Title: Thoracic dog bite wounds in cats: a retrospective study of 22 cases (2005–2015)

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Abstract

Objectives

Describe a series of cats suffering from thoracic bite wounds, in order to detail the clinical, radiographic, and surgical findings, and evaluate outcomes and factors associated with mortality.

Methods

Medical records of cats with thoracic dog bite wounds presenting to a single institution between 2005-2015 were retrospectively reviewed. Data relating to clinical presentation, wound depth and management, radiographic findings, surgical findings and mortality were collected. Wound depth was defined as: no external wound, superficial, deep or penetrating and wound management was defined as conservative, exploratory or thoracic exploration. Statistical analyses were performed using Fisher's Exact, Mann-Whitney U and Chi-Squared Test.

Results

Twenty-two cats were included, of which two were euthanased on presentation. In cats (21/22) where wound depth could be assessed, six had no external wounds, four had superficial wounds, three had deep wounds and eight suffered penetrating wounds. Sixteen cats also suffered wounds elsewhere, most commonly to the abdomen. Neither an abdominal wound nor abdominal surgery was associated with mortality. Pneumothorax was the most common radiographic finding (11/18). Individual radiographic lesions were not significantly associated with respiratory pattern, presence of pseudo-flail, need for thoracotomy or lung lobectomy, or survival. The presence of $\geqslant$3 radiographic lesions was associated with the presence of a penetrating wound ($p=0.025$) and with having thoracic exploration ($p=0.025$). Local exploration was performed in 7/20 cats, while 8/20 underwent thoracic exploration. Wound management type was not significantly associated with mortality. Overall mortality rate was 27%.

Conclusion and relevance

Presence of ⩾3 radiographic lesions should raise suspicion of penetrating injury and may be suggestive of injury requiring a greater level of intervention. The treating veterinarian should have a high index of suspicion for penetrating injury and be prepared in case thoracic exploratory surgery is necessary, particularly in the presence of pseudo-flail chest, pneumothorax or ⩾3 radiographic lesions.

Introduction

Dog bite wounds are commonly encountered in the small animal emergency setting and are reported to be the second most common traumatic presentation in cats.[1] The thorax is a commonly bitten region[1–5] and bites here have been associated with higher mortality rates.[2,4,6]

Bite wounds are unique because they cause a combination of crush, tear, avulsion and puncture injuries,[3,4] along with inoculation of bacteria.[7] Additionally, the external wound is often not representative of underlying injury. Two previous studies evaluating thoracic bite wounds (predominantly in dogs, although eight cats were included) found discrepancies between external wounds and underlying radiographic and surgical findings.[8,9] This is likely due to the high skin mobility and elasticity of the rib cage in dogs and cats, meaning that there can be significant damage to underlying structures with only minimal external damage.[2,4,8,9] The study by Scheepens et al reported either rib fractures (40/45), flail chest (35/45), pneumothorax (31/45) , muscle lacerations (44/45) or a combination of these in a majority of cases, despite 16 dogs having no evidence of skin perforation. Additionally, half of cases requiring lung lobectomy had no evidence of skin penetration.

To the author's knowledge, there have been a total of 13 cats with thoracic bite wounds described in the literature in the past 20 years. It is not possible to determine details of their injuries and treatment, as findings were summarised with dog populations.[6,8]

The aim of this study was to describe a series of thoracic bite wounds in cats, in order to detail the clinical-, radiographic- and surgical findings, and to evaluate outcomes and factors associated with mortality. We hypothesize that initial examination findings are not associated with radiographic and surgical findings, nor outcome.

Materials and methods

This study was approved by the Royal Veterinary College Ethics and Welfare Board. Electronic patient records of a single first-opinion emergency and referral veterinary centre (Queen Mother Hospital for Animals (QMHA), UK) were retrospectively searched for cases presented between March 2005–May 2015. Cats were included if they were confirmed to have suffered a dog bite to the thoracic area and if medical records were complete. Data relating to clinical examination, blood tests, bacteriology, radiographic lesions, surgical findings, management and outcome were recorded.

Clinical examination

Tachypnoea was defined as a respiratory rate >40 breaths per minute and dyspnoea was defined as an increase in respiratory effort or a requirement for oxygen supplementation as judged by the treating veterinary surgeon. Any paradoxical movement of part of the chest wall during respiration was interpreted as pseudoflail chest, unless radiographic findings confirmed true flail segment (⩾two fractures of at least two adjacent ribs).[10]

Radiographic findings

Specific radiographic lesions noted as present or absent in each case were: rib fracture, sternal fracture/luxation, pleural effusion, pulmonary contusions, diaphragmatic hernia, pneumothorax and pneumomediastinum.

