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PREDICTION OF OUTCOME IN POLYTRAUMA CANINE PATIENTS

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A retrospective study of 45 polytrauma patients was conducted in order to identify clinical and laboratory parameters with a prognostic value regarding the outcome. All data had been received from medical records. Twenty seven of dogs survived and were discharged from the hospital while the remaining 18 died and thus two groups were formed (survivals and nonsurvivals). Relationships between signalments, clinical, and laboratory parameters and outcomes were evaluated by means of logistic regression analysis. Based on the variables with the most significant influence upon mortality a new survival prediction scoring system was suggested.

Key words: dogs, multiple trauma, score system, survival

INTRODUCTION

Trauma is a common reason for presenting animals to veterinary hospitals on an emergency basis. In the large retrospective studies of Kolata and Johnston (1975), and Kolata (1980) was found that approximately 13% of admissions were for treatment of traumatic patients. About 36% of these cases involved multiple injuries with an overall mortality rate of 9-12.5%, but no relationship between injury severity and the outcome was identified. More recent studies reported 11% of trauma cases in the intensive care unit (Hayes *et al*., 2010) with 12% mortality rate (Simpson *et al*., 2009).

Traumatic injuries are typically categorized as blunt or penetrating. Over 90% of blunt trauma cases were due to motor vehicle accidents (Simpson *et al*., 2009) while 75% of penetrating trauma cases were the results of animal altercations (Risselada *et al*., 2008).

Animals experiencing trauma can have a wide variety of injuries, with considerably varying prognosis depending on the injury type and affected body systems. Primary injuries following blunt trauma involved their thora (70%), abdomen (50%), extremities (40%) and head (30%) (Simpson *et al*., 2009). The most common thoracic injuries in dogs were pulmonary contusions and pneumothorax (about 50% each). The most common abdominal injuries were haemoabdomen, abdominal hernias, and rupture of the urinary tract.

Polytrauma (multitrauma) is defined as occurrence of severe injuries in at least two areas of the body (Kroupa, 1990) and composed 35% of trauma cases.

Dogs with polytrauma had a higher mortality (Steeter *et al*., 2009). The severity of injuries and the affected organs and systems often determine the likelihood of survival. The treatment is expensive, time-, and energy-consuming so the exact prognosis would help prompt decision-making for treatment or euthanasia.

There is a paucity of data describing risk factors and their effects on the outcome in polytrauma canine patients. Acute physiology and chronic health evaluation (APACHE) II, APACHE III, and trauma and injury severity score (TRISS) systems were unreliable in human trauma patients and considerably underestimated the risk of death (Vassar *et al*., 1999).

The aim of the present study was to evaluate the predictive value of some signalment, clinical and laboratory parameters in polytraumatized dogs with regard to the outcome. Based on the variables with the most significant influence upon mortality a new survival prediction scoring system was suggested.

MATERIAL AND METHODS

Animals

Data from the medical records of 45 polytraumatized dogs presented at the Clinic between 2007 and 2010 were collected. Twenty seven of them survived and were discharged from the hospital, while the remaining 18 died and thus two groups were formed. The inclusion criterion for the research was the presence of multiple trauma according to the definition – animals that were injured with at least 2 affected body areas. Dogs were excluded if there was limited information available or were submitted to euthanasia. Information about dog's breed, age, sex, body condition, time elapsed from the accident, type of injury (biting, shooting, or hitting), applied treatment, main clinical and laboratory parameters, diagnosis, number of affected regions, presence of bone fractures, as well as animal trauma triage (ATT) and small animal comma scale (SACS) scores was obtained from the individual patient forms. Differences in these parameters between survivors and non-survivors were compared.

Statistical methods

Relationships between signalments, clinical, and laboratory parameters and outcomes were evaluated by means of logistic regression analysis with a statistical software package MedCalc software v. 10.2.0.0 (Belgium).

First, differences in the distribution of independent variables between survivors and non-survivors were made. Mann-Whithney non-parametric test was used to evaluate the difference of means of continuous parameters between survivors and non-survivors. Chi-square analysis was used for categorical variables. As mean values of vital signs expressed as continuous variables are of little clinical value, since excess mortality is only observed either above and/or below their normal ranges, continuous variables were converted into categorical variables and were presented as dicho /trichotomous variables. For example, although there were no differences in the mean body temperatures between those who died and those who survived, low temperature was associated with an increased chance of death in comparison with high or normal values. Mucous membrane colour (MMC) and pulse quality were presented as dichotomous variables. Appropriate cut-off points for capillary refill time (CRT), number of affected body areas, ATT and SACS scores were determined by receiver operator curve (ROC) and Youden index analysis.

