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Clinical parameters at time of admission as prognostic indicators in cats presented for trauma to an emergency centre in New Zealand: a retrospective analysis

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Abstract

Objectives The aims of this study were to describe the clinical features of cats presented for trauma in a first-opinion and referral teaching hospital in New Zealand, and to determine the relationship between those features and outcome.

Methods The electronic medical records of cats presented for trauma to the Massey University Pet Emergency Centre between September 2013 and January 2019 were examined, from which the signalment, clinical parameters and patient outcomes were extracted. Cases were assigned an animal trauma triage score (ATT) and modified Glasgow coma scale score (mGCS). Variables were selected for inclusion in a logistic regression model to predict survival, and backward elimination was used to find the minimal significant model.

Results In total, 530 cats met the inclusion criteria. The cause of injury was not known in the majority of cases (38.0%). The most common location of injury was the hindlimbs/pelvis/tail ($n = 247$; 41%**[AQ: 1]**), and skin lacerations/abrasions were the most common specific injury. Multivariate analysis revealed altered mentation (odds ratio [OR] 0.31, $P = 0.029$), hypothermia (rectal temperature $<$37.8°C [$<$100.04°F]; OR 0.45, $P = 0.015$) and an ATT score $>$4 (OR 0.13, $P < 0.001$) to be statistically significantly associated with mortality.

Conclusion and relevance Altered mentation and hypothermia are easily measurable perfusion parameter abnormalities associated with mortality in cats presenting with trauma. ATT score appears to be an accurate prognostic indicator in cats presenting with trauma in New Zealand. These results highlight the importance of incorporating a hands-on triage examination in each cat that presents as an emergency after trauma.

Keywords: Hypothermia; level of consciousness; animal trauma triage score; modified Glasgow coma scale; triage

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Introduction

Trauma is a common cause for the presentation of cats to both primary care practices, and secondary and tertiary intensive care facilities.[1–3] In addition to the primary and secondary orthopaedic and soft-tissue injuries incurred, trauma can lead to systemic consequences such as systemic inflammatory response syndrome, coagulopathies and multiple organ dysfunction syndrome.[4–7] Although cats, dogs and people exhibit some similar pathophysiological changes secondary to trauma, cats may also exhibit unique species-specific changes such as bradycardia, hypotension and hypothermia during circulatory shock,[8] which might affect their outcomes.

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Previous epidemiological studies have tested for the environmental and husbandry factors that correlated with outcomes in cats presenting for trauma. Several studies found that younger age[2,9,10] and risk-taking behaviour[11–13] are associated with risk of trauma in cats. Having outdoor access,[14] residing at an urban rather than rural address,[12] male sex[10,15] and season[10,15] have also been reported to be associated with increased risk for trauma, although less consistently. While identifying these factors is important for owner education and veterinary preparedness, they have little value when assessing the individual trauma patient.

Effective triage is an integral part of emergency medicine in both human and veterinary settings,[16] and knowledge of prognostic indicators recorded at admission may alert the clinician to the most urgent problems to be managed. A previous study from the Veterinary Committee on Trauma (VetCOT) registry has validated the severity of illness scores, animal trauma triage (ATT) and modified Glasgow Coma Scale (mGCS), as predictors of outcome in a large population of cats (n = 711) presented with trauma to US, Canadian, UK and Australian veterinary trauma centres,[17] where cats are almost exclusively housed indoors.[18] In contrast, very few cats in New Zealand are housed exclusively indoors, and may be at a lower risk of falls from height, especially in the rural regions. Furthermore, compared with cats in the USA and Canada, cats in New Zealand lack potential predators, which account for a proportion of feline trauma in other studies.18 Therefore, we wished to study cats presenting for trauma that are from a population whose environmental risks differ from those previously published.

The aim of the present study was to identify specific demographic and admission parameters associated with the clinical outcome of cats presenting with traumatic injuries to a veterinary emergency centre in the Manawatu region of New Zealand. We aimed to determine whether the ATT and mGCS scores perform similarly to the predominantly northern hemisphere populations in previous studies.[17,19–21] We hypothesised that changes in admission perfusion parameters – defined as mentation, heart rate, pulse quality, capillary refill time and rectal temperature – would correlate with the outcomes.

