T
raumatic diaphragmatic hernia (TDH) has been described extensively in the veterinary literature.1,2,6 In dogs and cats, TDH most often develops as a result of vehicular or other blunt abdominal trauma.1,2,6,7 The sudden increase in abdominal pressure at impact is dissipated cranially, resulting in disruption of the diaphragm.6,7 Herniation of abdominal organs into the thoracic cavity and any subsequent pleural fluid accumulation from hemorrhage or organ entrapment may result in the inability to inflate some or all of the lung lobes. Surgical repair of TDH is necessary to replace abdominal contents, relieve respiratory compromise, and reestablish diaphragmatic function.

Mortality rates for cats with TDH are 20.0 and 11.8% for acute and chronic hernias, respectively.4 Death in dogs after surgical repair of TDH has been associated with duration of the hernia; mortality rates are higher for TDH repaired within 24 hours of injury or more than 1 year after injury.1 Information regarding factors that correlate with mortality rates after surgical repair of TDH in cats is limited.1

The purpose of this study was to determine whether signalment, duration of hernia, clinical signs, contents of the hernia, CBC and serum biochemical abnormalities, concurrent injuries, perioperative treatment and administration of analgesics, results of intraoperative anesthetic monitoring, or level of training of the veterinarian performing the herniorrhaphy were associated with mortality rates after surgical repair of the herniorrhaphy was associated with mortality rates after surgical repair of TDH in cats.

Criteria for Selection of Cases

Medical records of the University of Tennessee and University of Georgia Colleges of Veterinary Medicine were searched from 1991 through 2001 for cats that had surgical repair of TDH. Cats were included if the diaphragmatic defect was described as a tear or irregular rent in a portion of the diaphragmatic muscle. Cats with peritoneal-pericardial diaphragmatic hernias were not included in the study.

Materials and Methods

Animals

For a traumatic diaphragmatic hernia to be included in this study, the hernia had to be present for 6 months. Cats were excluded if death occurred within 24 hours after the initial event or injury. A total of 34 cats met the criteria for inclusion in this study. The mean age of the affected cats was 3.6 years; tachypnea and dyspnea were most common. Mortality rate was not associated with duration of hernia or results of preoperative CBC and serum biochemical analyses, but was significantly associated with concurrent injuries. Mortality rate was not associated with hernia contents, intraoperative use of positive inotropes or corticosteroids, episodes of hypotension or severe hypoxia during anesthesia, or level of training of the veterinarian performing the surgery.

Conclusions and Clinical Relevance

Cats that are older or have low to mildly increased respiratory rates and concurrent injuries are more likely to die after surgical repair of traumatic diaphragmatic hernia. (J Am Vet Med Assoc 2003;222:1237–1240)

From the Department of Small Animal Clinical Sciences, College of Veterinary Medicine, University of Tennessee, Knoxville, TN 37901-1071 (Schmiedt, Tobias); and the Department of Small Animal Medicine, College of Veterinary Medicine, University of Georgia, Athens, GA 30602-7300 (McCrackin Stevenson). Dr. Schmiedt’s present address is the Department of Surgical Sciences, School of Veterinary Medicine, University of Wisconsin, Madison, WI 53706. Dr. McCrackin Stevenson’s present address is Laboratory of Intracellular Parasites, Rocky Mountain Laboratories, NIH, NIAID, Hamilton, MT 59840. The authors thank Tanya Cooper for technical assistance. Address correspondence to Dr. Tobias.
costeroids and positive inotropes, and postoperative administration of analgesics were also recorded. Long-term follow-up was obtained by a telephone interview with the owner or referring veterinarian or by review of the medical record.

