Perioperative mortality rate and risk factors for death in dogs undergoing surgery for treatment of thoracic trauma: 157 cases (1990–2014)

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OBJECTIVE
To determine perioperative mortality rate and identify risk factors associated with outcome in dogs with thoracic trauma that underwent surgical procedures and to evaluate the utility of the animal trauma triage (ATT) score in predicting outcome.

DESIGN
Retrospective case series.

ANIMALS
157 client-owned dogs.

PROCEDURES
Medical records databases of 7 veterinary teaching hospitals were reviewed. Dogs were included if trauma to the thorax was documented and the patient underwent a surgical procedure. History, signalment, results of physical examination and preoperative laboratory tests, surgical procedure, perioperative complications, duration of hospital stay, and details of follow-up were recorded. Descriptive statistics and ATT scores were calculated, and logistic regression analysis was performed.

RESULTS
123 of 157 (78%) patients underwent thoracic surgery, and 134 of 157 (85.4%) survived to discharge. Mean ± SD ATT score for nonsurvivors was 8 ± 2.4. In the multivariable model, female dogs and dogs that did not experience cardiac arrest as a postoperative complication had odds of survival 6 times and 102 times, respectively, those of male dogs and dogs that did experience cardiac arrest as a postoperative complication. Additionally, patients with a mean ATT score < 7 had odds of survival 5 times those of patients with an ATT score ≥ 7.

CONCLUSIONS AND CLINICAL RELEVANCE
The overall perioperative mortality rate was low for patients with thoracic trauma undergoing surgery in this study. However, male dogs and dogs that experienced cardiac arrest had a lower likelihood of survival to discharge. The ATT score may be a useful adjunct to assist clinical decision-making in veterinary patients with thoracic trauma. (*J Am Vet Med Assoc* 2018;252:1097–1107)

Thoracic trauma is a common condition in small animal patients examined in emergency hospitals. The extent of thoracic injuries sustained can range from minimal damage to severe trauma requiring intensive care and rapid surgical intervention.[1] In dogs, as in human trauma patients,[1] early and accurate assessment of the patient's condition and accurate prediction of the likelihood of subsequent complications can be challenging.

Thoracic trauma can occur secondary to blunt or penetrating injury. In a study[2] evaluating a large population of dogs with blunt trauma, 213 of 235 (91%) cases were the result of vehicular trauma, with the thorax being the most common area of injury. Another study[3] evaluating dogs sustaining fractures from vehicular trauma documented thoracic wall or pulmonary trauma in 104 of 267 (39%) cases, with dogs in 154 (58%) of those cases sustaining more than 1 injury.[3] Bite wounds have also been documented as a common cause of trauma in dogs.[4-7] Examination of dog bite wounds in 1 study[4] found that the thorax

ABBREVIATIONS

ATT	Animal trauma triage
CI	Confidence interval
ISS	Injury severity score
SIRS	Systemic inflammatory response syndrome

was the most common site of trauma. Beyond superficial wounds, thoracic bite wounds have the potential to result in severe muscle trauma, rib or sternum fractures, flail chest, traumatic body wall hernias, diaphragmatic hernias, pneumothorax, hemothorax, and lung trauma.[5,8–10]

Immediate treatment of penetrating chest wounds should involve triage, with necessary medical treatment to stabilize the patient followed by diagnostic evaluation to determine the extent of thoracic injury. Diagnostic testing may include thoracic radiography, thoracic ultrasonography, CT, and other tests.[11] Results of previous research have indicated that the severity of radiologic findings does not correlate with surgical outcome and may often underestimate the extent of tissue injury.[5,9] Indications for surgical intervention in patients with thoracic trauma are controversial.[4,12,13] Some authors recommend that medical management be pursued because it may decrease the mortality rate.[4,12,13] In general, wound care should include debridement of devitalized tissues and high-volume pressure lavage to remove debris and bacteria.[4–6] Surgical exploration may involve either a median sternotomy or intercostal thoracotomy; 3 previous studies evaluating short-term (within 2 weeks) outcome for dogs undergoing thoracic surgery documented mortality rates of 21% (21/98),[14] 10% (7/70),[15] and 44% (29/67).[16]

Trauma-scoring systems in human patients have been developed in an effort to predict the prognosis and outcome in patients with thoracic trauma. Historically, these scoring systems have been based on such variables as the presence of anatomic injuries, including parenchymal lesions.[17] In human patients, the ISS is a validated numeric description of the overall severity of injury in individuals who have sustained injury to more than 1 region of the body[18] and has been found to be a significant predictor of death.[19–23] Prognostic factors that have been identified in human patients include age, number of fractured ribs, presence of flail chest, presence of pulmonary contusions, the need for mechanical ventilation, and ISS.[22] One scoring system for veterinary patients, the ATT score, was developed to evaluate animals that have sustained trauma.[24] The ATT scoring system includes evaluation of specific parameters, including tissue perfusion, cardiac function, and signs of respiratory, ophthalmic, musculoskeletal, dermatologic, and neurologic dysfunction.[24]

It has been reported[4,12,25] that trauma with thoracic involvement significantly increases the mortality rate in small animal patients; however, the current veterinary literature lacks information on risk factors for death associated with surgical exploration of the thorax in patients with trauma. Therefore, the primary objectives of the study reported here were to describe the most common injuries, the complications of surgical treatment, and the risk factors associated with death in a series of dogs evaluated because of thoracic trauma and undergoing surgical intervention. A secondary objective was to determine whether the ATT score was associated with outcome; we hypothesized that the ATT score would be predictive of survival to discharge in dogs evaluated because of thoracic trauma.

Materials and Methods

Case selection criteria

Medical records of all dogs evaluated because of thoracic trauma that underwent surgical intervention at any of 7 referral hospitals (University of California-Davis, University of Tennessee, Kansas State University, University of Guelph, University of Illinois, Oregon State University, and University of Georgia) from January 1990 to December 2014 were reviewed. Dogs examined for thoracic trauma that were not treated or that were treated medically were excluded.

Medical records review

Preoperative data collected from the medical record included history, initial complaints, signalment, body weight, duration of clinical signs, clinical laboratory findings (CBC, serum biochemical analyses, lactate concentration, venous blood gas analyses, and coagulation profile), physical examination findings on initial examination including type of thoracic trauma, initial emergency treatment, and results of diagnostic imaging. Intraoperative data collected from the medical records included systolic blood pressure (mm Hg) and methods of measurement at any time prior to surgery, oxygen saturation (as measured with pulse oximetry) at any time prior to surgery, details of the surgical procedure, concurrent procedures, surgical complications (if applicable), blood product administration (product administered, if applicable), insertion of any drains at the end of surgery, and whether tissue or fluid samples were obtained intraoperatively for histologic examination and microbial culture and susceptibility testing. Postoperative data collected included postoperative complications (if applicable), blood product administration (product administered, if applicable), systolic blood pressure and results of pulse oximetry (if applicable), duration of hospital stay (days), and outcome (survival to discharge or death prior to discharge). Complications included SIRS, signs of renal or hepatic disease, coagulopathy, aspiration pneumonia, and death during the perioperative period. During the medical records review, the presence of flail chest or pseudo–flail chest[5,10] was recorded when documented. Pulmonary parenchymal lesions were classified as contusions or congestion, atelectasis, and damage or puncture of a lung lobe that required lobectomy; lesions were identified through author review of diagnostic imaging and surgery reports. Rib injuries were identified through author review of diagnostic imaging and surgery reports and classified as < 3 rib fractures, ≥ 3 rib fractures, and trauma that required surgical reconstruction. For documentation of perioperative complications and outcome, the perioperative period was defined as the time (days) from admission until death or discharge from the hospital.

