NJ.

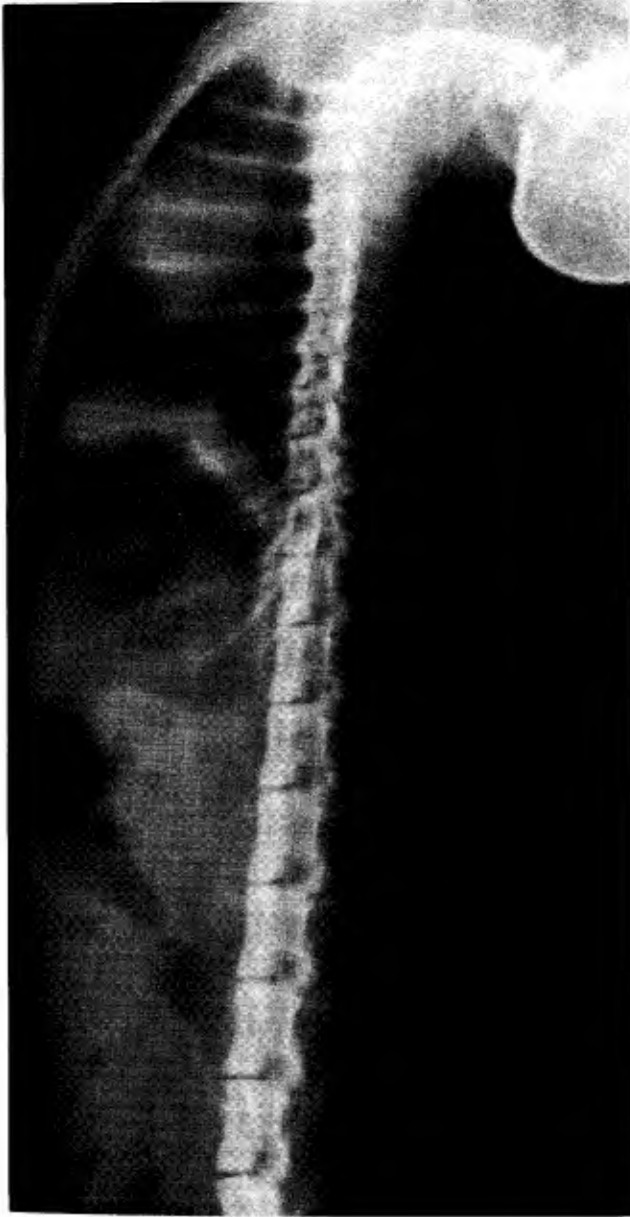


Fig 3—Standing lateral radiograph of tamarin 3 with pneumoperitoneum, showing eventration of the diaphragm containing a liver lobe.

described in case 1. At surgery, a hernia was found in the left hemidiaphragm, with colon, cecum, and liver protruding into the thorax. These organs were returned to the abdominal cavity and the hernia was repaired with 000 silk. A radiographic study 2 weeks following surgery showed loops of bowel within the thorax. At surgery 7 weeks later, a 2nd hernia was found in the right hemidiaphragm, with colon, cecum, and liver in the thorax. This hernia was reduced and repaired as before. Apparently at the 1st surgery, a lobe of liver was positioned against the defect on the right side and it was missed due to limited exposure resulting from the small size of the patient.

The postoperative care was as in case 1, and the tamarin recovered following the 2nd surgery; she

has since attained a normal weight of 685 g. There have been no recurrences of vomiting since surgery, but the *Rictularia* parasitism is also under control—and this might have been the cause of the vomiting, as originally suspected.

Case 3—A 571-g, 11-month-old, female golden lion tamarin, the great granddaughter of tamarin 1, was noted to have a thoracic density during routine radiography prior to shipment. The tamarin had no clinical signs of any distress. A barium series showed no bowel in the thorax, but the bowel appeared misplaced cranially, in the region where the liver should be. The animal was anesthetized as described in case 1. Pneumoperitoneum was induced, using 25 ml of CO₂, and standing radiography outlined an eventration of the diaphragm, with the liver displacing part of the pleural cavity (Fig 3). At surgery, the eventration was obliterated, using interrupted sutures of 000 silk. Recovery was uncomplicated.

Case 4—A 2½-year-old, 546-g, female golden lion tamarin from the San Antonio Zoo, apparently unrelated to the other 3, was found to have a radiodense thoracic mass during a quarantine physical examination (Fig 4A). The animal had no signs of illness. A barium series showed the stomach to be in the thorax, displacing the heart to the right (Fig 4B).