Materials and methods

Data collection

The electronic medical records of the Massey University Veterinary Teaching Hospital (Manawatu, New Zealand) between September 2013 and January 2019 were reviewed. Records from cats were included if the cat was presented for a traumatic event or injury. Cat bite abscesses were classed as infectious and were excluded. Data extracted from each record consisted of breed, age, sex, weight, client's home address (categorised into rural or urban), injury location (not including minor skin lesions), skin lesion location (only including minor abrasions and partial thickness lacerations), cause of injury, perfusion parameters (mentation, heart rate, pulse quality, capillary refill time, rectal temperature), respiratory rate, evidence of head injury, whether surgery was performed, location of surgery (categorised into operating theatre or emergency room), duration of hospitalisation and outcome. Causes of injury were categorised into 'hit by car', 'cat fight', 'dog fight', 'crushed by object', 'unknown' or 'other'. The cause was defined either from direct observation by the owner, or, when the cause of injury was not definitively known, the most likely source of trauma was reported. Whenever reasonable speculation could not be made, the cause of injury was listed as 'unknown'. The ATT and mGCS scores were recorded for all cases.[17,22,23] Specific injuries, with a differentiation made between injury to the integument and injury to underlying tissues, are presented in Table 1. 'Evidence of head injury' was determined to be present when any of the following were apparent: facial fractures; dental fractures; globe fractures; ocular proptosis; traumatic uveitis; abnormal pupillary light reflexes and menace response; epistaxis; and auricular haemorrhage; or evidence of cerebrospinal fluid rhinorrhoea, otorrhea or otorhinorrhoea; as well as any mucosal and integument injuries to the head. Polytrauma was defined as clinically significant injury to more than one of defined body regions (injury locations). Minor skin lesions were recorded separately and not included as clinically significant in the definition of polytrauma. Outcome was defined at the point of discharge, referral or death, and was categorised into 'euthanasia', 'death – not due to euthanasia' and 'survival'. Prandial status was determined by the presence or absence of stomach content as seen on the subset of cats from which admission survey radiographs (within 6 h of admission) were taken.

Statistical analysis

The distributions of candidate continuous variables were assessed for normality using the Shapiro–Wilk test, and bar plots of ordinal categorical variables (eg, mGCS) were visually inspected for data distribution. The distribution of mGCS was highly skewed, and was condensed into a binary variable (mGCS 18 = 'normal'; mGCS <18 = 'abnormal'). In addition, a new binary categorical variable (LOC.2) was created from the mGCS that used only the 'level of consciousness' (LOC) scale ('normal' LOC = 6; 'altered' LOC <6 [Table 2]). χ^2 analysis was used to test the association between LOC and the presence of head injury. The ATT score data were not normally distributed and were condensed into ordinal categorical variables. There were no clear breaks to create categories or a priori reasons to justify any, so the score was condensed into a binary variable (ATT.02; '<5', '⩾5'). Both temperature and heart rate were highly skewed and were

Table 1 Specific injuries and regions of injury to the integument

Specific injuries	Defined regions of injury to integument
Head fracture/concussive injury	Head
Forelimb fracture/luxation	Neck
Hindlimb fracture/luxation	Forelimb
Pelvic fracture/luxation	Thorax
Spinal fracture/luxation	Abdomen
Forelimb other	Hindlimb, pelvis, tail
Hindlimb other	
Rib fracture	
Lung contusions	
Pneumothorax	
Diaphragmatic hernia	
Thorax other	
Abdominal herniation	
Abdominal other	
Tail fracture/luxation/other	
Pelvis soft tissue	
Spine soft tissue	

Table 2 Descriptions of terms used to qualify level of consciousness and mentation, and their respective allocations in the multivariate model

	Description	Allocation
Level of consciousness	Occasional periods of alertness and responsive to environment	6
	Depression or delirium, capable of responding to environment, but response may be inappropriate	<6
	Stupor, responsive to visual stimuli	
	Stupor, responsive to auditory stimuli	
	Stupor, responsive only to repeated noxious stimuli	
	Coma, unresponsive to repeated noxious stimuli	
Mentation	Bright alert and responsive	Normal
	Quiet alert and responsive	
	Normal	
	No abnormality	
	Depressed	Altered
	Dull	
	Obtunded	
	Listless	
	Unresponsive	
	Stuporous	
	Comatose	
	Abnormal	

condensed into categories. Temperature was categorised as hypothermic (<37.8°C [<100.04°F]), hyperthermic (>39.5°C [103.1°F]) and normothermic. The distribution of heart rate data best suited three categories (⩽140 beats/min [bpm], 141–200 bpm, >200 bpm). Respiratory rate data were categorised into quartiles, which equated to ⩽30 breaths/min, 31–44 breaths/min, 45–64 breaths/min and >64 breaths/min. Capillary refill time was condensed into a binary variable: 'normal' or 'prolonged'. Pulse quality was condensed into a binary variable ('strong' and 'not strong'). Hospital duration was condensed into <24 h, 1 day and >1 day. Finally, the large number of breeds were condensed into two categories ('domestic' and 'pure'), to form the variable 'breed.02'.