The effects of single risk factors on death were examined further with logistic regression. Odds ratios (OR), as a quantitative measurement of association between an outcome and a potential risk factor, were calculated for each parameter. Ninety-five percent confidence intervals (CIs) for OR were also calculated.

After performing univariate logistic regression, all variables that showed a statistically significant relationship to outcome were entered in a stepwise multivariable regression model. The power of the model's predicted values to discriminate between positive and negative outcome is quantified by the area under the ROC (AUC). It is interpreted as the percent of all possible pairs of cases in which the model assigns a higher probability to a correct than to an incorrect case.

Finally, a multiple trauma scoring system was developed based on the results from uni- and multivariable analyses. Its predictive value was also presented by the area under the ROC (AUC).

RESULTS

Animals that fulfilled the inclusion criteria were from many different breeds such as Jagdterrier, Bulgarian Scenthound**,** Drahthaar, Kurzhaar, Pit-bull, Staffordshire terrier, Pekinese, Chi-hua-hua, Pincher, German Shepherd, Cocker spaniel, ect. There were not any differences between alive and dead with regard to sex, age, body weight, and condition, as well as most of the clinical and laboratory parameters. Diagnoses in both groups were also similar: bone fractures, joint dislocations, blunt abdominal, chest or head trauma, open abdominal, chest or head trauma, spinal trauma, bullet, lacerated or crushed wounds with all accompanying disorders. Animals from the two investigated groups were additionally distributed in three subgroups: cerebral, thoracic and abdominal/ pelvic trauma, but no association between the outcome and type of trauma was established. We did not find any connection either between the time elapsed from injury to treatment and the outcome, or between the preliminary applied treatment and outcome. In contrast, a connection between MMC, CRT, ATT score, SACS score, number of affected areas and lethality was found (Table 1).

Univariable logistic regression analysis (Table 2) demonstrated that subnormal body temperature increased the chance of death 6.4 times ($p=0.02$). The probability of lethal outcome increased 3.73 times ($p=0.04$) if pulse quality was weak; 4.75 times ($p=0.01$) if MMC was abnormal; and 6.91 times ($p=0.0005$) if CRT was above 2 seconds. One of the strongest death predictors was the ATT score which increased chance of death 17.5 times ($p=0.0003$) if an animal received more than 5 points. SACS score higher than 17 could be considered as a positive predicting factor for survival ($OR=0.05$; $p=0.0006$). The occurrence of one or two affected regions may be considered another predictor benefiting survival ($OR=0.1$; $p=0.0022$).

Table 1. Comparison of signalments, clinical and laboratory variables between survived and non-survived dogs with multiple trauma using Mann-Whitney test for continuous parameters and chi-square test for categorical parameters

Parameter	Survivors		Non-survivors		P-value
	n	Median (range) or ratio (%)	n	Median (range) or ratio (%)	
Signalment					
Sex (male/female)	27	16/11 (60/40)	18	15/3 (83/27)	0.16
Age, years	27	3.5 (0.5-10.0)	18	3.5 (0.25-10.0)	0.90
Body weight, kg	27	6.0 (1.5-40.0)	18	18.5 (1.3-40.0)	0.17
Body condition - good/ poor	27	13/14 (48/52)	18	12/6 (67/33)	0.36
Clinical variables					
Cause of injury (biting/ shooting/ hitting)	27	3/2/22 (11/7/82)	18	2/2/14 (11/11/78)	0.69
Time from injury to treatment (<24 hours/>24 hours)	27	18/9 (67/33)	18	10/8 (56/44)	0.66
Previously applied treatment (yes/no)	27	15/12 (56/44)	18	6/12 (33/67)	0.25
Rectal temperature, °C	27	38.7 (36.6-41.0)	18	38.05 (32.0-40.1)	0.25
Heart rate, min^{-1}	27	140 (56-200)	18	146 (58-220)	0.87
Pulse quality (strong/weak)	27	19/8 (67/33)	18	7/11 (39/61)	0.07
Respiratory rate (RR), min^{-1}	27	35 (16-108)	18	40.5 (20-120)	0.56
Mucous membrane colour (MMC) (normal, abnormal)	27	19/8 (67/33)	18	6/12 (33/67)	0.03
Capillary refill time (CRT) (<2 s; >2 s)	27	22/5 (81/19)	18	7/11 (39/61)	0.009
Skin elasticity (normal, decreased)	27	24/3 (89/11)	18	15/3 (83/17)	0.93
ATT score, points	27	4 (2-10)	18	8.5 (3-12)	0.0001
SACS score, points	27	18 (12-18)	18	15.5 (8-18)	0.0002
Number of affected areas (2/>2)	27	18/9 (67/33)	18	3/15 (17/83)	0.0001
Type of trauma (thoracic/abdominal/cerebral)	27	15/7/5 (56/30/14)	18	5/8/5 (28/44/28)	0.12
Presence of fracture (yes/no)	27	10/17 (37/63)	18	8/10 (44/56)	0.85