**Statistical analyses**—Data regarding age; sex; breed; duration of hernia; laboratory test results; respiratory rate at time of hospital admission; and intraoperative heart rate, blood pressure, and oxygen saturation of cats that were discharged from the hospital after surgery and those that died or were euthanatized within 2 days of surgery were compared by use of an unpaired Student t-test. Information regarding clinical signs, concurrent injuries, herniated organs, a left shift of neutrophils, administration of perioperative drugs and analgesics, and training level of the veterinarian performing surgery was compared between the 2 groups by use of a 2-tailed Fisher exact probability test. For all comparisons, a value of P ≤ 0.05 was considered significant.

**Results**

Data were collected from records of 34 cats, 28 of which survived to time of discharge (at least 48 hours after surgery). Mean ± SD age of affected cats was 3.6 ± 3.79 years (median, 2 years; range, 0.25 to 14 years). Cats that survived to time of discharge were significantly (P = 0.014) younger (mean ± SD age, 2.9 ± 2.91 years; median, 1.75 years; range, 0.25 to 12 years) than those that died or were euthanatized within 2 days of surgery (7 ± 5.59 years; median, 7.5 years; range, 1 to 14 years).

Data regarding cause of trauma were available for 16 of 34 (47.1%) cats. Of these, 12 cats were hit by a car, 2 cats were injured by dog bites, and 2 cats had recurrences of a TDH that were previously repaired. The remaining 18 cats were either missing for a period of time and found with other wounds suggestive of trauma or recently purchased or adopted; the latter group lacked histories but had not been clinically normal since adoption or purchase and had evidence of old injuries such as scars and healed fractures on physical or radiologic examination.

Affected breeds included domestic shorthair (27/34 cats [79.4%]), mixed breed (5/34 [14.7%]), Scottish fold (1/34 [2.9%]), and Himalayan (1/34 [2.9%]). Of the total population, 12 of 34 (35.3%) cats were castrated males, 10 of 34 (29.4%) were spayed females, 8 of 34 (23.5%) were sexually intact males, and 4 of 34 (11.8%) were sexually intact females. Breed and sex of the cats were not associated with mortality rate.

Clinical and physical examination findings at the time of hospital admission were recorded in all 34 cats. The most common clinical and physical examination findings were tachypnea (respiratory rate > 40 breaths/min, 79.4%), dyspnea (41.4%), muffled heart sounds (29.4%), and vomiting (11.7%). Other clinical findings (< 10%) included anorexia, diarrhea, open mouth breathing, increased or decreased lung sounds, exercise intolerance, pale mucous membranes, and hypothermia. Respiratory rate at the time of hospital admission was the only clinical finding that was associated with survival; mean ± SD respiratory rate for those cats that survived to discharge (64.7 ± 18 breaths/min) was significantly (P = 0.01) greater than that of cats that died or were euthanatized (37.6 ± 16.3 breaths/min).

Mean duration of TDH was 17.6 days (median, 5.5 days); there was no significant difference in duration between the 2 groups of cats. Seven cats had hernias for 24 hours or less; 1 of these cats died. Seventeen cats had hernias for 1 to 7 days, and 3 of these cats died. Ten cats had hernias for more than 7 days (range, 14 days to > 100 days) before surgery, and 2 of these cats died. There were no significant differences in mortality rates among cats that had hernias for 0 to 24 hours, 1 to 7 days, and > 7 days.

Concurrent injury was identified on physical examination, with radiography, or during surgery in 23.5% of cats. Three of 28 (10.7%) cats that survived had concurrent injury, which was limited to fractures of rib or other bones. Of the 6 cats that died or were euthanatized, 5 (83.3%) had concurrent injury, including rib fractures (1 cat) or additional inguinal or body wall hernias (3 cats), and 1 cat had cardiomyopathy. Mortality rate was significantly (P = 0.001) greater in cats that had concurrent injuries than those that did not.

Of the 32 cats in which Hct and TS results were recorded, 7 were anemic (Hct < 30%), 9 were hypoproteinemic (TS < 6 g/dL), and 4 were hyperproteinemic (TS > 7.9 g/dL). No significant differences were found in Hct or TS between cats that were discharged from the hospital after surgery and those that died or were euthanatized within 2 days of surgery.