A primary aim was to produce a logistic regression model to predict the binary outcome variable ('dead' or 'alive'). In order to optimise the selection of variables for inclusion, variables that were considered to be indicators of perfusion or shock were evaluated for significant association with outcome using stepwise logistic regression. Significant variables in the 'shock model' were then carried forward to the full logistic regression model. Variables included in the 'shock model' were binary mGCS score, temperature, initial heart rate, pulse quality, respiratory rate and capillary refill time. In the majority of clinical records, a subjective assessment of mentation was made. Altered mentation was recorded if the patients met a least one criterion listed in Table 2. Separate models were constructed using either LOC (model 1), 'altered mentation' (model 2) or binary mGCS (model 3). Models were compared using Akaike's information criterion. Data analysis was performed using the statistical processing software R (version 3.6.0; R Foundation for Statistical Computing).

Results

Descriptive statistics

The records of 530 cats met the study criteria of trauma and were included and constituted 19.6% of feline emergency consultations in the study period. These included 278 (52.4%) male, 243 (45.8%) female and nine (1.7%) cats of unknown sex. Of these, 470 (88.7%) were domestic shorthairs/longhairs, 57 (10.7%) were purebred and three (0.6%) had no breed recorded. The cats' median age was 55 months (range <1 to 240) and median weight was 4 kg (range 0.1–7.98). The median duration of hospitalisation for patients that survived to discharge was 1 day, while for those that did not survive, mean duration was <1 day. From the 514 cats with a known address, 82 (16.0%) were classified as being from a rural and 432 (84.0%) from an urban area.

From the known causes of injury (n = 324), 'hit by a car' was most common (n = 172; 53%), followed by 'dog fight' (n = 54; 17%), 'cat fight' (n = 50; 15%), 'crushed by an object' (n = 23; 7%) and 'other' (n = 25; 8%). The most common injury location, not including minor skin lesions, was the hindlimbs/pelvis/tail (n = 247; 47.0%), which included fractures, luxations, and severe lacerations and soft-tissue trauma. The next most common regions were the thorax (n = 105; 19.8%) and head (n = 97; 18.3%). Fifty-one cats (14.5%)[AQ: 2] experienced polytrauma, of which 22 (43.1%) died. Of the 530 cats enrolled, 80 (15.1%) had an ATT score >4. A strong association existed between the presence of head injury, and an abnormal level of consciousness ($\chi^2 = 27.442$, degrees of freedom = 1, $P < 0.001$). In total, 110 cats did not survive, a mortality rate of 20.8% (95% confidence interval 17.5–24.4). Of those that did not survive, 101 (92.7%) were euthanased[AQ: 3]. Of those that survived, 286 (54.0%) were discharged to the care of their owners and 134 were referred internally or externally for further veterinary care (25.3%).[AQ: 4]

Prandial status did not seem to influence the occurrence of trauma, with 72 (46.8%) cats presenting in a preprandial, and 82 (53.2%) in a postprandial state. Furthermore, prandial status had no effect on survival and was not associated with injury severity (ATT score).

Initial selection of perfusion parameters

A univariate analysis examining the perfusion parameters listed previously was performed. In this analysis all parameters, except for heart rate, were found to be associated with survival. After backwards stepwise regression, only hypothermia (<37.8°C [<100.04°F]), altered mentation and a LOC <6 (from mGCS score) were significantly associated with mortality ($P < 0.05$), while pulse quality ('not strong') approached statistical significance ($P = 0.079$).

Multivariate analysis for parameters associated with outcome

Initial logistic regression models included the following variables: month, breed.02, age, sex, weight, rural/urban, polytrauma, ATT.02, temp.3, pulse quality and either LOC.2 (model 1), mGCS.2 (model 2) or altered mentation (model 3). After backward elimination, model 2 had the lowest Akaike's information criterion (301 vs 361–441), and included ATT.02, altered mentation and temperature (Table 3).

