

Long-term outcome of cats treated conservatively or surgically for peritoneopericardial diaphragmatic hernia: 66 cases (1987–2002)

S. Brent Reimer, DVM; Andrew E. Kyles, BVMS, PhD; Dean E. Filipowicz, BS; Clare R. Gregory, DVM

Objective—To determine long-term outcome of cats treated conservatively or surgically for peritoneopericardial diaphragmatic hernia (PPDH).

Design—Retrospective study.

Animals—67 cats with PPDH.

Procedure—Medical records of cats with a diagnosis of PPDH made from 1987 through 2002 were reviewed. Information regarding long-term outcome was obtained from owners.

Results—Prevalences of PPDH in domestic longhair and Himalayan cats were significantly greater and prevalence of PPDH in domestic shorthair cats was significantly lower than prevalence of PPDH in the hospital cat population over the 15-year study period. Historical problems most commonly related to the respiratory and gastrointestinal tracts. Peritoneopericardial diaphragmatic hernia was the primary diagnosis in 40 cats and an incidental finding in 27 cats. One cat died prior to arrival at the Veterinary Medical Teaching Hospital. Thirty-seven of 66 cats were treated surgically, and 29 were treated conservatively. The postoperative mortality rate was 14%. Postoperative complications developed in 29 of 37 cats, the most common of which was hyperthermia. Two of 22 conservatively treated cats had progression of clinical signs necessitating surgical intervention or resulting in death. Owner satisfaction with treatment choice and long-term outcome was rated as very satisfied by 88% of owners of surgically treated cats and 68% of owners of conservatively treated cats.

Conclusions and Clinical Relevance—Cats with overt clinical signs attributable to PPDH are good candidates for surgical herniorrhaphy. Postoperative complications may develop but are generally minor and self-limiting. Long-term outcome of cats treated conservatively or surgically was rated as very good by most owners. (*J Am Vet Med Assoc* 2004;224:728–732)

Peritoneopericardial diaphragmatic hernia (PPDH) occurs when an abnormal communication between the pericardial sac and the peritoneal cavity develops. In cats, PPDH is solely the result of congenital anomalies.¹ In contrast, PPDH in humans may occur as a result of trauma or a congenital anomaly.² In humans, the

diaphragm forms 1 wall of the pericardial sac; traumatic rupture of this area of the diaphragm allows herniation of abdominal contents into the pericardial sac. In cats, the pericardium and diaphragm are not connected; therefore, PPDH as a result of trauma does not occur in cats.

Peritoneopericardial diaphragmatic hernia is one of the most common congenital cardiac defects diagnosed in cats ≥ 2 years of age.³ Peritoneopericardial diaphragmatic hernia is the most common congenital pericardial defect and the most common congenital diaphragmatic defect of dogs and cats.^{4,5} Several theories regarding the pathogenesis of PPDH have been proposed^{2,4,7}; most suggest failure of normal development of the septum transversum (the embryologic structure that forms the ventral portion of the diaphragm). One theory proposes that there is failure in closure of the septum transversum itself, and another proposes that there is failure of fusion of the septum transversum and the pleuroperitoneal folds (the embryologic structures that form the dorsolateral portion of the diaphragm).^{2,4,7}

In previous reports^{2,4,16} of feline PPDH, only a few clinical cases are described and follow-up information is often limited. The purposes of the study reported here were to review medical records of cats with a diagnosis of PPDH and compare clinical features, rationale for treatment choice, and long-term outcome of cats treated conservatively with those of cats treated surgically. We hypothesized that cats treated surgically would have a better long-term outcome than cats treated conservatively.

Criteria for Selection of Cases

Medical records of cats with a definitive diagnosis of PPDH made at the Veterinary Medical Teaching Hospital (VMTH), University of California, Davis, from 1987 through 2002 were retrieved. A definitive diagnosis of PPDH was made on the basis of results of thoracic radiography, thoracic and abdominal ultrasonography, surgery, or postmortem examination.