Clinical, laboratory, and diagnostic imaging findings were evaluated retrospectively by the authors to determine whether the following conditions were present and, if so, when they were documented in the medical record. Systemic inflammatory response syndrome was defined[26,27] as 2 or more of the following criteria detected within the same 24-hour period during hospitalization: rectal temperature (reference range, 38.5° to 39.5°C [101.3° to 103.1°F]) < 37.2°C (99.0°F) or > 39.2°C (102.6°F), heart rate (reference range, 70 to 160 beats/min) > 140 beats/min, respiratory rate (reference range, 12 to 40 breaths/min) > 30 breaths/min, total WBC count (reference range, 5.1×10^9 to 14×10^9 cells/L) < 6.0×10^9 cells/L or > 19.0×10^9 cells/L, or band neutrophil fraction (reference range, 0% to 2%) > 3%. The cutoff values for high or low rectal temperature, pulse rate, and respiratory rate were determined on the basis of criteria for the diagnosis of SIRS. Hypertension was defined as systolic blood pressure > 150 mm Hg, and hypotension was defined as systolic blood pressure < 90 mm Hg. Hypoxia was defined as oxygen saturation < 94%. On the basis of results of the coagulation profile, coagulopathy was defined as 3 or more of the following findings in a patient at the same time: thrombocytopenia (reference range, 147×10^3 to 423×10^3 platelets/µL), prolonged prothrombin time (reference range, 6.8 to 8.7 seconds), prolonged partial thromboplastin time (reference range, 10.4 to 12.9 seconds), or prolonged activated clotting time (reference range, < 120 seconds).[28] Acute kidney injury was defined as an increase in the serum creatinine concentration of 1.5 times the initial preoperative value.[29] Hepatic disease was defined as 2 or 3 of the following evident in a patient, compared with preoperative baseline values: increased alanine aminotransferase activity, increased alkaline phosphatase activity, or increased bilirubin concentration.[28] Aspiration pneumonia was determined on the basis of a diagnosis in the medical record and confirmation in the diagnostic imaging report for thoracic radiographs by a board-certified veterinary radiologist that findings were consistent with this diagnosis.[30]

An ATT score[7,24,31,32] was calculated for each patient on the basis of data recorded at initial examination and in operative reports. The ATT score was calculated by evaluation of 6 categories (perfusion, cardiac, respiratory, eye-muscle-integument, skeletal, and neurologic) and assignment of a score from 0 (slight or no injury) to 3 (severe injury) by means of predetermined criteria for each category (**Supplementary Appendix S1**, available at avmajournals.avma.org/doi/suppl/10.2460/javma.252.9.1097).[24]

Surgical procedures

Surgical intervention was defined as a procedure that required debridement of tissue or placement of surgical drains over the thoracic wall or within the thorax. Laparotomy approaches were included if entry of the thorax occurred with exploration of the thoracic cavity (ie, diaphragmatic approach to the thorax), if a diaphragmatic hernia was present and the thoracic cavity was explored, or if a laparotomy was performed concurrently with a thoracotomy. Specific procedures performed intraoperatively were recorded, including muscular, sternal, or rib reconstruction; excision of affected tissues, including lung lobectomy; and any abdominal procedures performed concurrently.

Statistical analysis

Descriptive statistics were calculated. Normally distributed data were expressed as mean and SD; nonnormally distributed continuous variables were expressed as median and range. Categorical data were expressed as frequencies. Logistic regression analysis was performed to evaluate the association of ATT score and other variables extracted from the medical record with the odds of survival to discharge. Two-way interactions among the main effects were investigated. An interaction term was retained on the basis of a P value < 0.05. Univariate analysis was performed initially, and factors with a P value < 0.20 were tested in the model. Factors were retained in the final model if they had a P value ≤ 0.05 or were found to be a confounder (changing model coefficients by > 15%). All analyses were performed with commercially available statistical software.[a]

Results

Animals

One hundred fifty-seven dogs met the criteria for inclusion in the study. The study population included 29 sexually intact males, 51 castrated males, 11 sexually intact females, and 66 spayed females (overall, 49% female and 51% male). The median age of the dogs during the study period was 48 months (range, 2 to 179 months), and the median body weight was 7.6 kg (14.7 lb; range, 2.1 to 48 kg [4.6 to 105.8 lb]). The following dogs were represented: mixed breed (n = 18), Yorkshire Terrier (16), Chihuahua (11), Toy or Miniature Poodle (11), Dachshund (9), Pomeranian (6), Labrador Retriever (6), Jack Russell Terrier (5), Maltese (5), Miniature Schnauzer (5), Boxer (5), Shih Tzu (4), Miniature Pinscher (3), Rat Terrier (3), Bichon Frise (3), Fox Terrier (3), Cocker Spaniel (3), Dalmatian (3), Border Collie (3), Lhasa Apso (2), Beagle (2), Collie (2), Golden Retriever (2), pit bull–type dog (2), Mastiff (2), Akita (1), Alaskan Malamute (1), Australian Shepherd (1), Basset Hound (1), Belgian Malinois (1), Borzoi (1), Brittany (1), Cavalier King Charles Spaniel (1), Chow Chow (1), French Bulldog (1), German Shepherd Dog (1), Gordon Setter (1), Greyhound (1), Havanese (1), Japanese Chin (1), Norfolk Terrier (1), Papillon (1), Pug (1), Chinese Shar-Pei (1), Siberian Husky (1), Treeing Walker Coonhound (1), West Highland White Terrier (1), and Whippet (1). None of the variables associated with signalment were significantly associated with likelihood of discharge from the hospital.