Table 3 Predictors of survival in 530 cats presented with trauma

Parameter	OR	SE	*Z* value	*P* value
ATT >4	0.130749	0.049036	−5.4247	<0.001
Altered mentation	0.308635	0.165691	−2.1898	0.029
Temperature <37.8°C (<100.04°F)	0.452105	0.14778	−2.4286	0.015

OR = odds ratio; ATT = animal trauma triage

Discussion

In the present study, trauma represented 19.6% of presenting complaints for cats admitted to the emergency service. Several previous studies have reported the incidence rate of trauma in cats admitted to emergency services, varying from 3.9% to 21%.[10,12,24–27] This variation is likely due to differences in emergency patient cohorts among settings, and also to study design. The high incidence of trauma in the present study could be explained by the outdoor status of New Zealand cats, meaning that they could simply be presented for trauma more frequently, compared to other emergency presentations.

Several previous studies have reported the mortality rate from trauma in cats admitted to first-opinion and referral settings, varying from 7.7% to 19.1%.[2,3,17,21,27–30] Two studies that evaluated cats with specific injuries – thoracic trauma necessitating surgery[31] and 'bottom-hung' window injury[32] – reported higher mortality rates (34.5% and 35%, respectively). One study reported that 74.5% of deaths in cats aged <12 months were due to traumatic injuries.[12] Similar to the abovementioned reports, mortality rates across studies vary as a result of differences in cohorts and settings, as well as study design. The mortality rate in the present study (20.8%) was at the higher end of this variation. Euthanasia was the main cause of death in this study (92.7%). However, the retrospective nature of this study did not allow us to discriminate between the causes for euthanasia. Therefore, financial concerns might have been a factor in the decision to euthanase. Indeed, a recent study from the VetCOT registry showed that, from an overall mortality rate of 17.2% in 6703 cats with trauma, fewer than half the deaths (8.1%) were due to spontaneous reasons or euthanasia owing to a grave prognosis, with the remainder being partially or fully related to financial concerns.[30] Economic euthanasia is common in veterinary emergency medicine,[33,34] and recording of the causes for euthanasia is needed to mitigate this bias.[30] Mortality in this study was associated with the severity of injury. However, increased severity of injury could be associated with more complications and therefore higher cost of intensive care. Moreover, patients with less severe injuries but still requiring surgical intervention have, in general, a higher cost of care than patients without surgical injuries. The intertwining of economic and prognostic causes for euthanasia is somewhat inevitable in veterinary medicine. Therefore, considering that financial concerns affect prognosis, it is perhaps just as important to develop stratification tools that incorporate costs in prognostication.

The present study found that hypothermia on admission (<37.8°C [<100.04°F]) was associated with mortality, similarly to previous studies in cats,[21,35] dogs[36] and people with trauma.[37,38] Whether hypothermia is a direct causal factor for death or is a marker for the severity of injury and circulatory derangement remains unknown.

In cats, circulatory shock often exhibits a decompensated 'phenotype', manifested with hypothermia, bradycardia and hypotension.[8] It is believed that the hypothermia is mediated by central stimulation of alpha (α)1- and α2-noradrenergic receptors in the hypothalamus.[39] A concurrent decrease in peripheral sympathetic tone results in peripheral vasodilation, which contributes further to hypothermia, as well as causing hypotension.[8,40,41] The reason for these seemingly different effects on central and peripheral adrenergic receptors in cats remains unknown. If the cause of shock is not reversed, inhibitory mechanoreceptors within the left ventricle are activated in response to the rapid contraction around an underfilled chamber, resulting in parasympathetic stimulation, which, paradoxically, leads to bradycardia. This vagally medicated bradycardia, known as the 'Bezold–Jarisch reflex', increases the duration of diastole, which increases ventricular filling during periods of severe volume depletion.[40,42,43] However, it is proposed to contribute to hypotension in cats with circulatory shock.[8] It is important to note that the majority of the research leading to these findings was performed on anaesthetised animals with experimental causes of hypovolaemia, and the true mechanism in cases of accidental trauma may not be the same.

Environmental hypothermia could be a contributing factor in the clinical presentation of cats with trauma, as many are outside when injured. Cats have a lower body volume to surface area ratio than dogs and humans, leaving them more prone to hypothermia due to environmental exposure.[44] Given their large home range,[45] a proportion of traumatised cats likely remain outside for a significant period of time, exacerbating the hypothermia further.