Procedures

Medical record review—Data obtained from the medical record included age, breed, sex, medical history, physical examination findings, and results of laboratory tests and diagnostic imaging studies. One cat had died prior to arrival at the VMTH. Data from this cat (age, breed, sex, medical history, and postmortem examination findings) were included in the data analysis. The other cats were either treated conservatively or surgically. Additional data for surgically treated cats included findings during surgery (ie, organs herniated and appearance of organs within and adjacent to the hernia), anesthetic and intraoperative problems, and

From the Veterinary Medical Teaching Hospital (Reimer, Filipowicz) and the Department of Surgical and Radiological Sciences (Kyles, Gregory), School of Veterinary Medicine, University of California, Davis, CA 95616. Dr. Reimer's present address is the Department of Small Animal Clinical Sciences, Veterinary Teaching Hospital, Michigan State University, East Lansing, MI 48824.

The authors thank Dr. Phil Kass for assistance with statistical analyses. Address correspondence to Dr. Reimer.

postoperative complications and mortality rate. Treatments prescribed for cats treated conservatively were recorded.

Assessment of long-term outcome—Long-term follow-up information (ie, response to treatment and long-term results) was collected from owners during a telephone interview. Information was included if the owners could be contacted at least 6 months after the original diagnosis of PPDH was made. Owners of conservatively treated cats were asked to give their reasons for choosing conservative treatment. Owners were asked to rate their satisfaction with treatment choice and long-term outcome as very satisfied, mostly satisfied, somewhat satisfied, or dissatisfied.

Statistical analyses—The hospital and breed prevalences and 95% confidence intervals (CIs) of PPDH over the 15-year period were calculated. χ^2 Tests of homogeneity, by use of large-sample and exact methods for inference, were used to determine differences in prevalence of PPDH in various breeds. Analysis was restricted to those breeds that represented $\geq 1\%$ of the total number of cats admitted over the 15-year period.

Results

Signalment and prevalence of PPDH—Medical records of 67 cats with a diagnosis of PPDH made over the 15-year study period were retrieved. Median age was 54 months, with a range of 1.5 to 204 months. Twenty-nine of 37 male cats were castrated, and 26 of 30 female cats were spayed. Breeds included domestic longhair ($n = 29$), domestic shorthair (16), Himalayan (7), domestic medium hair (4), Persian (4), Siamese (2), Manx (2), and Angora, Balinese, and Scottish Fold (1 each). During the 15-year study period, 26,788 cats were assessed at the VMTH. The prevalence of PPDH in the hospital population was 0.25% (95% CI, 0.19% to 0.31%).

Three breeds were significantly ($P < 0.001$) under- or overrepresented, compared with the overall hospital population. Domestic shorthair cats were underrepresented, with prevalence of PPDH of 0.1% (95% CI, 0.057% to 0.16%). Domestic longhair cats were overrepresented, with prevalence of PPDH of 0.68% (95% CI, 0.46% to 0.98%), and Himalayan cats were overrepresented, with prevalence of PPDH of 1.45% (95% CI, 0.59% to 3.0%).

History and clinical signs—Medical histories included problems that could be attributed to PPDH. These problems included breathing problems (ie, dyspnea or tachypnea [$n = 25$]), intermittent anorexia (20), intermittent lethargy (12), coughing (8), febrile episodes (6), exercise intolerance (6), small stature as perceived by the owner (5), collapse (5), intermittent diarrhea (5), vomiting (4), and intermittent palpable sternal clicking (1). Seventeen cats had no history of problems believed to be attributable to PPDH. One cat died prior to arrival at the VMTH, and a diagnosis of PPDH was made on postmortem examination. The cause of death was severe cardiac tamponade as a result of PPDH.

Medical histories revealed that 12 cats had clinical problems not typically associated with PPDH including

renal failure ($n = 3$), cutaneous masses (2), lower urinary tract disease (2), heart murmur (2), spots on the nasal planum (1), healing abscess (1), and sneezing (1).