Preoperative findings

The type of thoracic trauma sustained was recorded in 146 of 157 (93%) cases. Type of trauma sustained was as follows: dog bite or attack, 55% (86/157); motor vehicle accident, 11.5% (18/157); other animal attack, 11.5% (18/157); other trauma recorded as impalement injuries or falls, 8% (13/157); unknown, 7% (11/157); projectile causing penetrating trauma, 6.4% (10/157); and human abuse or nonaccidental trauma, 0.6% (1/157). Vital parameters were recorded as the highest and lowest values for all patients during preoperative evaluation and any emergency resuscitation **(Table 1)**. Tachycardia was present on initial examination in 46% (72/157) of patients, with bradycardia evident in 4% (7/157). Thirty-five percent (55/157) of patients were hypothermic preoperatively, and tachypnea was present in 77% (121/157). Oxygen saturation was measured in 75 of the 157 (48%) dogs and 51% (38/75) of those dogs were considered hypoxic. Systolic blood pressure was recorded in 93 of the 157 (59%) patients. Blood pressure data were obtained directly by means of placement of an arterial catheter (n = 4), indirectly by means of a Doppler ultrasonographic flow detector (54), or indirectly by means of Doppler oscillometry (35). For the 93 patients in which blood pressure was measured, 21 (22.5%) were considered hypertensive on initial evaluation, 21 were hypotensive (22.5%), and 51 (55%) had systolic blood pressure within reference limits.

Initial physical examination findings were recorded for all 157 patients. Punctures from animal attacks or open wounds from trauma were noted in 90% (141/157) of patients. Swelling and edema were noted adjacent to wounds in 43% (67/157), subcutaneous emphysema was present in 54% (84/157), and external contusions were evident in 28% (44/157). Flail chest and pseudo–flail chest were suspected during physical examination and confirmed on radiographs in 25% (39/157) and 6% (9/157) of patients, respectively. Abnormal respiratory patterns consistent with respiratory distress were noted in 41% (64/157) of patients. Abnormalities noted during thoracic auscultation were muffled lung sounds (55/157 [35%]), muffled heart sounds (26/157 [17%]), crackles (14/157 [9%]), and wheezes (6/157 [4%]). Cardiac auscultation on initial examination documented an arrhythmia in 7 of 157 (4%) dogs. An ECG confirmed the arrhythmia to be ventricular in origin in 6 patients and atrial in origin in 1 patient. Treatment of ventricular arrhythmias was pursued in 4 dogs. Abnormal mentation, including stupor, obtundation, and coma, was noted in 25% (39/157) of patients.

Leukopenia was present in 12% (11/91) of the dogs in which it was evaluated **(Table 2)**. Regenerative and degenerative left shifts were present in 37 of 60 (62%) patients and in 5 of 60 (8%) patients, respectively, in which these parameters were evaluated. Anemia was noted preoperatively in 21% (24/114) of patients and hypoalbuminemia was present in 66% (56/85) of patients in which these parameters were measured. Hyperlactatemia was present in 57% (55/97) of patients and hypoglycemia was detected in 3% (4/144) of patients in which these parameters were measured. Venous blood gas analysis was performed in 115 of the 157 (73%) dogs, 19 of which also underwent arterial blood gas analysis, with 49% (56/115) of these dogs having acidemia.

Thoracic radiography was performed in 85% (133/157) of patients. Abnormal findings included rib fractures in 51% (68/133) of patients, pulmonary contusions in 48% (64/133), pneumothorax in 46% (61/133), pleural effusion in 33% (44/133), pneumomediastinum in 24% (32/133), atelectasis in 20% (27/133), diaphragmatic hernia in 11% (14/133), sternal fracture or avulsion injury in 4% (5/133), and pericardial effusion in 0.8% (1/133). Thoracic ultrasonography was performed in 18 dogs, and pleural effusion was diagnosed in 14 of the 18. Thoracocentesis was performed in 43 of the 157 (27%) patients and was most commonly performed to evacuate air caused by pneumothorax (32/43). Abdominal and skeletal (appendicular and axial) radiographic abnormalities were present in 42 of 157 (27%) and 21 of 157 (13%) dogs, respectively. Abdominal radiographic abnormalities included pneumoperitoneum (10/42), subcutaneous emphysema (8/42), decreased serosal detail suggestive of peritoneal effusion (6/42), diaphragmatic hernia (5/42), gas distention of the gastrointestinal tract (3/42), abdominal body wall hernia (3/42), urolithiasis (2/43), and hepatomegaly (2/42). Skeletal radiographic abnormalities included fractures of the manus or pes (6/21), pelvic fractures (5/21), fractures involving the vertebral column (4/21), long bone fractures (4/21), and 1 fracture each of the scapula and skull.

Table 1—Vital parameters recorded preoperatively in 157 dogs with thoracic trauma that underwent surgical procedures.

Variable	No. of dogs	Median highest value	Median lowest value	Range
Heart rate (beats/min)	154	140	110	50–212
Body temperature (°C)	151	38.2	37.4	32.4–41.0
Respiratory rate (breaths/min)	136	62 ± 73*	43 ± 77*	5–200
Spo_2 (%)	75	98	94	65–100
Systolic blood pressure (mm Hg)	93	133 ± 26*	110 ± 30*	35–220

Highest and lowest values represent the highest and lowest values recorded during preoperative evaluation and any emergency resuscitation.
*Values represent mean ± SD because data were normally distributed. Spo_2 = Oxygen saturation as measured by pulse oximetry.

An ATT score was calculated for 98% (154/157) of patients. The 3 dogs for which an ATT score was not calculated had insufficient data in the medical record to complete the scoring. The overall mean ± SD ATT score was 7.0 ± 2.5 (range, 1 to 13; n = 154). The mean ± SD ATT score for surviving patients was 6.7 ± 2.5 (range, 1 to 12; n = 132), and the mean ± SD ATT score for nonsurviving patients was 8.0 ± 2.4 (range, 3 to 13; 22).

Preoperative treatment

Oxygen supplementation was administered to 78 of the 157 (50%) patients, and 15 of 157 (10%) patients required endotracheal intubation to aid in preoperative stabilization; only 8 of 157 (5%) dogs required mechanical ventilation prior to surgery. The specific sedation or anesthesia protocol that may have been required to facilitate mechanical ventilation could not be documented. Antimicrobials were administered to 96% (150/157) of patients, and 83 of 157 (53%) patients received > 1 antimicrobial. Analgesics were administered to 95% (149/157) of patients, blood products were administered to 33% (51/157) of patients, and IV fluids were administered to 91% (143/157) of patients **(Table 3)**. No preoperative treatment was significantly associated with perioperative death.

Table 2—Clinical laboratory variables measured preoperatively in the dogs in Table 1.