Another interpretation is that hypothermia could actually have a protective effect in the injured cat. Hypothermia leads to decreased metabolic rate and oxygen demand, and blunting of the inflammatory and immune responses,[8] allowing a focus of resources on recovery from injury. As described above, hypothermia in cats in circulatory shock seemingly results from complex pathophysiological responses, some of them of protective in nature. Further research is needed to investigate the effects of hypothermia in cats with naturally occurring trauma and optimal treatment regimens.

ATT score is a severity of illness score for dogs and cats with trauma, comprised of admission physical examination parameters only.[23] It was recently validated in a population of 711 traumatised cats from the VetCOT registry. It was found that the odds of mortality increased by 1.78 times with every 1 point increase in ATT score.[17] The present study showed similar results, as an ATT score >4 resulted in a significantly decreased likelihood of survival, although the distribution of scores in our data set precluded a precise quantitative analysis of the scale. These results corroborate findings from other previous studies in cats with 'all-cause trauma'[21] and specific causes of injury, namely high rise syndrome[20] and bite wounds.[19] Severity of illness scores could be used to aid owner decision-making.[20] However, score-based euthanasia is not appropriate in any clinical context as false positives can lead to unnecessary measures being taken.[46] Ultimately, prognostic indicators should be used with caution in clinical settings to avoid them becoming 'self-fulfilling prophesies'.[47]

The mGCS is a score adapted from human medicine, designed to determine the severity of neurological impairment.[22,48] The scale has been recently validated in a population of 711 traumatised cats from the VetCOT registry.[17] The present study showed that the mGCS was outperformed by the ATT score in predicting survival in cats with trauma. These findings corroborated the results of two previous studies.[17,21]

In the present study the model that included only the LOC component of the mGCS score provided a good fit. This is in contrast to the findings of Lapsley et al,[17] who found that the composite score was more accurate than its components in predicting mortality. In human research, a decreased LOC based on other specific scoring systems has been shown to be a negative predictive factor for survival in both traumatic[49–51] and atraumatic[52–54] conditions.

Often, the first vital sign assessed by the emergency clinician is alertness or LOC, and is generally subjective. In the present study, the subjective measurement of mentation as either 'alert' or 'not alert' provided a slightly more accurate prediction of mortality than the LOC component of the mGCS. This highlights that even a subjective assessment of mentation during the initial examination could provide useful prognostic information, without the need for a more complex definition, especially in the context of triage. However, given the retrospective nature of this study, transforming the wording of a specific LOC component from the mGCS score might have introduced inaccuracy in the results as opposed to recording the score at admission. While some cats had a trauma admission sheet available, others did not. Therefore, the validity of those statements needs to be corroborated in a prospective study.

It has been suggested that the mGCS may serve 'as a proxy variable for a systemic shock state in patients where motor function and level of consciousness are compromised by perfusion abnormalities'.[17] Cardiovascular shock in cats could lead to changes in LOC.[55] However, the present study also found a significant association between the decreased LOC component from the mGCS score and head trauma. Similarly, Lapsley et al found that only 9.3% of cats with abnormal mGCS score had no evidence of head injury.[17] Abnormalities in perfusion should be considered in all patients presenting with an abnormal mGCS score; however, the potential effects of overt or occult traumatic brain injury can interfere with interpretation.

The main limitation of this study is its retrospective nature. In many cases, trauma scoring was applied retrospectively by investigators based on written records, which could have affected data collection accuracy.

Conclusions

Cats with an increased ATT score, hypothermia and altered mentation on presentation following trauma are at greater risk of mortality (from spontaneous deaths or euthanasia). Given that all the significant predictors of survival require a physical examination to be performed, the present study reveals the importance of immediate basic triage and physical examination of all cats presenting for trauma. Moreover, this highlights the importance of stabilising the cardiovascular system before performing a neurological examination, especially when focusing on prognostication.

Conflict of interest The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethical approval The work described in this manuscript involved the use of non-experimental (owned or unowned) animals. Established internationally recognised high standards ('best practice') of veterinary clinical care for the individual patient were always followed and/or this work involved the use of cadavers. Ethical approval from a committee was therefore not specifically required for publication in *JFMS*. Although not required, where ethical approval was still obtained, it is stated in the manuscript.

Informed consent Informed consent (verbal or written) was obtained from the owner or legal custodian of all animal(s) described in this work (experimental or non-experimental animals, including cadavers) for all procedure(s) undertaken (prospective or retrospective studies). No animals or people are identifiable within this publication, and therefore additional informed consent for publication was not required.

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