Historical clinical signs that could be attributed to PPDH were the primary reason for initial examination in 40 of 67 (60%) cats. Peritoneopericardial diaphragmatic hernia was an incidental finding in 27 (40%) cats.

The most common abnormal finding detected via physical examination was muffled heart sounds, found in 31 of 66 live cats. In 17 cats, heart sounds were muffled to a greater degree on 1 side of the thorax than on the other, and in 14 of these cats, the heart sounds were muffled to a greater degree on the right side. Other abnormalities detected via physical examination included cardiac murmurs ($n = 9$), pyrexia (range, 39.2° to 40.2°C [102.6° to 104.4°F]; 9), tachypnea (8), dyspnea (7), thin body condition (5), abnormal lung sounds (3), sternal click (1), palpable pectus excavatum (1), auscultable thoracic borborygmi (1), expiratory wheeze (1), and microphthalmia and lid atresia (1). No abnormalities were detected during physical examination of 13 cats.

Diagnostic results—Thoracic radiography was performed on 66 of 67 cats (thoracic radiography was not performed on the cat that died prior to arrival at the VMTH). Survey radiography revealed changes consistent with PPDH^{6,11} in 65 of 66 cats. A pulmonary mass was found on thoracic radiographs of 1 cat; subsequent surgical exploration of the thorax revealed a PPDH. Thoracic ultrasonography^{11,16,17} provided information to support a diagnosis of PPDH in 32 of 33 cats in which thoracic ultrasonography was performed. No abnormalities were detected via thoracic ultrasonography in 1 cat with PPDH. A positive-contrast peritoneogram performed in 1 cat revealed PPDH.

Results of a CBC and serum biochemical analyses were available for review in 54 of 66 cats. All parameters were within reference range in 26 of 54 cats. Various nonspecific abnormalities in the CBC and serum biochemical values were detected in the remaining cats.

Eight of 67 cats had skeletal abnormalities. The most commonly detected skeletal abnormalities were pectus excavatum ($n = 4$) and decreased number of sternebrae, compared with typical cats (4). One cat had 8 lumbar vertebrae and lordosis of the thoracic spine. Nonskeletal anatomic abnormalities included eyelid atresia and microphthalmia ($n = 1$), atrial septal defect (1), pulmonic stenosis (1), stenotic nares (1), and pseudotruncus arteriosus (1).

Several concurrent medical conditions were detected including hypertrophic cardiomyopathy ($n = 3$), renal insufficiency (2), upper respiratory tract infection (2), pericardial cyst and effusion (2), bronchitis (2), unclassified cardiomyopathy (2), polycystic kidney disease (2), hyperthyroidism (2), urinary tract obstruction (2), chylothorax (2), seizures (2), and diabetes mellitus (2). One cat each had 1 of the following concurrent conditions: cardiac tamponade as a result of herniated abdominal organs in the pericardial sac (the cat that died prior to arrival at the VMTH), pleural lipoma, cystic endometrial hyperplasia-pyometra

complex, pelvic fractures, salivary adenocarcinoma, third degree A-V block, right heart failure and ascites, pyothorax, positive test result for FIV, and lymphoma.

Surgery—Thirty-seven of 66 (56%) cats were treated surgically. Twenty-one of 25 cats with a history of respiratory problems were treated surgically. Thirteen of 29 cats with a history of problems that could be attributed to the gastrointestinal tract and 6 of 17 cats with a history of problems that could not be attributed to PPDH were treated surgically. Peritoneopericardial diaphragmatic hernia was considered to be the primary clinical problem in 27 of 37 (73%) cats that were treated surgically.

Intraoperative complications developed in 14 of 37 cats, and some cats developed multiple complications. These complications included hypotension ($n = 9$), respiratory acidosis (3), hypoventilation (2), hypoxia (1), loss of palpable pulses (1), and multifocal ventricular premature contractions (1).