Variable	No. of dogs	Median	Range	Reference range
WBCs (X 10^3 cells/µL)	91	11.8	0.6–27.7	5.1–14
Neutrophils (X 10^3 cells/µL)	89	7.97	0.02–67.2	2.6–9.8
Band neutrophils (X 10^3 cells/µL)	60	0.6	0.06–6.0	0–0.3
Platelets (X 10^3 platelets/µL)	88	218	53–495	147–423
PCV (%)	114	43.1 ± 10.3*	18–74	35–55
Total protein (g/dL)	127	5.5 ± 1.2*	2.0–7.6	5.4–6.8
Hct (%)	109	39.1 ± 10.6*	16–69.3	41–60
Glucose (mg/dL)	144	117	34–329	84–120
BUN (mg/dL)	109	15	2.7–46	7–26
Creatinine (mg/dL)	106	0.7	0.2–2.1	0.5–1.6
Albumin (g/dL)	85	2.7	0.9–4.2	3.0–4.1
Creatine kinase (U/L)	36	10,389	3–98,934	49–155
Prothrombin time (s)	26	9.5	5.9–16	6.8–8.7
Partial thromboplastin time (s)	24	19.3	10.6–120	10.4–12.9
Activated clotting time (s)	19	105	80.5–700	< 120
Venous pH	115	7.33 ± 0.6*	7.16–7.46	7.32–7.42
$Paco_2$ (mm Hg)	19	43.9 ± 8.6*	25.4–55.2	25–45
$Pvco_2$ (mm Hg)	102	40.1	21.5–79.5	25–45
Pao_2 (mm Hg)	20	233.7 ± 144.2*	54.1–556	80–100
Pvo_2 (mm Hg)	87	52.1	20.9–136.1	40–60
Lactate (mmol/L)	97	2.5	0.3–16	0–2

*Represents mean value ± SD instead of median for normally distributed data.
$Pvco_2$ = Partial pressure of dioxide, venous. Pvo_2 = Partial pressure of oxygen, venous.

Table 3—Preoperative treatments administered to the dogs in Table 1.

Type of treatment	Drug or product	No. (%) of patients
Antimicrobial drugs	Enrofloxacin (IV and PO)	60 (38)
	Ampicillin (IV)	51 (32)
	Cefazolin (IV)	40 (25)
	Ampicillin-sulbactam (IV)	31 (20)
	Amoxicillin-clavulanic acid (IV and PO)	40 (25)
Analgesic drugs	Hydromorphone (IV)	69 (44)
	Fentanyl (IV)	64 (41)
	Oxymorphone (IV)	20 (13)
	NSAID	44 (28)
Blood products	Fresh-frozen plasma (IV)	34 (22)
	Packed RBCs (IV)	23 (15)
	Whole blood (IV)	15 (10)
IV fluids	Isotonic crystalloid* (IV)	127 (81)
	Synthetic colloid (hetastarch; IV)	38 (24)
	Hypertonic saline (IV)	4 (3)

*Several different types of isotonic crystalloid fluids were administered IV.
The type of treatment and product, when available, were documented as well as the number of patients receiving each treatment; only the most commonly administered treatments are listed.

Surgical procedures

Surgical procedures requiring a sterile operating room (n = 127) or a treatment room dedicated to minor surgical procedures (17) were performed in 144 of the 157 (92%) patients. The remaining dogs (13/157 [8%]) had surgical procedures performed in an emergency room or in an area not specifically dedicated to surgical procedures. General anesthesia was required for the surgical procedures in 88% of patients (138/157), with the remaining 12% (19/157) requiring moderate to heavy sedation to undergo the procedure. The anesthetic or sedative drugs used were recorded for 80% (126/157) of patients. Operative reports were available for review in 81% (127/157) of patients' medical records. Surgical procedures that required or resulted in entry into the thoracic cavity were performed in 78% (123/157) of patients, and procedures that required or resulted in entry into the abdominal cavity were performed in 25% (39/157) of patients. Pulmonary parenchymal lesions consisted of puncture or trauma to a lung lobe requiring partial or complete lung lobectomy in 26% (41/157) of patients, contusion or congestion of lung lobes in 20% (31/157) of patients, and atelectasis of lung lobes in 15% (24/157) of patients. Rib injuries included < 3 rib fractures in 35% (55/157) of patients, ≥ 3 rib fractures in 25% (39/157) of patients, and trauma that required stabilization of the ribs or rib reconstruction in 16% (25/157) of patients. The most common abdominal surgical procedures consisted of diaphragmatic herniorrhaphy or repair of diaphragmatic rents in 30 of 39 (77%) patients; exploratory laparotomy with resection or repair of damaged tissues such as gastrointestinal segments, liver, kidney, gallbladder, and pancreas in 13 of 39 (33%) patients; and abdominal wall herniorrhaphy in 5 of 39 (13%) patients. The most common injuries noted at the time of surgery included skin wounds that required debridement or drain placement in 89% (140/157) of patients, rib fractures or luxations in 62% (97/157), muscular defects of the thoracic or abdominal body wall in 50% (78/157), lung lobe lesions in 43% (68/157), and fractures or avulsions of the sternum in 4% (6/157). Other surgical procedures not involving the thoracic or abdominal cavities included wound exploration with debridement of devitalized tissue (n = 18), resulting in placement of Penrose (11) or Jackson-Pratt drains (4). Overall, surgical drains were placed in 141 of 157 patients. Thoracic drains were placed in 67% (105/157) of patients, active-suction Jackson-Pratt drains allowing evacuation of the abdominal cavity were placed in 4% (6/157), active-suction Jackson-Pratt drains were placed in non–cavity-penetrating wounds located anywhere on the body in 36% (56/157), passive Penrose drains were placed in non–cavity-penetrating wounds located anywhere on the body in 27% (43/157), and vacuum-assisted drainage systems were placed in 2% (3/157).

Surgical biopsy specimens for microbial culture and susceptibility testing were collected in 87 of 157 (55%) patients, and 33 of the 87 (38%) yielded bacterial growth. The most common species cultured were *Streptococcus* spp in 11% (10 /87) of patients, *Staphylococcus* spp in 11% (10/87), *Pseudomonas* spp in 9% (8/87), Enterobacteriaceae in 9% (8/87), and *Bacillus* spp in 8% (7/87).

Postoperative findings

Multiple traumatic injuries were present in 59% (92/157) of patients, with some dogs experiencing trauma to multiple body systems, including abdominal trauma in 20% (32/157), appendicular trauma in 18% (29/157), trauma to the face or neck in 18% (28/157), head trauma in 4% (7/157), pelvic trauma in 5% (8/157), spinal trauma resulting in neurologic deficits in 2% (3/157), and pericardial trauma in 1% (2/157). Postoperative complications occurred in 67 of 157 (43%) patients and included incisional complications in 20% (32/157), gastrointestinal complications in 12% (19/157), cardiopulmonary arrest in 10% (15/157), cardiac arrhythmias in 7% (11/157), and aspiration pneumonia in 4% (7/157). Nonthoracic disease developed postoperatively in 64 of 157 (41%) patients, including anemia in 24% (37/157) of patients, hepatopathy in 13% (21/157), coagulopathy in 8% (13/157), and acute kidney injury in 1% (2/157). When postoperative complications and development of nonthoracic disease were considered, some patients experienced complications affecting multiple body systems. When evaluating patient records for parameters meeting the criteria for SIRS, 55% (86/157) of patients were classified as having SIRS preoperatively, 34% (53/157) were classified as having SIRS postoperatively, and 27% (42/157) were classified as having SIRS throughout the entire perioperative period.

