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Clinical and biochemical factors associated with survival in equids attacked by dogs: 28 cases (2008-2016)

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Abstract

Background: Trauma from dog attacks has been associated with mortality rates as high as 23% in some species. However, the prognosis and clinical features of this type of injury have not been described in equids.

Hypotheses/Objectives: To describe survival rate, signalment, clinical features, and biochemical results in equids presented for emergency care after presumed dog attacks. We hypothesized there would be differences between survivors and nonsurvivors.

Animals: A total of 28 equids presented for presumed dog attacks from 3 referral centers.

Methods: A retrospective study was performed using data from 3 hospitals between 2008 and 2016. Survival was defined as survival at 14 days postdischarge. Variables were compared between survivors and nonsurvivors using a *t* test, Mann-Whitney *U* test, or Fisher's exact test as appropriate.

Results: Overall mortality rate was 21%. Ponies and miniature horses represented 16/28 (57%) of the animals in the study. Full-sized equids had a lower risk of nonsurvival as compared to smaller patients (odds ratio = 0.02; 95% confidence intervals = 0.00-0.27; $P < .005$). Animals with lower body temperatures had increased risk for nonsurvival ($P = .0004$). Increased admission blood lactate concentrations ($P = .003$) and decreased serum total protein concentrations ($P = .006$) were associated with nonsurvival.

Conclusions: The mortality rate in equids attacked by dogs was similar to what is reported for other veterinary species. Smaller equids and those with increased admission blood lactate concentration, lower body temperature, and lower total serum protein concentrations were less likely to survive.

KEYWORDS
creatine kinase, hyperlactatemia, hypoproteinemia, hypothermia

Abbreviations: AST, aspartate aminotransferase; BUN, blood urea nitrogen; CI, confidence intervals; CK, creatine kinase; GGT, gamma-glutamyl transferase; OR, odds ratios; PCV, packed cell volume; SIRS, systemic inflammatory response syndrome.

1 | INTRODUCTION

Trauma is a common emergency in equids presented to referral centers and may account for approximately 20% of the emergency caseload.[1,2] Although considerable research focuses on fractures and orthopedic injuries, other types of trauma also have been reviewed.[3-5] Dog attack trauma, and specifically dog bite wounds, are a unique type of traumatic injury that has been evaluated in dogs, cats, sheep, goats, camelids, and humans.[6-9] Even in the species where dog attack injuries have been evaluated, only a few studies provide information about the association between clinical or biochemical variables and survival.[6-10]

Dog attack trauma is unique because of the extent of contamination and damage to tissue that may not be evident at the skin surface. Dog bite wounds are considered dirty and contaminated with oral flora from the dog, skin flora from the area of the bite, and microorganisms from the environment.[11] These wounds are also unique because of the 3 types of trauma involved: puncture by canine teeth, crushing by molars and premolars, and lifting and shaking leading to separation of skin from underlying structures.[12] Blood loss can be substantial. Furthermore, dog attacks may be preceded by chasing and struggling, which can cause stress and muscle damage consistent with capture myopathy.[13] These unique features of dog attacks may increase mortality compared with other types of wounds and trauma.

In studies evaluating dog or coyote attacks of other dogs, the size (<10 kg) and sex (male) of the animal bitten was associated with increased severity or frequency of injuries or both.[8,14] Similarly, in studies of humans, mortality is significantly associated with size or age of the person or both.[15,16] Wounds involving the thorax have been associated with nonsurvival in small animals and humans.[7,8] In a study evaluating dog bites in small ruminants and camelids, a significant increase in mortality was found for animals with abdominal or thoracic injuries and those with respiratory complications.[9]

To our knowledge, a group of equids with dog bite injuries has not been described in the veterinary literature. Our purpose of was to conduct a multicenter retrospective case study of presumed dog bite attacks in equids to determine the signalment, clinical findings, and laboratory features of this type of injury in these species. In addition, we aimed to determine the mortality rate of dog bite injuries in equids and factors associated with short-term survival (14 days after discharge). We hypothesized that the mortality rate in equids after dog bite attacks would be similar to that observed in other veterinary species and that mortality would be associated with a smaller size of animal and increased admission blood lactate concentration.