Abdominal viscera found in the pericardial sac included liver ($n = 36$), gallbladder (23), small intestine (9), omentum (7), stomach (4), colon (2), falciform ligament (2), and spleen (1). Adhesions between the pericardium and herniated structures were noted in 3 cats.

Postoperative complications (complications that arose within the first 3 days after surgery) developed in 29 of 37 (78%) cats. Postoperative hyperthermia (ie, rectal temperature $> 39.2^{\circ}\text{C}$) was detected in 20 of 37 (54%) cats. Hyperthermia was first detected 1 to 12 hours after surgery and generally resolved within 12 hours of detection; however, in 1 cat it persisted for 48 hours. Other postoperative complications included tachypnea ($n = 5$), dyspnea (2), hypoventilation (2), persistent acidemia (2), partial blindness (2), and hypoxia and refractory pneumothorax (1 each). Two cats that became partially blind recovered their sight fully within 2 days and 6 months of surgery, respectively.

Complications that arose after the first 3 days but within the first 6 months after surgery were reported in 15 of 36 cats. These complications included surgical wound inflammation ($n = 4$); slow recovery as perceived by owner (ie, decreased activity and discomfort persisting for several days; 3); pleural effusion (3); decreased appetite (2); and infection of the surgical incision, vomiting, pericardial effusion, and coughing (1 each). Two of 3 cats with pleural effusion were the cats with a preoperative diagnosis of chylothorax; the effusion persisted postoperatively.

The postoperative mortality rate was 14% (5 cats). Peritoneopericardial diaphragmatic hernia was the primary problem in 4 of 5 cats that died postoperatively and an incidental finding in the remaining cat. The deaths occurred at 4 hours and 4, 5, 9, and 27 days after surgery. Records indicated that 3 of these cats had periods of hypoventilation during surgery or in the immediate postoperative period.

Two of the cats that died postoperatively had a preoperative diagnosis of chylothorax. One cat developed cardiopulmonary arrest and died 4 days after surgery, and the other cat was euthanatized 27 days postoperatively because of persistence of chylous effusion.

After surgery, 1 cat developed pneumothorax, then

respiratory arrest, and was resuscitated and returned to surgery. Histopathologic examination of a resected lung lobe revealed moderate diffuse alveolar emphysema. The cat recovered without complications, was discharged 3 days later, and died at home on day 5.

Another cat became dyspneic 2 days after surgery and was euthanatized 9 days postoperatively because of lack of response to treatment and progression of dyspnea. The fifth cat had a slow recovery from anesthesia, developed respiratory arrest 3 hours after surgery, was ventilated manually for 1 hour, and was eventually euthanatized because of progressive acidemia and deteriorating neurologic status.

Conservative treatment—The owners of 29 cats chose conservative treatment. This group included the owner of 1 cat that died suddenly at home (the result of herniation that caused cardiac tamponade) while awaiting surgery after a diagnosis of PPDH had been made. A variety of reasons for choosing conservative treatment were given, and several owners gave multiple reasons. The most common reason for choosing conservative treatment was because the hernia was not the cat's primary medical problem ($n = 10$). Four owners opted for conservative treatment because of the advanced age of their cats. Another 4 owners chose conservative treatment because their cats had a concurrent major disease. Financial concerns and concerns over the potential morbidity and mortality rates associated with anesthesia and surgery were each major determining factors for 3 owners. One owner was evidently unaware of a surgical treatment option. One owner received a recommendation for weight loss for their cat as an alternative to surgery. The weight loss regimen was successfully carried out and resulted in amelioration of clinical signs.

Long-term follow-up—Owners of 34 of 37 surgically treated cats and 22 of 29 cats treated conservatively could be contacted for follow-up information via a telephone interview. Median follow-up time for the 56 cats was 66.5 months (range 6 to 188 months). Median follow-up time for surgically treated cats was 73.5 months (range 6 to 188 months) and for conservatively treated cats 55.5 months (range 6 to 153 months).