Electrolyte abnormalities included hypernatremia (sodium, > 156 mEq/L; 9/26 [34.6%] cats), hyponatremia (sodium, < 146 mEq/L; 1/26 [3.8%]), hyperchloremia (chloride, > 130 mEq/L; 3/26 [11.5%]), hypochloremia (chloride, < 115 mEq/L; 7/26 [26.9%]), and hyperkalemia (potassium, > 6.1 mEq/L; 1/26 [3.8%]). Six of 23 (26.1%) cats were hypocalceemic (calcium, < 9.7 mg/dL), and 1 of 23 (4.3%) cats was hypercalcemic (calcium, > 11.7 mg/dL). Increases in BUN (> 36 mg/dL) and creatinine (> 2.2 mg/dL) were noted in 2 of 26 (7.7%) and 2 of 23 (8%) cats, respectively. Of 25 cats evaluated, 16 (64%) had increased activity of ALT (> 97 U/L), and 3 (12%) had increased activity of ALP (> 35 U/L). Eleven of 28 (39.3%) cats were hyperglycemic (glucose, > 140 mg/dL). No significant differences in serum biochemical analyses values were found between the 2 groups of cats.

A total WBC count was available for 20 of 28 (71.4%) cats that survived and 6 of 6 cats that died or were euthanatized, and a WBC differential count was available for 13 of 28 (33.6%) cats that survived and 4 of 6 (66.7%) cats that died or were euthanatized. Leukocytosis (WBC, > 19.5 × 10⁹/L) was detected in 4 of 26 (15.4%) cats tested, and a left shift (band cells, > 0.3 × 10⁹/L) was detected in 7 of 19 (36.8%). No cats were leukopenic. No significant differences were found in CBC results between the 2 groups of cats.

During surgery, results of pulse oximetry and indirect systolic blood pressure measurements were recorded for 13 and 22 cats, respectively. A severe hypoxic
episode (SpO₂ < 85%) was noted in 3 of 10 cats that survived and 2 of 3 cats that died or were euthanatized. Hypotension (indirect systolic blood pressure, < 75 mm Hg) was noted in 14 of 20 (70%) cats that survived and 2 of 2 cats that died or were euthanatized. No significant differences between groups were found for the number of cats that had hypotensive or hypoxic episodes during anesthesia or the maximum and minimum intraoperative heart rates.

At surgery, location of the hernia was determined to be on the left side in 15 of 34 (44.1%) cats, on the right side in 13 of 34 (38.2%) cats, ventral in 5 of 34 (14.7%) cats, and in multiple sites in 1 (2.9%) cat. Organs most commonly herniated into the thorax included the liver (28/34 [82.3%] cats), stomach (17/34 [50%]), small intestine (16/34 [47%]), omentum (15/34 [44.1%]), and spleen (15/34 [44.1%]). Other herniated organs included large intestines (5/34 [14.7%]), gall bladder (3/34 [8.8%]), and pancreas (3/34 [8.8%]). Although contents of the hernia were not significantly associated with survival, all cats that died or were euthanatized had herniation of the liver, whereas 22 of 28 (78.6%) cats that survived had liver herniations. Surgical residents performed 64.7% of the herniorrhapies; training level of the veterinarian performing the surgery (resident vs faculty member) was not significantly associated with survival. Thoracic drainage tubes were placed during surgery or immediately after abdominal closure in 32 of 34 (94%) cats, including all cats that died or were euthanatized. In 2 cats, negative pressure in the thoracic cavity was reestablished by transthoracic thoracocentesis before abdominal closure.