2 | MATERIALS AND METHODS

Medical records of equids evaluated by the Field Service Departments or admitted to the Loomis Basin Equine Medical Center, University of California Davis School of Veterinary Medicine, and University of Georgia College of Veterinary Medicine teaching hospitals between 2008 and 2016 were reviewed. Key words searched included "animal attack" or "dog attack" and "animal bite" or "dog bite." Cases were included for equids with presumptive or observed dog bite-associated injuries. Information obtained from the medical records included signalment, location of wounds (limbs, trunk, or face and neck), admission physical examination findings (temperature, heart rate, respiratory rate), and admission laboratory results including packed cell volume (PCV), serum total protein concentration, blood lactate concentration, total white blood cell count, neutrophil count, lymphocyte count, platelet count, serum albumin concentration, gamma-glutamyl transferase (GGT) activity, total bilirubin concentration, aspartate aminotransferase (AST) activity, serum creatinine concentration, blood urea nitrogen (BUN) concentration, serum calcium concentration, blood glucose concentration, creatine kinase (CK) activity, and serum concentrations of sodium and potassium. In addition, treatments, location of treatment (field service versus clinic), duration of hospitalization, and survival were recorded. Survival was defined as survival 14 days after discharge from the hospital (clinic cases) or 14 days after the initial field visit (field service cases). Deteriorating clinical condition was defined as worsening of clinical signs and laboratory results despite treatment. All variables were evaluated as continuous variables except for animal size, sex, and CK activity. Creatine kinase activity > 15 000 IU/L at 1 hospital were reported as above the system range (VetScan VS2 Operations Manual 2013, Abaxis, Union City, California). Therefore, the CK variable was treated as categorical (<15 000 or > 15 000 IU/L) for the entire group.

Mean ± SD and median (range) are reported for variables with normal and nonnormal distributions, respectively. Commercial software programs were used for analysis (GraphPad Prism version 8.2.1 for Windows, GraphPad Software, La Jolla, California; Stats Direct version 3.2.1, StatsDirect Ltd, Merseyside, UK). Normality was determined using the Kolmogorov-Smirnov test. Continuous variables were compared between survivors and nonsurvivors using a t test or Mann-Whitney U test for normally distributed or nonnormally distributed data, respectively. For categorical variables, Fisher's exact test was used for comparison between survivors and nonsurvivors and 95% confidence intervals (CI) for odds ratios (OR) were calculated. For instances in which a category contained zero animals, the Haldane-Anscombe correction was applied to avoid generating an OR of zero or infinity.[17] A P value of <.05 was used to determine statistical significance.

3 | RESULTS

A total of 28 equids fulfilled the inclusion criteria for the study. A summary of the data for signalment, physical examination findings, and laboratory variables is presented in Tables 1 and 2. A total of 15/28 (56%) cases were evaluated and treated by study center 1, 3/28 (11%) cases by study center 2, and 10/22 (36%) cases by study center 3. Seven of 28 (25%) patients were evaluated and treated on the farm by a field services division, whereas 21/28 (75%) animals were treated at a veterinary hospital.

The mean age of the 28 animals was 10 ± 7 years. There were 18/28 (64%) females, 7/28 (25%) castrated males, 2/28 (7%) intact males, and 1/28 (4%) male of unknown neuter status. There were

TABLE 1 Signalment and clinical examination variables in surviving and nonsurviving equids presented for emergency veterinary care after presumptive dog attack injuries

Variable	Survivors	n	Nonsurvivors	n	*P* value	Odds ratio (95% CI)	Ref. range	N
# of animals	22		6		N/A		N/A	28
Age (years)	10 ± 8	22	11 ± 6	6	.76		N/A	
Duration of hospitalization (days)	3.5 (0-46)	16	5 (0.25-42)	5	.48		N/A	28
Full size horse	12	22	0	6	<.005	0.02 (0.00-0.27)	N/A	28
Temperature (°C)	37.9 ± 0.5	18	36.1 ± 1.7	6	<.005		37.2-38.3	24
Heart rate (bpm)	68 (32-120)	20	100 (56-108)	6	.23		28-44	26
Respiratory rate (bpm)	26 (12-80)	20	29 (24-48)	6	.50		8-20	26
Sex (female)	15	22	3	6	.64		N/A	28

Note: Data are presented as mean ± SD where all data for the variable is normally distributed and median (range) where one or more groups of the data for the given variable were not normally distributed.