Anesthesia and surgical approach were as before. The hernia was on the left side, and the liver, stomach, and spleen were found in the thorax. These contents were replaced in the abdomen and the hernia was repaired with interrupted sutures of 000 silk. Dyspnea during recovery was attributed to atelectatic lung tissue, but the condition improved over the next 24 hours, while the animal was in an incubator with supplemental O₂. The tamarin did well afterward and has had no further problems.

Necropsy Cases

Besides the 4 cases that were corrected surgically, 7 other cases were identified at necropsy and are listed (Table 1) noting the sex, age, location of the diaphragmatic defect, and the animal's relationship to tamarin 1.

Discussion

The tamarins with the diaphragmatic defects were from the breeding stock of the National Zoological Park in Washington, DC, the Monkey Jungle in Florida, and the San Antonio Zoo. These collections are stable, breeding colonies and are in good general health.⁷

The gross and microscopic changes found in these defects have been reported.⁸ The defects mainly involved the ventromedial to lateral aspects of the costal and sternal muscular portions of the diaphragm. Either a thin pleuroperitoneal sac remained, or there were wide gaps, allowing eventration or herniation of liver lobes, spleen, and various segments of the gastrointestinal tract. Microscopi-

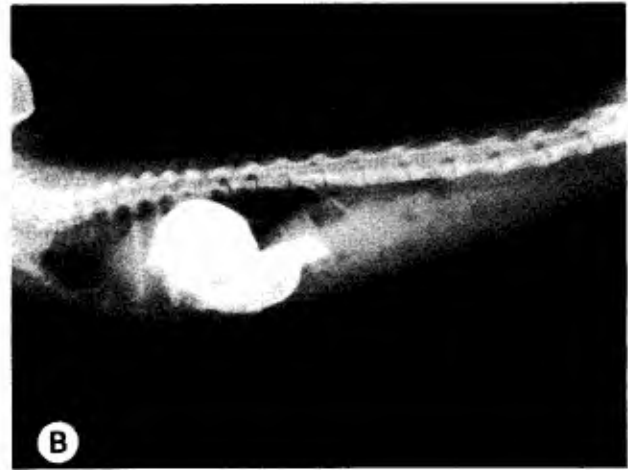
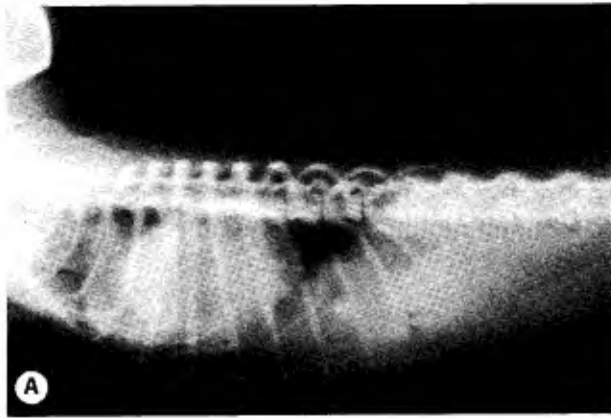


Fig 4A—Lateral radiograph of tamarin 3, showing a large thoracic mass.

Fig 4B—Lateral radiograph following a barium swallow, showing the thoracic mass contains the stomach.

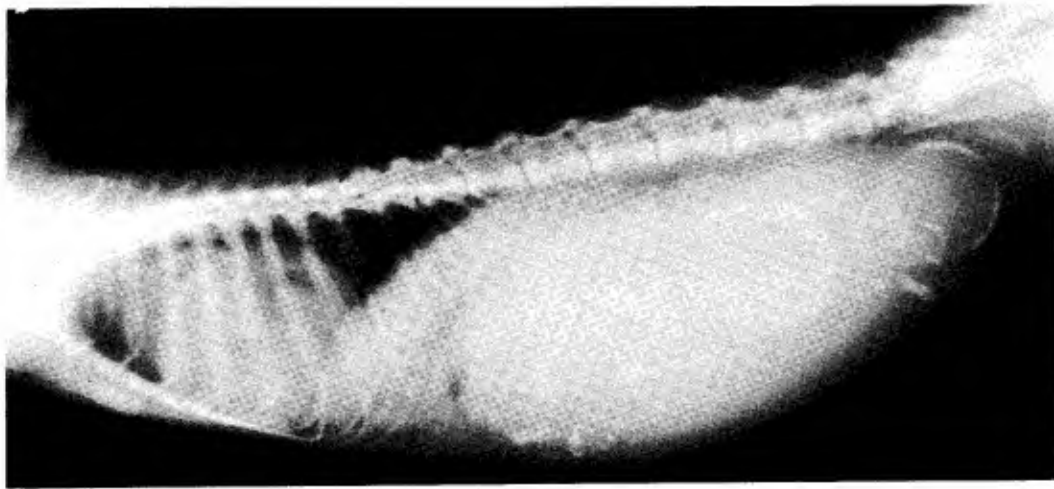


Fig 5—Lateral radiograph of tamarin 1 when pregnant. Notice the large size of the twin fetuses, which increase intraabdominal pressure and potentiate herniation through a diaphragmatic defect.