The overall mortality rate was 14.6% (23/157; **Table 4**). Overall mortality rate included patients that died (13/23) and patients that were euthanized (10/23). The documented reasons for euthanasia included the following: patients that could not be weaned from a mechanical ventilator (n = 3), clinical deterioration of the dogs' condition despite directed medical treatment (eg, blood product transfusions or vasopressor therapy; 3), financial considerations (2), documentation of metastatic neoplasia during diagnostic evaluation (1), and owner decision for euthanasia after initiation of cardiopulmonary cerebral resuscitation (1). When the mortality rate specific to each institution was evaluated, the median mortality rate was 14.3% (range, 0% to 31%). The institution in which the mortality rate was the lowest (0%) contributed 2.5% (4/157) of the study population, and the institution in which the mortality rate was the highest (31%) contributed 8.3% (13/157) of the study population (**Supplementary Table S1**, available at avmajournals.avma.org/doi/suppl/10.2460/javma.252.9.1097). The percentage of patients surviving the surgical procedure alone was 99% (155/157). The mean ± SD number of days from surgery to death

Table 4—Results of univariate logistic regression analysis of whether specific injuries or conditions in the dogs in Table 1 were associated with outcome (died or euthanized vs survived to discharge).

Traumatic injury or condition	No. (%) of patients	No. that died or were euthanized	*P* value*
Flail chest	39 (25)	8	0.408
Lung lesion requiring lung lobectomy	41 (26)	6	0.986
≥ 3 rib fractures	39 (25)	8	0.071
Rib injury requiring rib reconstruction	25 (16)	4	0.835
Muscular body wall defect	78 (50)	13	0.360
SIRS preoperatively	86 (55)	18	0.280
SIRS postoperatively	53 (34)	9	0.048
Aspiration pneumonia	7 (4)	3	0.048
Coagulopathy	13 (8)	4	0.099
Acute kidney injury	2 (1)	1	0.209
Cardiac arrest	15 (10)	13	< 0.001

**P* values represent results of univariate logistic regression analysis of whether the specific traumatic injury was associated with outcome (died or euthanized vs survival to discharge). Overall 23 dogs died or were euthanized and 134 survived to discharge.

in the dogs that failed to survive to discharge was 2.6 ± 2.9 days (median, 2 days; range, 0 to 13 days). Discharge from the hospital occurred a median of 4 days (range, 0.5 to 27 days) postoperatively.

On logistic regression analysis, there were 11 variables in addition to ATT score with *P* values < 0.2 that were considered for inclusion in the multivariable model: sex, presence of subcutaneous emphysema, rib fractures on radiographs, pleural effusion on radiographs, active abdominal drainage, cardiac arrest, aspiration pneumonia, SIRS, coagulopathy, acidemia, and hypoglycemia. In the final model, sex and development of cardiac arrest were significantly associated with survival to discharge from the hospital. No measured laboratory values, surgical treatments, or surgical findings were associated with survival to discharge in the final model. The ATT score was retained in the model as a confounder. In female dogs, odds of survival to discharge were 6 times (95% CI, 1.3 to 28.9; *P* < 0.03) those of male dogs. In patients that did not experience cardiac arrest, odds of survival to discharge were 102.3 times (95% CI, 14.5 to 722.4; *P* < 0.001) those of patients that experienced cardiac arrest. The ATT score was a confounder for the association between cardiac arrest and survival to discharge (OR, 33.2 vs 102.3 with exclusion vs inclusion of ATT score). Patients with an ATT score < 7 had odds of survival 5.1 times (95% CI, 1.4 to 18.1; *P* < 0.02) those of patients with an ATT score ≥ 7. Fourteen percent (13/92; 95% CI, 7.7% to 23.0%) of patients with an ATT score ≥ 7 developed cardiac arrest, whereas only 2% (1/62; 95% CI, 0.4% to 8.7%) of patients with an ATT score < 7 developed cardiac arrest (*P* = 0.009).

Discussion

The present multi-institutional retrospective case series evaluated common injuries, complications of surgical treatment, and potential risk factors associated with death in a series of dogs with thoracic trauma that underwent surgical intervention over a 24-year period. The ATT score was significantly associated with outcome in the present study, suggesting that the ATT score could be useful in determining severity of disease and guiding decision making with regard to diagnostic tests and treatments in affected dogs. Whereas previous studies suggest that thoracic trauma generally carries a poor prognosis, the mortality rate for patients in the present study, in which 78% (123/157) required thoracic surgery, was only 14.6% (23/157).

Previous studies[2,4,9,33] have evaluated trauma in dogs, and the thorax is consistently one of the most common locations of injury during traumatic events. Whereas previous recommendations for surgical intervention in cases of bite wounds penetrating the thorax have been controversial, in view of the higher mortality rates associated with surgery,[4,13] newer reports suggest that it may be difficult to predict internal injuries without exploratory surgery.[5,8] Additionally, in human patients, rib fractures resulting from blunt trauma are indicators of more severe intrathoracic and abdominal injury,[34] although blunt trauma rarely requires surgical intervention in human or veterinary patients.[2,34]

Initial indicators of severe thoracic injury in human patients include the presence of multiple rib fractures and flail chest, as described by the abbreviated injury scale used to calculate the ISS.[18] The ISS is a validated numeric description of the overall severity of injury in human patients with injury to more than 1 area of the body and has been found to be a significant predictor of death.[18–21] Additionally, higher mortality rates have been reported for human patients with > 3 rib fractures and flail chest following thoracotomy.[21,22] In the patients of the present study, flail chest was diagnosed in 25% (39/157), ≥ 3 rib fractures were reported in 25% (39/157), and a thoracotomy procedure was performed in 78% (123/157); none of these factors were found to be significantly associated with survival to discharge. However, direct comparison with results of studies in human patients may be challenging in view of the fact that those studies[21,22] included patients undergoing both medical and surgical treatment of thoracic trauma, whereas only patients undergoing surgical treatment were included in the present study.

Results of multiple studies[4,6,9,25] suggest that male dogs are overrepresented in patient populations in which trauma is a result of dog fights or dog bite wounds. In 1 such study,[4] 10 of the 13 dogs that died of bite wounds were male. Another prospective multicenter study[7] of dogs with trauma included mostly (208/312) young dogs, with a higher proportion of males (178/315 [57%]) than females. In the present study of dogs with thoracic trauma, male dogs represented 51% (80/157) of patients, and it was unclear why female dogs were 6 times (95% CI, 1.3 to 28.9; $P < 0.03$) as likely to survive as male dogs. However, a previous study[35] suggests that male dogs may be overrepresented in patient populations of dogs with aspiration pneumonia, and 5 of 7 dogs experiencing aspiration pneumonia in the present study were male. Aspiration pneumonia was included in the multivariable model ($P = 0.048$), but was not a significant risk factor for failure to survive to discharge in the final model. In several previous studies,[36,37] sexually intact male dogs have been reported to be at higher risk for the development of postoperative infections, which we speculate may contribute to higher morbidity and mortality rates in this subset of patients.