Complications related to PPDH developed in 2 of 34 surgically treated cats. In 1 cat, PPDH recurrence was unexpectedly revealed on routine thoracic radiography 9 years after herniorrhaphy. This cat did not have clinical signs related to PPDH either prior to or after surgery, and a second herniorrhaphy was not performed. One cat had progressive respiratory distress for 1 month after it had fallen from a tree 12 months after surgery. Echocardiography revealed a cystic pericardial mass that was subsequently removed. Histopathologic examination of the mass revealed cystic hepatic tissue.

Nine surgically treated cats had died or had been euthanatized. Two cats were killed by coyotes, and 7 cats were euthanatized. The reasons for euthanasia included injuries that resulted from a motor vehicle accident (1 year postoperatively), pancreatitis and heart disease (4 years), urine spraying (5 years), mega-colon (6 years), old age and deteriorating condition (7

years), profound weight loss (9 years), and pulmonary neoplasia (12 years).

Eight of 22 cats that were treated conservatively had a variety of clinical signs that could be attributed to PPDH in the follow-up period. Clinical signs included intermittent coughing, tachypnea, or dyspnea ($n = 6$); intermittent vomiting (2); and small stature, intermittent lethargy, and sudden death (1 each). One cat developed severe acute respiratory distress after exuberant playing. The respiratory distress was attributed to PPDH by the referring veterinarian. Herniorrhaphy was performed, and the cat recovered without complications.

Nine cats treated conservatively had died. Three cats died as a result of thromboembolic disease 1 week, 14 months, and 44 months after initial examination, respectively. All 3 cats had underlying cardiac disease (hypertrophic cardiomyopathy, unclassified cardiomyopathy, and pseudotruncus arteriosus, respectively). The 6 remaining cats were euthanatized. One cat each was euthanatized because of renal failure (5 months after the initial examination), intractable grand mal seizures (7 months), recurrence of lower urinary tract obstruction (22 months), recurrence of a salivary gland adenocarcinoma (24 months), inappetence and weight loss (45 months), and necrotizing dermatitis (77 months).

Twenty-six of 34 (76%) owners of surgically treated cats and 17 of 22 (77%) owners of conservatively treated cats perceived their pets as being normal. Owner satisfaction with their treatment choice and clinical outcome was rated as very satisfied by 30 (88%) owners, somewhat satisfied by 2 (6%) owners, and dissatisfied by 2 (6%) owners of surgically treated cats and very satisfied by 15 (68%) owners, mostly satisfied by 3 (14%) owners, somewhat satisfied by 2 (9%) owners, and dissatisfied by 2 (9%) owners of conservatively treated cats. No owners of surgically treated cats reported being mostly satisfied.

Discussion

The prevalence of PPDH in our hospital population was 0.25%, which is consistent with previous reports^{7,14,18} of low prevalence of PPDH in other populations of cats. Previous studies of PPDH have reported that either no breed predilection² for PPDH exists or that PPDH is more prevalent in Persian cats.^{8,16} In our study, domestic longhair cats and Himalayans were significantly overrepresented, whereas domestic shorthair cats were underrepresented.

The historical clinical signs in the cats of our study were similar to those described in previous reports.^{2,5,6,8,10,11,16} Most cats had clinical signs related to the respiratory and gastrointestinal tracts. The PPDH was considered the primary cause of clinical signs in 40 of 67 (60%) cats. In contrast, in previous studies,^{2,5,9} PPDH was reported frequently as an incidental finding. The most common abnormal finding detected on physical examination in our study and in previous reports¹⁹ was muffled heart sounds. The finding of muffled heart sounds mainly on the right side of the thorax in cats with asymmetrically muffled heart sounds may be attributed to the presence of liver lobes in the pericar-

dial sac; the liver was the most common abdominal organ found in PPDH of cats in our study. In clinically normal cats, the liver lies predominantly on the right side of the abdomen; presumably, in cats with PPDH, the liver herniated into the right side of the pericardial sac. Concurrent skeletal abnormalities are common findings in cats with PPDH^{2,4,6}; however, these abnormalities were identified in only 8 of 67 cats in our study.