TABLE 1—Diaphragmatic Defects Found at Necropsy

Case No.	Sex	Age at death	Relationship to tamarin 1	Location of defect
5	Male	6 months	Son	Left side
6	Female	34 days	Daughter	Right side
7	Male	1 day	Son	Both sides
8	Male	1 day	Grandson	Both sides
9	Female	2½ months	Granddaughter	Left side
10	Male	1 day	Grandson	Both sides
11	Male	1 day	Grandson	Right side

cally, there was either a lack of or diminished muscle fibers in the affected portions of the diaphragm. The serous membranes from pleural and peritoneal surface continued to form the thin pleuroperitoneal sac. The membranes forming the sac contained irregular bundles of fibrocytes associated with collagen and blood vessels. In some areas, there were mild perivascular infiltrates of lymphoplasmocytes. The intact muscular and tendinous portions of the diaphragm were microscopically unremarkable.

Branches of the phrenic nerve appeared normal. The defects were on the left and/or right side, at the level of the caudal vena cava. In 4 cases, both sides of the diaphragm were affected.

In man, the majority of diaphragmatic defects involve the caudolateral aspect of the diaphragm. The defects in man that most resemble those in the tamarins are retrosternal and involve the foramen of Morgagni, which account for the minority of defects in man and are not associated with organ displacement into the thorax. In human beings, this particular defect appears to be nongenetic.³

Clinical signs possibly attributed to the defect were seen in case 1, in which the tamarin developed a cranial caval syndrome, and in case 2, in which the tamarin was underweight and vomited. The 2 other tamarins (cases 3 and 4) appeared normal and were very active.

The prevalence of the defect may not be found by the present radiographic techniques. A defect in the