Pleural effusion and pneumothorax were defined as presence of fluid or air within the pleural space, respectively. Areas of poorly marginated, increased soft tissue opacity in the lung were interpreted as pulmonary contusions.[11]

Surgical findings

In order to aid comparison with previous literature, wound depth of the thoracic lesion was retrospectively classified (in accordance with the descriptions by Cabon) as: no external wound, superficial (skin only), deep (involving subcutaneous tissue) or penetrating (communication between external thorax and pleural space).[8] In the case of multiple thoracic wounds, the case was classified according to the more severe lesion. The presence or absence of injury to other body areas was noted.

Likewise, wound management was retrospectively classified from evaluation of the surgery report (according to the description by Cabon) as: conservative (no surgical exploration), exploratory (local exploration) or thoracic exploration (entry into thoracic cavity) and details of the specific management of each case were documented.[8]

Surgical findings were recorded as per the classification of radiographic lesions. Pulmonary contusions were recoded as present if lung parenchyma was described in

the surgical record as contused, discoloured or containing areas of haemorrhage within the parenchyma.

Surgical treatment and subsequent care was at the discretion of the attending veterinary surgeon.

Complications/Post-operative progression

The primary care practices of any cases that had been transferred were contacted via telephone in order to try to establish outcome.

Where possible, cause of death was recorded. In cases where owners elected for euthanasia, the underlying cause was reviewed. Cases euthanased due to financial constraints were excluded from mortality calculations.

Statistical analysis

Data were assessed for normality using Kolmogorov-Smirnov test. Statistical analyses were performed using Fisher's Exact, Mann-Whitney U, Chi-Squared Test and Kruskal-Wallis Test. Normally and non-normally distributed data are reported as mean and standard deviation (SD), and median and interquartile range (IQR), respectively. Statistical tests were undertaken using a statistical software package (SPSS Statistics, version 24; IBM). *P* values <0.05 were considered significant.

Results

Descriptive

22 cats met the inclusion criteria, including two entire females, ten neutered females, four entire males and six neutered males. There were 20 Domestic Shorthair cats (DSH), one Abyssinian and one British Blue cat. Median age was 48 months (IQR 17-72 months) and mean bodyweight 4.35kg (SD 1.14 kg). Ten cases were presented as referrals, while twelve were initially presented to the institution's emergency first opinion service. Eight of these were subsequently referred for specialist management.

Clinical Examination

Only 4/22 cats were considered to have normal respiration on presentation, with 15/22 and 12/22 presenting with tachypnoea or dyspnoea, respectively, with nine cats presenting with both.

Assessment of thoracic wounds revealed that 6/22 cats had no external wounds. One cat with no externally visible wound was euthanased shortly after arrival and was excluded from further detailing of wound depth and management. Another cat, with a visible thoracic wound, was euthanased shortly after arrival, and it was not possible to comment further on wound depth in this case. Of the remaining 20 cases, 4/20 were deemed to have superficial wounds, 3/20 were deep while 8/20 were penetrating. Further details regarding each case can be found in Table 1.

A majority of cases (16/22) had wounds elsewhere, predominantly affecting the abdomen (11/22) and limbs (7/22). Pseudo-flail chest was present in 9/20 cases. Respiratory status was not significantly associated with the presence of pseudo-flail, wound depth, wound management, surgical findings or survival.

Radiographic findings

The two that cats were euthanased shortly after arrival did not undergo thoracic imaging and are excluded from further evaluation. Radiographs were performed in 18/20 cats. The reason for not performing radiographs was financial constraints in one case and unclear in the other. A subsequent CT scan was performed in a single case. In the case where a CT scan was performed, a rib fracture, pulmonary contusions and pleural effusion were diagnosed in addition to the pneumothorax noted on radiographs. The most common radiographic lesion was pneumothorax (11/18), followed by pulmonary contusions (7/18), pleural effusion, sternal fracture and rib fracture (6/18 cases each).

Individual radiographic lesions were not significantly associated with respiration, presence of pseudo-flail, need for thoracotomy or lung lobectomy, or survival. The presence of $\geqslant$3 radiographic lesions was, however significantly associated with the presence of a penetrating wound ($p=0.025$) as well as with undergoing thoracic exploration ($p=0.025$). Of cats that underwent thoracic exploration, 7/8 had $\geqslant$3 radiographic lesions. Of the remaining cats which underwent radiography and treatment, only 3/10 had $\geqslant$3 radiographic lesions. The presence of $\geqslant$3 radiographic lesions was not significantly associated with survival, nor length of hospitalisation. The presence of a sternal fracture was also significantly associated with having a thoracic exploration ($p=0.043$)

The presence of rib fractures was significantly associated with having a deep wound ($p=0.025$). There was otherwise no association between individual radiographic

lesions or grouped number of radiographic lesions and wound depth or wound management.

There was not a statistically significant association between presence of pneumothorax and pseudo-flail chest (p=0.05).