Anesthetic protocols varied widely within both groups of cats so that statistical comparison was not possible. Premedications included butorphanol tartrate (19/34 [55.9%] cats), glycopyrrolate (17/34 [50%]), acepromazine maleate (10/34 [29.4%]), midazolam HCl (7/34 [20.6%]), atropine sulfate (7/34 [20.6%]), oxymorphone HCl (6/34 [17.6%]), and morphine sulfate (1/34 [2.9%]). Anesthesia in cats was induced with ketamine HCl (16/34 [47.1%]), diazepam (13/34 [38.2%]), isoflurane by mask (7/34 [20.6%]), propofol (6/34 [17.6%]), thiopental sodium (3/34 [8.8%]), or tiletamine HCl and zolazepam HCl (3/34 [8.8%]). Anesthesia in all cats was maintained by use of isoflurane in oxygen.

Intraoperative administration of the positive inotropic drugs dopamine or dobutamine and preoperative or intraoperative administration of corticosteroids were noted in 8 and 10 cats, respectively, that survived surgery and in 3 and 4 cats, respectively, that died or were euthanatized. All cats received analgesics before surgery. Analogesics were administered after surgery in 24 of 28 cats that survived and in 4 of 6 cats that died or were euthanatized after surgery. Use of positive inotropes, corticosteroids, or analgesics was not associated with mortality rate.

All cats recovered from anesthesia in the intensive care unit, received fluids IV and supplemental oxygen, and were monitored for evidence of pain, dyspnea, and hyper- or hypothermia. Seventeen of 34 (50%) cats developed postoperative complications during hospitalization, including tachypnea (7/34 [20.6%] cats), dyspnea (5/34 [14.7%]), herniation at the surgical site (3/34 [8.8%]), and infection (3/34 [8.8%]). Other complications (< 6%) included pyrexia, hemothorax, pneumothorax, anorexia, and gastroesophageal reflux. Five cats died within 48 hours of surgery (median, 12 hours), and 1 was euthanatized. The most common cause of death (3/6 cats) was sudden cardiac arrest; the underlying cause could not be discerned from the records of these cats. Re-expansion pulmonary edema (REPE) was recorded as the cause of death in 1 cat on the basis of clinical signs at the time of death and was suggested as the cause of death in a second cat that was described as frothing from the mouth immediately before death. Necropsies were not performed; thus, the causes of death could not be confirmed. One cat was euthanatized after developing septicemia secondary to intestinal necrosis. At the time of diaphragmatic herniorrhaphy, this cat had also undergone reduction and resection of a portion of the small intestine that had become entrapped in an inguinal hernia.

Long-term follow-up was available for 14 of 28 (50%) cats that survived diaphragmatic herniorrhaphy; these cats were discharged from the hospital. The mean duration of long-term follow-up was 3.29 ± 2.28 years (median, 3.5 years; range, 0.16 to 7 years). No clinical abnormalities were noted in 10 of 14 cats. One cat was reported to breathe heavily after strenuous exercise; it is unknown if this was a pathologic condition. Three of 14 cats were dead. One cat was euthanatized 7 months after surgery because of urinary incontinence resulting from the same traumatic incident that caused TDH. Another cat reportedly died 8 months after surgery from chronic nasal hemorrhage that was unresponsive to antimicrobial treatment; no necropsy was performed. The third cat was found dead outdoors approximately 3 years after surgery. Cause of death was unknown; however, before death, the cat had no respiratory or gastrointestinal abnormalities.

**Discussion**

In our study, several factors, including age, respiratory rate at the time of hospital admission, and multiple concurrent injuries, had significant associations with mortality rate after surgical repair of TDH in cats. Cats that died or were euthanatized before discharge from the hospital were significantly older than those that survived. The greater mortality rate in older cats may be because of other subclinical conditions that compromised the cats’ abilities to recover from the trauma and subsequent anesthesia and surgery. To the authors’ knowledge, age has not been reported as a risk factor for cats with diaphragmatic hernia.

As in other reports, dyspnea and tachypnea were common clinical signs in cats with TDH in our study. Cats that died or were euthanatized within 2 days of surgery had a significantly lower respiratory rate at initial evaluation than those that survived. A causal link between lower respiratory rate and death is unknown.