TABLE 2 Hematological and biochemical variables in surviving and nonsurviving equids presented for emergency veterinary care after presumptive dog attack injuries

Variable	Survivors	n	Nonsurvivors	n	*P* value	Odds ratio (95% CI)	Ref. range	N
Packed cell volume (PCV) (%)	35 ± 5	9	35 ± 8	5	.97		30-42	14
Total protein (TP) (g/dL)	6.4 ± 0.6	9	5.1 ± 1.0	5	.006		5.2-7.9	14
Lactate (mmol/L)	3.1 ± 1.6	10	13.1 ± 8.5	5	<.005		<2.0	15
White blood cells (WBC) (cells/μL)	9610 (3510-16 490)	10	4980 (3070-17 330)	4	.45		5400-14 300	14
Neutrophils (cells/μL)	6452 (2300-12 714)	10	4220 (1380-15 550)	3	.81		1638-7238	13
Lymphocytes (cells/μL)	2123 (661-4077)	10	790 (490-1490)	3	.09		3149-12 558	13
Platelets (cells/μL)	198 (141-330)	10	278 (94-365)	3	.41		100 000-270 000	13
Globulins (g/dL)	3.4 (2.5-4.5)	10	2.3 (1.9-3.8)	3	.15		2.6-4.0	13
Albumin (g/dL)	2.9 (2.0-3.7)	10	3.0 (2.1-3.5)	3	.78		2.6-3.7	13
Gamma-glutamyl transferase (GGT) (IU/L)	24 (11-124)	10	24 (17-26)	3	.81		6-29	13
Total bilirubin (mg/dL)	0.3 (0.3-5.0)	10	1.4 (0.1-3.9)	3	.66		1.0-2.0	13
Aspartate aminotransferase (AST) (IU/L)	478 (275-683)	9	539 (288-1227)	3	.37		140-306	12
Creatinine (mg/dL)	1.2 (0.8-2.1)	10	1.6 (1.2-2.3)	4	.11		0.6-2.2	14
Blood urea nitrogen (BUN) (mg/dL)	14 (5-24)	10	17 (10-30)	4	.47		15-33	14
Calcium (mg/dL)	11.4 (10.2-11.7)	9	10.5 (10.1-11.3)	3	.15		10.1-12.6	12
Glucose (mg/dL)	179 ± 67	10	175 ± 77	5	.92		68-126	15
Creatine kinase (CK) >15 000 IU/L	2	9	3	3	.07		N/A	12
Potassium (K) (mmol/L)	3.7 ± 0.7	10	4.5 ± 1.1	5	.11		3.7-5.3	15
Sodium (Na) (mmol/L)	133 ± 3	10	134 ± 3	5	.79		132-140	15

Note: Data are presented as mean ± SD where all data for the variable is normally distributed and median (range) where one or more groups of the data for the given variable were not normally distributed.

8/28 (29%) Miniature Horses, 5/28 (18%) Miniature Donkeys, 3/28 (11%) Ponies, 3/28 (11%) Arabians, 3/28 (11%) Quarter Horse or Quarter Horse Cross, and 1/28 (4%) each of Morab, Irish Sport Horse Cross, Donkey, Paint, Thoroughbred, and unknown breed. Sixteen (57%) animals were ponies or miniatures (horses or donkey), whereas 12 animals were considered regular-sized animals. The patient population consisted of approximately 3.6%, 3.0%, and 4.6% miniature equids and ponies at study centers 1 to 3, respectively.

Twenty-three (82%) of 28 animals sustained wounds to >1 location. The limbs sustained ≥1 wounds in 22/28 (79%) animals. The face or neck was injured in 14/28 (50%) animals. The trunk (abdomen or thorax) was affected in 8/28 (29%) animals. One animal sustained a penetrating injury to the upper airway (trachea). Four animals had wounds suspected to involve a synovial structure. Synovial involvement was confirmed in 1 animal by arthrocentesis. In 1 animal, the clients declined sampling of the synovial structure despite suspicion of joint involvement. In the 3rd animal, arthrocentesis was considered not definitive and in the 4th animal arthrocentesis confirmed that the joint was not involved. Six animals had radiographs taken of ≥1 locations, but no fractures were identified. One animal had a wound involving the rectum, and 1 animal had a wound involving the scrotum. These abnormalities were identified on physical examination.

Various treatments were administered, including 28/28 (100%) equids that received a nonsteroidal anti-inflammatory drug. Systemically administered antimicrobials typically were broad spectrum and were used in 27/28 (96.4%) cases. Combinations of antimicrobials frequently were used and included ceftiofur and gentamicin (2/28; 7%), ceftiofur and gentamicin followed by trimethoprim-sulfamethoxazole (4/28; 4%), gentamicin followed by trimethoprim sulfamethoxazole (1/28; 4%), ceftiofur followed by trimethoprim-sulfamethoxazole (2/28; 7%), ceftiofur and gentamicin and metronidazole (1/28; 4%), ceftiofur and gentamicin and metronidazole followed by trimethoprim-sulfamethoxazole (2/28; 7%), potassium penicillin and gentamicin and metronidazole (1/28; 4%), procaine penicillin and gentamicin (1/28; 4%), ampicillin and amikacin followed by trimethoprim-sulfamethoxazole and metronidazole (1/28; 4%), procaine penicillin and gentamicin followed by trimethoprim-sulfamethoxazole (1/28; 4%), procaine penicillin and gentamicin followed by doxycycline (1/28; 4%), procaine penicillin and enrofloxacin followed by chloramphenicol (1/28; 4%), procaine penicillin and gentamicin followed by minocycline (1/28; 4%), and ceftiofur and gentamicin followed by enrofloxacin (1/28; 4%). A total of 6/28 animals (21%) received trimethoprim-sulfamethoxazole alone and 2/28 (7%) received ceftiofur alone.