cont. Table 1.

Parameter	Survivors		Non-survivors		P-value
	n	Median (range) or ratio (%)	n	Median (range) or ratio (%)	
Laboratory variables					
Haemoglobin, g/L	27	85 (39/150)	18	107.5 (26/171)	0.08
Hematocrit (Hcr), %	27	23 (10/41)	18	29 (0.6-50)	0.7
Red blood cells (RBC), T/L	27	5.16 (2.33/6.48)	18	5.76 (1.37/7.89)	0.54
White blood cells (WBC), G/L	27	28.5 (4.2/43.8)	18	16.85 (4.6/25.3)	0.23
Platelets (PLT), G/L	27	194 (41/327)	18	149 (33/497)	0.88
Total protein (TP), g/L	27	66 (58/71)	18	61(55/68)	0.32
Albumin, g/L	27	36 (33/39)	18	30 (27/34)	0.36
Blood urea nitrogen (BUN), mmol/L	27	4.86 (2.22/13.77)	18	9.86 (3.38/22.2)	0.14
Creatinine, μmol/L	27	67.9 (39.7/262.6)	18	83.65 (48.9/109.8)	0.77
Alanine aminotransferase (ALT), U/L	27	102.96 (33.76/426)	18	130.33 (23/238)	0.69
Aspartate aminotransferase (AST), U/L	27	168.8 (64/748)	18	265.33 (45/728)	0.42

Table 2. Significant results of univariable logistic regression analysis showing individual predictors of death in dogs with multiple trauma (n=45)

Variable		n	OR	95% CI	P-value
Clinical parameters					
Core body temperature	Normal	21	–	–	–
	Increased	12	2.29	0.50-10.50	0.29
	Decreased	12	6.40	1.34-30.60	0.02
Pulse quality	Strong	26	–	–	–
	Weak	19	3.73	1.06-13.12	0.04
Mucous membrane color	Normal	25	–	–	–
	Abnormal	20	4.75	1.31-17.11	0.01
CRT	<2 sek	29	–	–	–
	>2 sek	16	6.91	1.78-26.85	0.0005
ATT score	<5 points	24	–	–	–
	>5 points	21	17.5	3.77-81.32	0.0003
SACS score	<17 points	24	–	–	–
	>17 points	21	0.05	0.001-0.28	0.0006
Number of affected areas	2	21	0.1	0.02-0.44	0.0022
	>2	24	–	–	–

Cut-off points as established by ROC curve analysis: for ATT score: >5 points (AUC=0.629); for SACS score >17 points (AUC=0.600).

The only three predictors of outcome retained by the multivariable logistic regression model in the present work were body ATT score, SACS score, and the number of affected areas (Table 3). The ROC curve analysis of the model showed that 88.89% of cases were correctly classified with AUC=0.921.

Table 3. Individual predictors of dead in dogs with multiple trauma (n=45) that have entered the multivariable logistic regression model

Variable	Coefficient	Standard error	OR (95% CI)	P-value
Constant: 0.6223				
ATT score >5 points	1.7074	0.9917	5.5147 (0.7895-38.5219)	0.085
SACS score >17 points	-2.7042	1.0464	0.0669 (0.0086-0.5204)	0.00976
Less than 2 affected regions	-1.9889	1.0378	0.1368 (0.0179-1.0462)	0.05531

Finally, based on the results a simple scoring system (Table 4) for the prediction of the outcome was composed. According to ROC curve analysis this scoring system classified correctly 94.83% of cases with AUC=0.924 (p=0.0001). In concordance with our scoring system, a total score <6 points predicted survival with sensitivity 100%, specificity 66.67%, and positive and negative predictive values of 66.7% and 100%, respectively (Table 5). Animals that received between 12 and 16 points will rather die than live; and those having 11 points are considered with a 50% chance to survive (sensitivity 83.33%, specificity 92.59%, positive and negative predictive values of 88.2% and 89.3%, respectively).