Orthopedic, body wall, myocardial, and multigang organ injuries are frequently reported in animals with
TDH. Downs et al noted an association between additional injuries and mortality rates in animals with acute TDH. Pleural fluid, pregnancy, liver disease, and kidney disease have been associated with increased mortality rates in dogs and cats with chronic TDH. Visceral damage was a major or contributory cause of postoperative death in 17.8% of animals after diaphragmatic herniorrhaphy in 1 study. In our study, 3 of 6 (83.3%) cats that died had concurrent injury, whereas only 3 of 20 (15%) cats that survived had concurrent injury. Additionally, 3 of 6 cats that died or were euthanized in the immediate postoperative period had other hernias, suggesting that degree of trauma may have been more severe in these cats. Cats with concurrent disease or injury may not be able to compensate for additional physiologic stresses caused by surgery and anesthesia.

In our study, duration of injury, contents of the hernia, CBC and serum biochemical abnormalities, episodes of intraoperative hypotension and severe hypoxemia, and training level of the surgeon had no significant association with mortality rates. There was also no evidence that use of supportive or protective drugs, such as positive inotropes and glucocorticoids, or postoperative administration of analgesics had significant associations with mortality rates in our study. An association between duration of the hernia and mortality rates was reported in a study of dogs with TDH. Higher mortality rates in dogs were noted when surgery was performed within the first 24 hours after trauma or more than 1 year after trauma. A high mortality rate in dogs that had surgery within 24 hours of trauma was associated with multiorgan system failure compounded by anesthesia and surgery. Adhesions, chronic atelectasis, or other medical problems may increase the likelihood of death in animals with chronic TDH. As in other studies, no association between duration of hernia and mortality rates was noted in our study. However, this study lacked large numbers of cats with hernias of long duration (> 100 days), so interpretation of these results may not be possible. Death in animals with acute TDH may be reduced if patients are stabilized before anesthesia and surgical repair are performed.

Similar to previous studies, the liver was the most frequently herniated in cats with TDH. Presence of the liver within the hernia was not associated with high mortality rate. Although the stomach was identified within the thorax in 50% of cases in this study, its presence within the hernia was not associated with an increased risk of death. Gastric dilation secondary to gastric incarceration is an important cause of preanesthetic death in dogs with TDH. Gastric dilation was not noted in cats with gastric herniation in our study. Major complications after TDH repair include REPE, pneumothorax, hydrothorax, hemorthorax, reherenniation through the same site (surgical hernia), gastric torsion, shock, hemorrhage, and cardiac arrhythmias. The most common postoperative complications in our study were tachypnea and dyspnea; these may have been secondary to pain, stress, acidosis, residual pneumothorax, rib fractures, or primary lung disease.

In our study, similar to other studies, mortality rate during hospitalization was 17.6%. Postoperative acute cardiac or respiratory arrest was reported in 3 of 34 cats within 48 hours after surgery. Potential causes of cardiopulmonary arrest may include primary heart or lung disease caused by the initial trauma, effects of anesthetics on cardiovascular function, pulmonary edema, poor tissue perfusion, pulmonary atelectasis from residual hemothorax or pneumothorax, multisystem organ failure, and acid-base imbalances. Re-expansion pulmonary edema can develop with sudden inflation of a chronically collapsed lung and is reported rarely in humans. Re-expansion pulmonary edema has been reported in cats after repair of TDH and after correction of pectus excavatum. Re-expansion pulmonary edema can develop immediately after lung re-expansion or as long as 24 hours later and may involve just the affected lung lobes, all lung lobes, or, more rarely, contralateral lung lobes. Gradual re-expansion of chronically collapsed lungs is recommended to prevent REPE. Because radiography and necropsy were not performed on the 2 cats that died of respiratory distress in our study, REPE could not be confirmed.

References