Fifteen of 28 (53.6%) animals received IV crystalloids. Intravenous colloids were administered in 3/28 (11%) animals. Nine of 28 (32%) animals received IV dextrose supplementation or a combination of IV dextrose and amino acids. A whole blood transfusion was given to 1 equid that had a PCV that decreased to 18% and a blood lactate concentration that increased to 9.2 mmol/L approximately 8 hours after presentation. In 16 animals, the rabies vaccination status was unknown. In 9 of the animals, the rabies vaccination status was current and 3 of the animals were described as unvaccinated.

For the entire group of hospitalized patients, the duration of hospitalization was a median (range) of 4 (0-46) days. For patients evaluated and treated by field services, the number of visits was median (range) of 1 (1-21) farm calls.

The overall survival rate was 22/28 (79%), where 5 of the nonsurviving animals were clinic cases and 1 of the nonsurviving animals was treated by field services. Of the 5 clinic cases that did not survive, 4 died in the hospital and 1 died 12 days after discharge. Two of the 6 (33%) nonsurvivors died and 3 (50%) were euthanized because of a deteriorating clinical condition despite treatment. Deteriorating clinical condition was determined by the clinician, but typically included worsening of laboratory (eg, blood lactate concentration) or clinical examination variables (temperature, pulse, respiration, mucous membrane color, extremity temperature, pulse quality, capillary refill time) despite treatment. The remaining survivor was euthanized, but the medical record did not indicate whether financial considerations or physical condition played a role in the decision to stop treatment.

4 | DISCUSSION

The overall short-term survival rate (14 days after discharge from hospital or 14 days after the first field visit) for equids attacked by dogs was 79%, which is similar to reports for other animal species, and smaller animals are at higher risk for mortality.[7,9,18] Lower body temperature, higher admission blood lactate concentration, and lower total serum protein concentration appear to be associated with decreased chances of survival and could be used by clinicians to help guide the prognosis given to clients.

The survival rate in our study was 79%, as compared to other animal species, including 77% in small ruminants and camelids, 85% in dogs, and 88% in cats.[7,9,18] A difference between dogs and cats versus equids could be that horses are more prone to running from a predator. This factor may be associated with capture myopathy or other associated complications.

The survival rate in our study was lower than the 97.7% to 99.6% survival rate reported in humans presenting for emergency care after dog attacks.[6,11] The difference in survival between people and animals may relate to health insurance and availability of care. However, it also is possible that many minor dog bites are reported and treated in humans whereas only more severe cases of dog bite injuries may be presented to veterinary hospitals.

Size of the animal or person is a risk factor for being bitten by dogs, and also is associated with mortality from these injuries.[8,14,19] Our results support these findings because the majority of animals that were included were miniature equids or ponies compared to the general case population of all 3 centers. None of the horses in the nonsurviving group were full-sized. Veterinarians working with clients with smaller equids should advise them of the increased risk and take additional precautions to protect these smaller animals from dog attacks. In addition to their small size, miniature equids may be more likely to be housed differently (eg, pasture boarding) than full-sized horses, and this factor could explain the increased association with attacks.

Hypothermia is a component of the lethal triad that is used to evaluate human trauma patients, and the other 2 factors are acidosis and coagulopathy.[20,21] The lethal triad has been shown to have prognostic value for mortality.[20,21] The other 2 factors in the lethal triad (pH and coagulation parameters) were not measured consistently in our study, but potentially could be important for future research. In our study, hypothermia could have been related to hypoperfusion and shock and the smaller size of some animals. One animal, in particular, was cornered by the dogs in a pond where it remained for a number of hours. Another factor that could contribute to hypothermia is blood loss. Few of the animals in our study had a PCV below the normal range (Table 2), but acute blood loss may not be reflected in the recorded PCV.