Cats that were treated surgically had persistent and overt clinical signs, particularly respiratory tract signs, that could explain owners' and clinicians' choice of surgical treatment for these cats. Cats that were treated conservatively had less obvious and persistent clinical signs, or the PPDH was an incidental finding. Owners of older cats may be less likely to choose surgical treatment for their cats; 4 of 22 owners interviewed at long-term follow-up indicated that the advanced age of their cat was the primary reason for choosing conservative treatment over surgical treatment.

Surgery was associated with several complications including hypotensive episodes, multifocal ventricular premature contractions, and loss of palpable pulses. These complications were often associated with reduction of the herniated viscera and may have been the result of liberation of endotoxin from liver lobes that had undergone long-standing compromised hemoperfusion or release of free-radicals following reperfusion of hypoperfused hepatic parenchyma. Cats undergoing surgical repair of PPDH should, therefore, be carefully monitored during anesthesia, particularly during reduction of abdominal viscera, to allow for rapid treatment of complications.

Transient postoperative hyperthermia was detected in 54% of surgically treated cats. To the authors' knowledge, postoperative hyperthermia has not been previously reported in cats that have undergone surgical repair of PPDH. In a study²⁰ conducted in humans, it was reported that 64% of patients who had undergone major hepatic surgeries developed transient postoperative hyperthermia. In other studies²⁰⁻²⁵ in humans and other animals, detection of hyperthermia following hepatic and other types of surgery was reported; hyperthermia was only rarely associated with infection.

The postoperative mortality rate was 14%. Two cats with a preoperative diagnosis of chylothorax died in the postoperative period. In a previous report,⁹ herniorrhaphy, pulmonary lobectomy, and ligation of the thoracic duct that resolved clinical signs in a cat with a diagnosis of PPDH, chylothorax, and a lung lobe torsion was described. Re-expansion pulmonary edema is believed to occur when a chronically collapsed lung is reinflated rapidly and with some force; overzealous positive-pressure ventilation has been implicated.²⁶ The clinical and pathologic findings in 1 cat in our study that was euthanatized 4 hours after surgery were consistent with re-expansion pulmonary edema. The cat received intermittent positive-pressure ventilation during surgery; however, it is not clear what role, if any, it played in the cat's death.

Long-term follow-up of surgically treated cats revealed that owners were generally pleased with the results of surgical correction. Peritoneopericardial

diaphragmatic hernia recurred in 1 cat. One cat developed a cystic hepatic mass in the pericardial sac; this underscores the importance of removing all contents of the pericardial sac during surgery.

Cats treated conservatively and that had historical problems attributable to PPDH commonly had episodic recurrences of clinical signs of PPDH. Only 1 conservatively treated cat improved clinically over the long term; this obese cat's intermittent dyspnea was ameliorated after weight reduction.

Owner perception of their cat and satisfaction with their decision regarding treatment was positive. At final follow-up, approximately 75% of owners of surgically treated and conservatively treated cats perceived their cats as clinically normal. Eighty-eight percent of owners of surgically treated cats reported being very satisfied with their decision to treat surgically, and 68% of owners of conservatively treated cats were very satisfied with their choice. Most surgically treated cats were overtly affected by PPDH and had obvious clinical signs of respiratory difficulty or other abnormalities prior to surgery; their status often improved markedly after surgery. Some owners of conservatively treated cats worried about the safety and well-being of their pets, which may account for some owners categorizing their overall satisfaction as mostly satisfied rather than very satisfied.

This study had several limitations. The study was retrospective, and a consistent protocol for evaluation and treatment of cats with PPDH was not used. Cats were not randomly assigned to surgical or conservative treatment, and most cats with overt and persistent clinical signs were treated surgically. For these reasons, comparisons of morbidity rate, mortality rate, and outcome of surgically and conservatively treated cats should be made with caution.

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