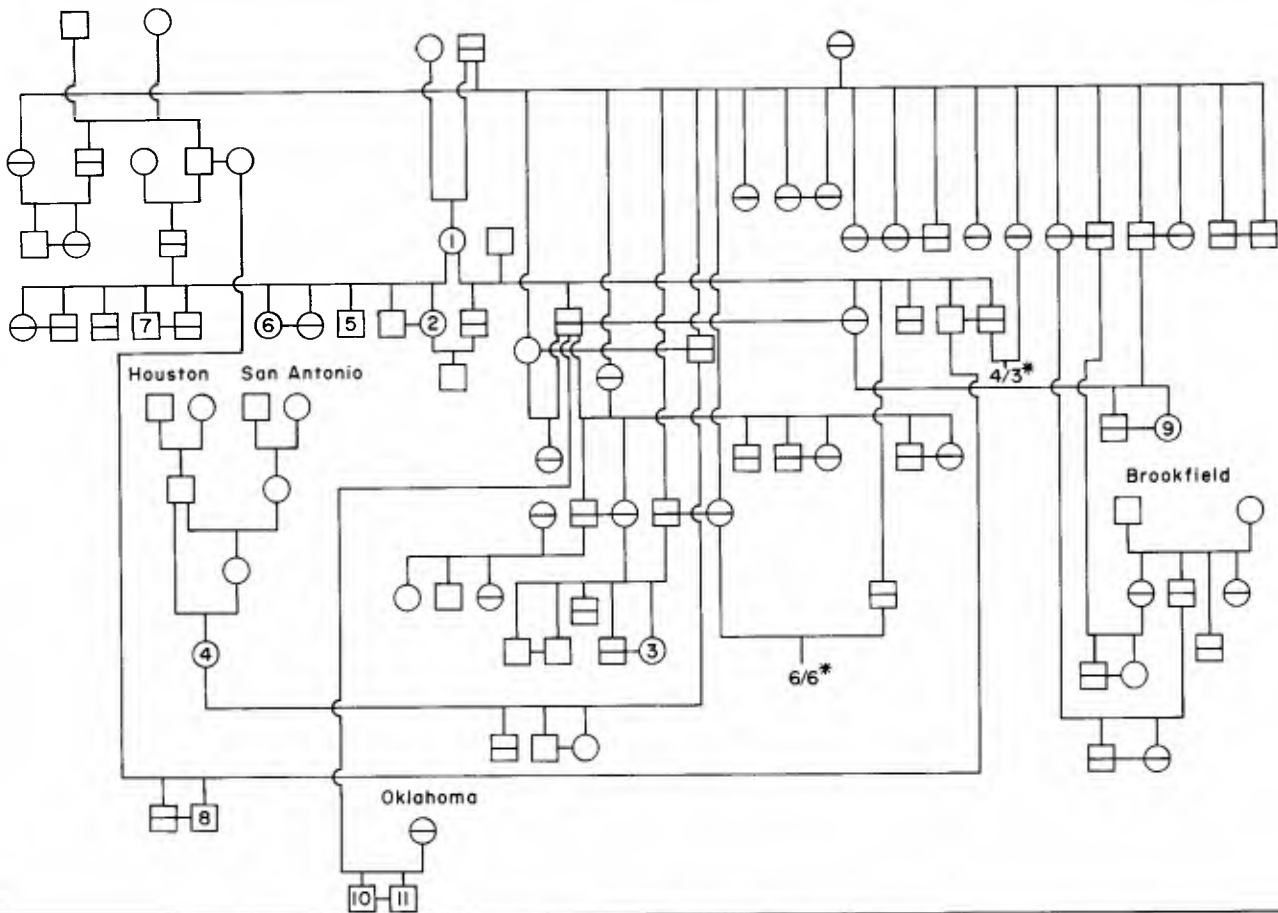


Fig 6—Pedigree of golden lion tamarins with diaphragmatic defects. □ = male; ○ = female; only those squares and circles with numbers represent known affected animals. ⊠ ⊗ = determined to be unaffected.
 *Animals from this mating were determined to be unaffected (designated simply as male/female because of lack of space).

diaphragmatic muscle with an intact pleuroperitoneal membrane may not necessarily lead to eventration if the defect is small. Also, the defect could be potentiated during pregnancy (Fig 5), eg, where enlarging twin fetuses filled the abdominal cavity of tamarin 1 and displaced gas-filled loops of bowel into the thorax.

Of the 110 living tamarins in our collection, we have radiographed 78 and found 4 defects; of the 52 necropsied, 7 had defects. Thus, we found 11 defects in 130 animals, a prevalence of 8.5%. The occurrence of these defects appears to have a heritable basis in 10 of the 11 cases (Fig 6). Of 9 cases, 4 were siblings, and there were 3 grandsons, 1 granddaughter, and 1 great granddaughter of tamarin 1. Tamarin 4 did not have any documented relationship to the other animals. However, the extent of the known genealogy was not extensive and there may have been a relationship that existing records did not show, since all the original animals were obtained from a limited wild population. The precise mode of inheritance cannot be determined at this time, but the pattern suggests a simple autosomal recessive mode. Other factors of Mendelian inheritance, eg, dominance with incomplete penetrance, cannot be eliminated from consideration. There is no sex predilec-

tion noted and no evidence of any sex linkage. Further tests are being conducted to provide more information on the genetics of this condition.

References

1. Kleiman DG: *International Stud Book, Golden Lion Tamarin, (Leontopithecus rosalia rosalia)*. Washington, DC, Dept of Zoological Research, National Zoological Park, Smithsonian Institution, 1980.
2. Hendrichs AG, Gasser RF: A description of a diaphragmatic hernia in a sixteen week baboon fetus (*Papio* sp.). *Folia Primatol* 7:66-74, 1967.
3. Warkany J: *Congenital Malformations*. Chicago, Yearbook Med Publications, Inc, 1971, pp 751-757.
4. Dalgard DW: Herniation of a hepatic lobe into the right thorax of a rhesus monkey (*Macaca mulatta*): An incidence report. *Lab Anim Care* 19:109-110, 1969.
5. McClure HM: Animal model for human disease, Down's syndrome (mongolism, trisomy 21). *Am J Pathol* 67:413-416, 1972.
6. Montali RJ, Bush M: Diagnostic exercise: *Rictularia* sp. in golden lion tamarins. *Lab Anim Sci* 29, 1980.
7. Kleiman DG, Jones M: The current status of *Leontopithecus rosalia rosalia* in captivity with comments on the breeding success at the National Zoological Park, in Kleiman DG (ed): *The Biology and Conservation of the Callithricidae*, The Symposia of the National Zoological Park, Washington, DC, Smithsonian Institution Press, 1977.
8. Montali RJ, Bush M, Kleiman D, et al: Familial diaphragmatic defects in golden lion tamarins. Sonderdruck aus Verhandlungsbericht des XXII Internationalen Symposiums über die Erkrankungen der Zootiere, Arnhem, pp 173-179, 1980.