Hyperlactatemia has been associated with nonsurvival in many species, and it was significantly associated with a higher trauma score in bite wounds in cats.[22] Our findings are consistent with the hypothesis that more severely affected animals have higher blood lactate concentrations. Lactate concentrations may be increased for a variety of reasons including stress, sepsis, and hypovolemia.[23,24] Interestingly, some of the animals in our study were reported to be chased by dogs for extended periods of time, and thus extreme exertion with increased oxygen demand also could have been a contributing factor.[23] Other studies have reviewed blood lactate concentration as a prognostic indicator for different types of emergencies in many species and cutoff concentrations of 6.0 mmol/L often are cited.[25]

Lower serum total protein concentration was associated with mortality in our study. Low serum albumin concentration is a common finding in critically ill patients and can be associated with development of acute kidney injury and mortality.[26,27] The association between hypoproteinemia and mortality in horses attacked by dogs needs further research into a potential relationship with hypoglobulinemia.

All of the animals with CK < 15 000 IU/L survived, but the P value for Fisher's exact test was not significant (P = .07). Rhabdomyolysis (muscle necrosis) indicates injury to organelles within a muscle fiber, an inability to maintain homeostasis, and subsequently cell death. In studies of humans, trauma has been shown to be a common cause of rhabdomyolysis.[28]

Creatine kinase has been used as a prognostic indicator of acute kidney injury in humans experiencing rhabdomyolysis, and higher mortality rate has been documented in patients who develop acute kidney injury after rhabdomyolysis.[28,29] Hypovolemia is another factor that could be present in animals attacked by dogs and could lead to renal injury. High CK activity also has been directly associated with mortality, as well as the need for and duration of inotropic support in critically injured human adults.[30]

An important limitation when interpreting CK activity is the duration of time between the attack and blood sample collection. In our study, CK activity could have been much higher than observed if samples were taken at a different time. The CK activity in patients with rhabdomyolysis can easily exceed 100 000 IU/L. The AST activities were increased in both survivors and nonsurvivors, supporting the conclusion of clinically relevant muscle damage, although results were not different between groups.

In our study, 80% of the animals had injuries affecting the extremities, but synovial involvement only was identified rarely. In addition, fractures were not found in animals in which radiographs were obtained. These findings are in contrast to dog attacks in small ruminants and camelids, in which 27% of animals had substantial musculoskeletal injuries.[9] The size of the animals (horses compared to goats) may play a factor in these findings. In our study, few cases specifically involved penetrating injuries to the thorax. Therefore, a statistical analysis was not completed for this subgroup as compared to previous reports.[7,8]

A limitation of our study is that very few of the attacks were observed, but dog bite injuries were the presumed cause based on the appearance of the wounds. In addition, dogs had access to the animals that were attacked in many of the cases. However, it is possible that some of these injuries could have been inflicted by coyotes, mountain lions, or other animals. It is likely that many of our findings could be applied to attacks from other animals in addition to dogs.

An additional limitation of the study is the small sample size and incomplete data sets in many animals, particularly for laboratory results. It is likely that milder dog attacks are treated at home by clients and veterinarians are not consulted. Therefore, the mortality rate in our study may be biased, because animals with severe injuries are more likely to be presented for treatment. A prospective study that includes client education might identify a larger case population. Likewise, a retrospective study that includes a client survey for dog attacks not reported to veterinarians also might increase the number of animals.

If a larger number of animals had been included in the study, a multivariable logistic regression model would have been more appropriate to determine which variables were associated with mortality. Twenty-five variables were evaluated in our study. Recommendations are that 10 to 20 events per predictor variable would be needed for a logistic regression model, requiring a total of 250 to 500 animal attack cases.[31] A Bonferroni correction was not used in our study because suggested criteria for its use were not met.[32] Specifically, a universal test across all variables for the null hypothesis was not the purpose, the risk of avoiding a type I error was not imperative, and the hypothesis was preplanned based on previous studies on related topics. We believe that the increase in type II error by using a Bonferroni correction would not have been justified.

In retrospective survival studies, it is always difficult to determine whether the nonsurvivors were euthanized for financial reasons or because of a grave clinical prognosis and deteriorating condition. In our study, 5 of the animals either died or were euthanized for reasons that did not appear to be influenced by the cost of treatment. One remaining animal may have been euthanized based on reasons that were not completely clinical, but this information was not available.

In conclusion, clinicians should be aware that smaller equids and those with increased admission blood lactate concentration, lower body temperature, and lower total serum protein concentrations are less likely to survive.

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CONFLICT OF INTEREST

Authors declare no conflict of interest.

OFF-LABEL ANTIMICROBIAL DECLARATION

Authors declare no off-label use of antimicrobials.

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

HUMAN ETHICS APPROVAL DECLARATION

Authors declare human ethics approval was not needed for this study.

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