Previous reports suggest that the incidence of aspiration pneumonia in dogs undergoing intervertebral disk surgery or laparotomy is approximately 5%.[38,39] In the present study, aspiration pneumonia affected 4% (7/157) of patients with thoracic trauma. Risk factors for the development of postoperative aspiration pneumonia may include preexisting respiratory disease, neurologic disorders, and thoracotomy and laparotomy,[30] all of which affected some dogs in the present study. Three of 7 patients with aspiration pneumonia in the present study died, and this mortality rate was higher than rates previously reported[30,35] to be associated with aspiration pneumonia (18% to 19%). We suggest that preexisting thoracic disease contributed to this outcome in the patients of the present report. Additionally, the higher cost of care associated with a previous surgical procedure may have contributed to euthanasia for financial reasons. We were unable to evaluate this variable (ie, postoperative aspiration pneumonia) in the final multivariable model as a risk factor for death because of the small number of affected patients.

Cardiac arrest occurred in 15 of 157 (9.5%) patients in the present study, and 2 of those 15 dogs survived to discharge. Dogs that did not experience cardiac arrest had odds of survival to discharge 102 times (95% CI, 14.5 to 722.4; $P < 0.001$) those of patients that experienced cardiac arrest. Results of a previous study[40] of dogs surviving cardiopulmonary cerebral resuscitation indicate that most causes of cardiopulmonary arrest are the result of anesthetic complications, with only 5 of 18 patients in that study developing acute cardiovascular collapse. Other studies[41,42] evaluating survival in small animal patients after cardiopulmonary cerebral resuscitation suggest that the most common causes of cardiopulmonary arrest, when known, are related to hypovolemia, anemia, and respiratory compromise. Patients with anemia and respiratory distress represented 24% (37/157) and 41% (64/157) of our patient population, respectively. The previous studies[41,42] of dogs and cats document rates of return of spontaneous circulation of 37% to 58%, with discharge from the hospital for only 5% to 6% of patients. We suggest that at least 2 of 15 patients in the present study likely experienced return of spontaneous circulation, a rate lower than previously reported; however, the retrospective nature of the study did not allow us to specifically evaluate the outcome for patients that underwent cardiopulmonary cerebral resuscitation.

Several reports[7,8,31,32] detailing the use of the ATT score to predict outcome for veterinary trauma patients have been published since its initial description[24] in 1994. Studies[7,8,24,31,32] have evaluated patients with many forms of trauma, including blunt trauma, vehicular trauma, bite wounds, and traumatic body wall herniation, and found the ATT score to be significantly related to outcome. Reported ATT scores associated with nonsurviving populations in these retrospective analyses ranged from 6 to 8.[7,8,24,31,32] In 2 prospective studies,[7,24] for each 1-point increase in the ATT score, the likelihood of survival decreased by a factor of 2.3, and an ATT score ≥ 5 was a predictor of outcome, with a sensitivity of 83% and specificity of 91%. The ATT score was not able to predict ventricular ectopic arrhythmias in a group of dogs, but the 1 patient in that population that died had an ATT score of 7.[43] The mean ± SD ATT score of the nonsurviving patients in the present study was 8 ± 2.4, which was similar to findings in previous reports. Additionally, patients with an ATT score < 7 had odds of survival 5.1 times (95% CI, 1.4 to 18.1; $P < 0.02$) those of patients with an ATT score ≥ 7, and 14% (13/92) of patients with an ATT score ≥ 7 experienced cardiac arrest. The ATT score has also been useful in evaluating dogs with polytrauma,[31] which is likely because the ATT score is derived from evaluation of multiple body systems. In 1 study,[31] 71% (169/239) of dogs with vehicular trauma had multiple injuries, and these dogs had significantly higher ATT scores than did dogs with single injuries. Another study[2] of dogs with blunt trauma found evidence of polytrauma in 72% (170/235) of patients. Polytrauma was present in 59% (92/157) of patients in the present study, with patients commonly sustaining penetrating trauma. This result likely was related to our case selection criteria, in that only patients that experienced trauma severe enough to warrant surgical intervention were included. A higher ATT score was significantly associated with a poorer outcome (ie, death) in our patient population, similar to results of other studies.[7,8,24,31,32]

However, the ATT score should probably not be used to predict survival or direct decisions regarding euthanasia in individual patients.[7,44] A previous study[45] in human patients indicated that neither clinical judgement nor a scoring model was reliable for survival prediction when the 2 methods were compared. Instead, we suggest that the ATT score might be used to provide additional objective information for clinicians, with a high score suggesting a need for more thorough diagnostic investigation, aggressive treatment, or both. The ATT score alone should not be used for definitive clinical decision-making.

We are not aware of prior published studies in veterinary patients with thoracic trauma describing mortality rates after surgical intervention. Mortality rates have been reported in patient populations that experienced penetrating thoracic trauma, among other injuries, including bite wounds and projectile trauma (eg, gunshot wounds), and have ranged from 11% to 38%.[4,5,9,46] Thoracic involvement in trauma patients has been documented to significantly increase the risk of death,[4,12,25] and in 1 report of 93 dogs with bite wounds, the mortality rate for dogs undergoing exploratory thoracotomy was 100%.[12] Mortality rates of 12% to 14% have been reported[2,31] in 2 large retrospective studies totaling 474 dogs with blunt trauma, including injuries to the thorax, and a mortality rate of 27% was reported in 26 dogs with traumatic body wall herniation.[8] The most recent study[14] evaluating death associated with intrathoracic surgery in 98 dogs reports a mortality rate of 21%.[14] A prospective study[7] of dogs with trauma found that patients with blunt trauma were significantly less likely to survive, whereas surgical intervention was a significant positive predictor of survival.[7] In the present study, 78% (123/157) of patients with thoracic trauma requiring surgical intervention underwent intrathoracic procedures, with an overall mortality rate of 14.6% (23/157). The most common reason for trauma in this study was dog bite wounds (86/157; 55%), and neither this nor an intrathoracic surgical procedure was a significant risk factor for death prior to discharge.

Systemic inflammatory response syndrome has been reported in human patients with severe dog bite wounds and recently was reported in 54% (51/94) of dogs with bite wounds.[33] In the present case series of dogs with thoracic trauma, 55% (86/157) of patients had dog bite wounds, with 55% (86/157) and 34% (53/157) classified as having SIRS pre- and postoperatively, respectively. Although a diagnosis of SIRS was not significantly associated with survival in the final multivariable model, it was significantly associated with survival in a prior study.[33] In the present study, mortality rates for patients with SIRS preoperatively and postoperatively (21% [18/86] and 23% [12/53], respectively) were similar to findings of a prior report[33] that indicated a 24% mortality rate associated with SIRS.[33] Systemic inflammation, severe tissue trauma, and metabolic acidosis have been reported to be associated with acute traumatic coagulopathy.[47] Indicators of coagulopathy and acid-base imbalance in patients of the present study varied, as would be expected in view of the variety of injuries described. Whereas abnormal laboratory values may represent clinically important injury or disease in an individual patient, evaluation of these values in our patient population resulted in median values that were within reference ranges for most measured variables. Additionally, no laboratory variable measured was a significant risk factor for survival to discharge in the final model.