Table 4. Score system used for prediction of dead in polytraumatized dogs. Single predictive variables with p value <0.05 received 1 point; those with p<0.01 received 2 points; those with p<0.001 received 3 points; and all the parameters entering multivariable model received 5 points

Parameter	Points
Subnormal body temperature	1
Weak pulse	1
Abnormal MMC	2
CRT 2 s	3
ATT score 5	5
SACS score	5
Three or more affected body areas	5
	Total max. score - 22

Table 5. Test characteristics of score system for different cutoff points in the predicted probability of death

Criterion	Sensitivity	Specificity	+LR	-LR	+PV	-PV
0	100.00	0.00	1.00		40.0	
>6	100.00	66.67	3.00	0.00	66.7	100.0
>7	88.89	74.07	3.43	0.15	69.6	90.9
>10	83.33	81.48	4.50	0.20	75.0	88.0
>11*	83.33	92.59	11.25	0.18	88.2	89.3
>14	72.22	92.59	9.75	0.30	86.7	83.3
>16	66.67	96.30	18.00	0.35	92.3	81.2
>21	27.78	96.30	7.50	0.75	83.3	66.7
22	0.00	100.00		1.00		60.0

* 1-6 pts – 100% live; 7-10 pts – rather live than dead; 11 pts – 50% risk of death; 12-16 pts – rather dead than live

DISCUSSION

Multiple traumas are common life-threatening conditions in dogs and comprise about 36% (Kolata, 1980) to 72.3% (Simpson *et al*., 2009) of all trauma cases. Our canine patients sustaining multiple traumas were usually young to middle aged, and males predominated that was in concordance with other studies (Kolata and Johnston, 1975). These parameters however did not have any impact on survival, as did body weight and body condition. With less physiologic reserve older patients may not have been able to adequately compensate for traumatic hypoperfusion and organ dysfunction, thus the overall mortality rate could be overestimated (Schulman *et al*., 2002). Bochicchino *et al*. (2005) found out that increased age and preexisting diseases strongly influenced survival in critically ill trauma patients. The small percentage of geriatric patients in our cohort study decreased the probability of co-morbidities including heart disease, chronic renal or endocrine diseases, as well as the likelihood of death overestimation in polytraumatized patients.

Dogs classified as underweight at the time of diagnosing chronic kidney disease had a significantly shorter survival time compared to both moderate and overweight dogs (Parker and Freeman, 2011). Thus, a good body condition at the time of diagnosis was significantly associated with improved survival from chronic kidney disease as opposing to our results regarding trauma patients.

Vehicle trauma was the most common cause of multiple injuries in dogs but was not connected with the outcome. The overall mortality rate was significantly higher (40%) than that reported in other studies (12% - Kolata & Johnston, 1975; Stephens, 2009) because of multiple trauma cases selected in our investigation.

The cause of injury and its anatomic localization were both factors that influenced the outcome of trauma patients (Kolata, 1980). Our results showed that these parameters were not connected with the outcome, but the number of body areas affected had a critical role. This means that in polytraumatized dogs, stratification of injuries should be considered. Mortality rate increased as the number of dysfunctional organ systems increased in dogs with sepsis (Kenney *et al*., 2010). Survival was 46% in dogs with two affected organs.

As in other reports (Simpson, 2009) head injuries were associated with significant mortality. The modified Glasgow Coma Scale is a useful index of outcome prediction in dogs with head trauma (Platt *et al*., 2001). According to the same authors patients with head trauma alone have 50% probability of survival if their score is 8 points. Our patients suffered from polytrauma and their SACS score below 17 together with other parameters (such as subnormal body temperature, weak pulse, abnormal MMC, CRT >2 s, ATT score >5, three or more affected organs) were proved to be negative outcome predictors.

Similarly to our results body weight, vital signs, PCV, total plasma protein, BUN, glucose, lactate, acid-base status, and electrolytes did not differ between survivors and non-survivors with severe blunt trauma (Simpson *et al*., 2009). The most common features associated with poor outcome were head trauma, cranium fractures, or evidence of multiorgan failure, including ARDS, DIC, and cardiopulmonary arrest. Several different blood biochemical variables were identified as prognostic indicators in dogs following trauma such as ionized calcium concentrations (Holowaychuk and Monteith, 2011), plasma histamine levels (Ennis *et al*., 1990), and plasma beta-D-glucuronidase lysosomal enzyme activity (Chow *et al*., 2004). The purpose of our study was to determine which of the most easily and routinely measurable clinical and laboratory parameters had a prognostic value with regard to the outcome in polytraumatized dogs.