There were several limitations to the present study, many of which were related to the study's retrospective nature. Retrospective studies rely on review of medical records, and although evaluation of medical records was sufficient to collect the data required for the present study, data were not complete for all patients with regard to surgical findings, details of pre- and postoperative care, and results of preoperative laboratory and diagnostic testing. Information with regard to timing from trauma to hospital admission, admission to surgery, and surgery to discharge or death was not always present in the record, and this information may have been valuable for analysis. Additionally, the ATT score was retrospectively assigned to study patients on the basis of details from the medical records. Furthermore, although the study patient population was relatively large, compared with populations in some previous studies, it would be beneficial to further explore the different types of injuries (eg, flail chest) in a larger population of patients. It would also be useful to evaluate an equally large population of patients with thoracic trauma that did not undergo surgical intervention, although identifying patients with a similar severity of disease in which surgical intervention was not pursued would be challenging. Defining a population in which the recommended treatment of surgical exploration was not pursued may introduce euthanasia bias.[44] This would make comparison of the groups challenging, as patients may well be euthanized because of the perception of a poorer prognosis without surgical exploration. In addition, the present study included patients examined over a 24-year period; however, the year of hospital admission could not be evaluated as a risk factor for survival to discharge because of incomplete medical record information. Medical and surgical treatments may vary greatly depending on the time frame of treatment because of advances in care, clinician preferences, and institutional management and protocols. In fact, the range in mortality rates specific to each institution was 0% to 31%, with a median mortality rate of 14.3%. Although the year of admission and institution of treatment were not specifically evaluated in the statistical model, the population of dogs evaluated in the presented study was diverse with regard to geographic location and clinical management, and we suggest this diversity added strength to our results.

In the present study, no imaging finding, surgical finding, or surgical procedure was significantly associated with survival in the perioperative period. This finding suggested that neither the severity of trauma documented with diagnostic imaging nor findings at the time of surgery were significant predictors of an increased risk of perioperative death for patients with thoracic trauma undergoing surgery. However, patients with presumably the most severe postoperative complications or sequelae of thoracic trauma, such as cardiopulmonary arrest, were significantly less likely to survive the perioperative period.

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Footnotes

a. Stata, version 13, StataCorp, College Station, Tex.

References

1. Wang SH, Wei TS, Chen CP. Prognostic analysis of patients with blunt chest trauma admitted to an intensive care unit. *J Formos Med Assoc* 2007;106:444–451.
2. Simpson SA, Syring R, Otto CM. Severe blunt trauma in dogs: 235 cases (1997–2003). *J Vet Emerg Crit Care (San Antonio)* 2009;19:588–602.
3. Spackman CJ, Caywood DD, Feeney DA, et al. Thoracic wall and pulmonary trauma in dogs sustaining fractures as a result of motor vehicle accidents. *J Am Vet Med Assoc* 1984;185:975–977.
4. Shamir MH, Leisner S, Klement E, et al. Dog bite wounds in dogs and cats: a retrospective study of 196 cases. *J Vet Med A Physiol Pathol Clin Med* 2002;49:107–112.
5. Scheepens ETF, Peeters ME, L'eplattenier HF, et al. Thoracic bite trauma in dogs: a comparison of clinical and radiological parameters with surgical results. *J Small Anim Pract* 2006;47:721–726.
6. Shahar R, Shamir M, Johnston DE. A technique for management of bite wounds of the thoracic wall in small animals. *Vet Surg* 1997;26:45–50.
7. Hall KE, Holowaychuk MK, Sharp CR, et al. Multicenter prospective evaluation of dogs with trauma. *J Am Vet Med Assoc* 2014;244:300–308.
8. Shaw SR, Rozanski EA, Rush JE. Traumatic body wall herniation in 36 dogs and cats. *J Am Anim Hosp Assoc* 2003;39:35–46.
9. Risselada M, de Rooster H, Taeymans O, et al. Penetrating injuries in dogs and cats: a study of 16 cases. *Vet Comp Orthop Traumatol* 2008;21:434–439.
10. Pawloski DR, Broaddus KD. Pneumothorax: a review. *J Am Anim Hosp Assoc* 2010;46:385–397.
11. Lisciandro GR. Abdominal and thoracic focused assessment with sonography for trauma, triage, and monitoring in small animals. *J Vet Emerg Crit Care (San Antonio)* 2011;21:104–122.
12. Cowell AK, Penwick RC. Dog bite wounds: a study of 93 cases. *Compend Contin Educ Pract Vet* 1989;11:313–320.
13. Davidson EB. Managing bite wounds in dogs and cats. Part II. *Compend Contin Educ Pract Vet* 1998;20:974–991.
14. Tattersall JA, Welsh E. Factors influencing the short-term outcome following thoracic surgery in 98 dogs. *J Small Anim Pract* 2006;47:715–720.
15. Moores AL, Halfacree ZJ, Baines SJ, et al. Indications, outcomes and complications following lateral thoracotomy in dogs and cats. *J Small Anim Pract* 2007;48:695–698.
16. Burton CA, White RN. Review of the technique and complications of median sternotomy in the dog and cat. *J Small Anim Pract* 1996;37:516–522.
17. Pape HC, Remmers D, Rice J, et al. Appraisal of early evaluation of blunt chest trauma: development of a standardized scoring system for clinical decision making. *J Trauma* 2000;49:496–504.
18. Baker SP, O'Neill B, Haddon W, et al. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 1974;14:187–196.
19. Emircan S, Ozgüç H, Akköse Aydın S, et al. Factors affecting mortality in patients with thorax trauma. *Ulus Travma Acil Cerrahi Derg* 2011;17:329–333.
20. Liman ST, Kuzucu A, Tastepe AI, et al. Chest injury due to blunt trauma. *Eur J Cardiothorac Surg* 2003;23:374–378.
21. Athanassiadi K, Theakos N, Kalantzi N, et al. Prognostic factors in flail-chest patients. *Eur J Cardiothorac Surg* 2010;38:466–471.
22. Perna V, Morera R. Prognostic factors in chest traumas: a prospective study of 500 patients. *Cir Esp* 2010;87:165–170.
23. Esme H, Solak O, Yurumez Y, et al. The prognostic importance of trauma scoring systems for blunt thoracic trauma. *Thorac Cardiovasc Surg* 2007;55:190–195.
24. Rockar RA, Drobatz KS, Shofer FS. Development of a scoring system for the veterinary trauma patient. *J Vet Emerg Crit Care (San Antonio)* 1994;4:77–83.
25. McKiernan BC, Adams WM, Huse DC. Thoracic bite wounds and associated internal injury in 11 dogs and 1 cat. *J Am Vet Med Assoc* 1984;184:959–964.
26. Boller EM, Otto CM. Sepsis and shock. In: Silverstein DC, Hopper K, eds. *Small animal critical care medicine*. 2nd ed. St Louis: Saunders Elsevier, 2015;472–473.
27. Hauptman JG, Walshaw R, Olivier NB. Evaluation of sensitivity and specificity of diagnostic criteria for sepsis in dogs. *Vet Surg* 1997;26:393–397.
28. Osterbur K, Mann FA, Kuroki K, et al. Multiple organ dysfunction syndrome in humans and animals. *J Vet Intern Med* 2014;28:1141–1151.
29. Keir I, Kellum JA. Acute kidney injury in severe sepsis: pathophysiology, diagnosis, and treatment recommendations. *J Vet Emerg Crit Care (San Antonio)* 2015;25:200–209.
30. Ovbey DH, Wilson DV, Bednarski RM, et al. Prevalence and risk factors for canine post-anesthetic aspiration pneumonia (1999–2009): a multicenter study. *Vet Anaesth Analg* 2014;41:127–136.
31. Streeter EM, Rozanski EA, Laforcade-Buress A, et al. Evaluation of vehicular trauma in dogs: 239 cases (January–December 2001). *J Am Vet Med Assoc* 2009;235:405–408.
32. Stillion JR, Fletcher DJ. Admission base excess as a predictor of transfusion requirement and mortality in dogs with blunt trauma: 52 cases (2007–2009). *J Vet Emerg Crit Care (San Antonio)* 2012;22:588–594.
33. Ateca LB, Drobatz KJ, King LG. Organ dysfunction and mortality risk factors in severe canine bite wound trauma. *J Vet Emerg Crit Care (San Antonio)* 2014;24:705–714.
34. Wanek S, Mayberry JC. Blunt thoracic trauma: flail chest, pulmonary contusion, and blast injury. *Crit Care Clin* 2004;20:71–81.
35. Tart KM, Babski DM, Lee JA. Potential risks, prognostic indicators, and diagnostic and treatment modalities affecting survival in dogs with presumptive aspiration pneumonia: 125 cases (2005–2008). *J Vet Emerg Crit Care (San Antonio)* 2010;20:319–329.
36. Nicholson M, Beal M, Shofer F, et al. Epidemiologic evaluation of postoperative wound infection in clean-contaminated wounds: a retrospective study of 239 dogs and cats. *Vet Surg* 2002;31:577–581.
37. Fitzpatrick N, Solano MA. Predictive variables for complications after TPLO with stifle inspection by arthrotomy in 1000 consecutive dogs. *Vet Surg* 2010;39:460–474.
38. Brainard BM, Alwood AJ, Kushner LI, et al. Postoperative pulmonary complications in dogs undergoing laparotomy: anesthetic and perioperative factors. *J Vet Emerg Crit Care (San Antonio)* 2006;16:184–191.
39. Java MA, Drobatz KJ, Gilley RS, et al. Incidence of and risk