Evidence of hypoperfusion and hypovolemia (pale MMC and high CRT) were common in polytraumatized dogs and were also factors exerting a negative influence on survival. This is confirmed by the investigation of Ponce *et al*. (2009) who measured blood lactate levels as a marker of tissue hypoxia in dogs with multiple trauma. They concluded that lactate levels can be used as a predictor of mortality as all dogs with lactate levels over 4 mmol/kg died.

Scoring systems for veterinary trauma are limited, and only the animal trauma triage (ATT) scoring system for dogs and cats is statistically validated (Rockar, 1994). An index of disease severity called the improved survival prediction index (SPI2) has also been created for critically ill dogs, but it is not specific to the trauma patients and relies on the most severe values for the first 24 hours of admission (King *et al*., 2001). In human medicine, the injury severity score (ISS) and the new injury severity score (NISS) are used to predict survival in trauma patients. Both ISS and NISS predicted mortality with high accuracy (AUC=0.9), but they are prone to underscore the severity in trauma victims with multiple injuries (Husam and Strada, 2002).

We tried to perform a disease-independent scoring system based on the most frequently measured parameters with predictive power in order to obtain a widely applicable system. We used multivariable logistic regression analysis to select the most predictive variables. Disease-specific models were reported to have many disadvantages such as lack of applicability in stratifying patients groups with heterogeneous disease processes (Hayes *et al*., 2010) as with multiple trauma cases.

Our scoring system also had another advantage over the others in that all fatal outcomes in this survey occurred by natural deaths and not by euthanasia.

The addition of easily measurable cardiovascular variables to ATT score and SACS scores in our scoring system improved significantly the reliability of its outcome predictive properties in polytraumatized patients. Kevin *et al*. (2007) also concluded that early non-invasive haemodynamic monitoring is helpful in outcome prediction in patients with long-bone fractures and pelvic fractures. After the first 48 hours haemodynamic patterns were more influenced by fever, sepsis, wound complications and organ failures.

Model discrimination is assessed by the AUC. An AUC of 1.0 implies a perfect performance, whereas an AUC of 0.5 implies a model with no better discrimination than a coin flip (King, 2002). We considered that our scoring system was a good model for accurate differentiation between those animals that will live from those that will die based on the AUC = 0.924. In comparison, testing of SPI resulted in AUC of 0.723 and testing of SPI2 revealed an AUC of 0.773 (King *et al*., 2001). The ATT score assesses only the severity of injury whereas SACS assesses only the severity of head trauma. A combination of the two in conjunction with the most reliable clinical cardiovascular parameters give a modified trauma score system with higher predictive value in polytraumatized dogs.

In conclusion, subnormal body temperature, weak pulse, abnormal MMC, CRT >2 s, ATT score >5, SACS score <17, and three or more affected body areas all appeared to be reliable prognostic indicators for fatal outcome in

polytraumatized dogs. Our modified trauma score system classified correctly 94.83% of cases with AUC = 0.924 (p=0.0001). Total scores <6 points predicted survival with sensitivity 100%, specificity 66.67%, and positive and negative predictive values of 66.7% and 100%, respectively. Animals that received between 12 and 16 points would rather die than live; while those having 11 points are considered with a 50% chance to survive (sensitivity 83.33%, specificity 92.59%, positive and negative predictive values of 88.2% and 89.3%, respectively).

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PREDVIĐANJE ISHODA POLITRAUME KOD PASA

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SADRŽAJ

U ovoj retrospektivnoj studiji je obrađeno 45 pasa sa politraumom radi utvrđivanja kliničkih i laboratorijskih pokazatelja koji imaju prognostičku vrednost. Od ukupnog broja životinja, njih 27 je preživelo politraumu dok su ostale uginule, tako da su formirane dve grupe. Regresionom analizom su utvrđivani odnosi između znakova povrede, kliničkih i laboratorijskih parametara. Na osnovu vrednosti varijabli koje su imale najveći uticaj na mortalitet predložen je nov sistem za predviđanje ishoda politraume pasa.