factors for postoperative pneumonia in dogs anesthetized for diagnosis or treatment of intervertebral disk disease. *J Am Vet Med Assoc* 2009;235:281–287.
40. Waldrop JE, Rozanski EA, Swanke ED, et al. Causes of cardiopulmonary arrest, resuscitation management, and functional outcome in dogs and cats surviving cardiopulmonary arrest. *J Vet Emerg Crit Care (San Antonio)* 2004;14:22–29.
41. McIntyre RL, Hopper K, Epstein SE. Assessment of cardiopulmonary resuscitation in 121 dogs and 30 cats at a university teaching hospital (2009–2012). *J Vet Emerg Crit Care (San Antonio)* 2014;24:693–704.
42. Hofmeister EH, Brainard BM, Egger CM, et al. Prognostic indicators for dogs and cats with cardiopulmonary arrest treated by cardiopulmonary cerebral resuscitation at a university teaching hospital. *J Am Vet Med Assoc* 2009;235:50–57.
43. Snyder PS, Cooke KL, Murphy ST, et al. Electrocardiographic findings in dogs with motor vehicle-related trauma. *J Am Anim Hosp Assoc* 2001;37:55–63.
44. Hayes G, Mathews K, Doig G, et al. The Acute Patient Physiologic and Laboratory Evaluation (APPLE) score: a severity of illness stratification system for hospitalized dogs. *J Vet Intern Med* 2010;24:1034–1047.
45. Meyer AA, Messick WJ, Young R, et al. Prospective comparison of clinical judgment and APACHE II score in predicting outcome in critically ill surgical patients. *J Trauma* 1992;32:747–753.
46. Baker JL, Havas KA, Miller LA, et al. Gunshot wounds in military working dogs in Operation Enduring Freedom and Operation Iraqi Freedom: 29 cases (2003–2009). *J Vet Emerg Crit Care (San Antonio)* 2013;23:47–52.
47. Palmer L, Martin L. Traumatic coagulopathy—part 1: pathophysiology and diagnosis. *J Vet Emerg Crit Care (San Antonio)* 2014;24:63–74.

From this month's *AJVR*

Comparison of desflurane and propofol at equipotent doses in combination with a constant rate infusion of dexmedetomidine on global and peripheral perfusion and oxygenation in horses

Stephan Neudeck et al

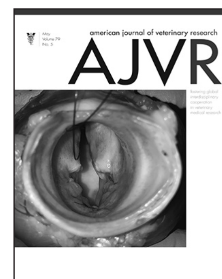
OBJECTIVE
To determine global and peripheral perfusion and oxygenation during anesthesia with equipotent doses of desflurane and propofol combined with a constant rate infusion of dexmedetomidine in horses.

ANIMALS
6 warmblood horses.

PROCEDURES
Horses were premedicated with dexmedetomidine (3.5 μg•kg^{-1}, IV). Anesthesia was induced with propofol and ketamine and maintained with desflurane or propofol (complete crossover design) combined with a constant rate infusion of dexmedetomidine (7 μg•kg^{-1}•h^{-1}). Microperfusion and oxygenation of rectal, oral, and esophageal mucosa were measured before and after sedation and during anesthesia at each minimal alveolar concentration and minimal infusion rate. Heart rate, mean arterial blood pressure, respiratory rate, cardiac output, and blood gas pressures were recorded during anesthesia.

RESULTS
Mean ± SD minimal alveolar concentration and minimal infusion rate were 2.6 ± 0.9% and 0.04 ± 0.01 mg•kg^{-1}•min^{-1}, respectively. Peripheral microperfusion and oxygenation decreased significantly after dexmedetomidine administration for both treatments. Oxygenation returned to baseline values, whereas tissue microperfusion remained low during anesthesia. There were no differences in peripheral tissue microperfusion and oxygenation between treatments. Cardiac index was significantly higher and systemic vascular resistance was significantly lower for desflurane treatment than for propofol treatment. For the propofol treatment, PaO_2 was significantly higher and there was less dead space and venous admixture than for the desflurane treatment.

CONCLUSIONS AND CLINICAL RELEVANCE
Dexmedetomidine decreased blood flow and oxygen saturation in peripheral tissues. Peripheral tissues were well oxygenated during anesthesia with desflurane and propofol anesthesia combined with dexmedetomidine, whereas blood flow was reduced. (*Am J Vet Res* 2018;79:487–495)



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