Clinical pathology

An in-house blood gas, electrolyte and metabolite panel was performed in 17/22 cats. Hyperlactataemia was present in 9/17 cases. Hyperlactataemia was not associated with respiratory status, radiographic findings, wound depth, wound management or survival.

Bacteriology was performed in 16/20 cats, of which six were positive, most commonly culturing *Staphylococcus* species (3/6) or *Escherichia Coli* (2/6).

All but one cat were treated with broad-spectrum antibiotic therapy, most commonly amoxycillin-clavulanate. Based on the culture results, the organisms cultured in 4/6 cats were susceptible to amoxycillin-clavulanate.

Of the isolates not sensitive to amoxycillin-clavulanate, one sample cultured a multi-resistant *Escherichia Coli* and a multi-resistant coliform.[12] Antimicrobials to which both organisms were susceptible were amikacin, polymyxin b and imipenem only. Culture from the other case isolated a coagulase negative *Staphylococcus* species as well as *Pseudomonas* species. The *Staphylococcus* species was sensitive to amoxycillin-clavulanate, whereas the *Pseudomonas* species was susceptible only to enrofloxacin or oxytetracycline.

Surgical management

Of cats managed for their bite wounds, 5/20 were initially treated conservatively, although 3/5 were transferred to their primary care practice for further management as necessary. The two cats that remained at the QMHA and were managed conservatively both survived to discharge. Local exploration was performed in 7/20 cats, while 8/20 underwent thoracic exploration, of which five and four cats survived, respectively (Figure 1). Wound management type was not significantly associated with mortality (conservative ($p=0.52$)/exploration ($p=0.99$)/thoracic exploration ($p=0.34$)) or length of hospitalisation ($p=0.357$). Neither an abdominal wound ($p=0.99$) nor abdominal surgery ($p=0.99$) was associated with mortality. The presence of a sternal fracture was significantly associated with thoracic exploration ($p=0.043$), as was the presence of a penetrating wound ($p=0.001$). There was not a statistically significant association between pseudo-flail chest and thoracic exploration ($p=0.05$).

Post-operative progression

Mean length of hospitalisation was 10 days (SD 6.3). In total, eleven cats survived to discharge and three cats were transferred to their primary care practice, prior to definitive treatment. One cat was lost to follow-up, while the other two survived. Of the two with follow-up information available, one did not require further management of thoracic injuries. It was not possible to determine treatment in the other case, although the patient was known to be alive five month following injury.

Two cats were euthanased shortly after presentation, due to financial constraints. These were excluded from mortality calculations. During hospitalisation, six cats died or were euthanased due to worsening of their condition, most commonly due

to sepsis/systemic inflammatory response syndrome (SIRS) (5/6 cases). Overall mortality rate was 27% (6/22 cases).

Discussion

This study describes the largest reported population of cats suffering from thoracic dog bite wounds. These cases can be challenging to manage given the potential for severe underlying pathology, in the absence of externally visible injuries or clinical signs, as evidenced by the lack of association between underlying injury and respiratory status or radiographic signs in this study.

Despite a majority of cases presenting with dyspnoea/tachypnoea, this was not associated with outcome, which is in agreement with previous studies.[8] Given the retrospective nature of this paper it was not possible to determine the influence of other factors, such as pain, on respiration. Of the 18 cats in which thoracic radiography was performed, all but one were found to have at least one radiographic lesion. Pneumothorax was diagnosed in a majority of cases, suggesting penetrating injury or lung lobe laceration, and potentially requiring further interventions. In contrast to findings by Cabon[8], who evaluated eight cats and 54 dogs suffering thoracic dog bite wounds, our study found a significant association between the presence of $\geqslant$3 radiographic lesions and a penetrating wound, as well as need for thoracic exploration. It is possible that more severe radiographic findings influenced decision making regarding the need for surgery, leading to bias in those undergoing thoracic exploration. Additionally, sternal fracture and rib fracture were associated with thoracic exploration and presence of a deep wound, respectively. Presence of these radiographic lesions are therefore likely to affect the course of

246 treatment and may also require additional intervention. These results suggest that
247 thoracic radiography should be performed in all cats suffering from thoracic dog bite
248 wounds, which is in accordance with previous recommendations in the literature.[8]

249 Of cats managed at the QMHA (excluding the two that were euthanased shortly
250 after presentation and three that were transferred elsewhere), 15/17 underwent
251 surgical exploration. Older literature advocated a conservative approach to
252 management of bite wounds,[3,4] while more recent publications recommend
253 exploratory surgery.[5,6,8,9,13,14] One study advocated thoracic exploration in any cases
254 found to have rib fracture, radiographic evidence of lung contusions, pneumothorax,
255 or severe subdermal trauma, which resulted in only one unnecessary thoracotomy.[9]
256 Application of these guidelines to our study population in which radiographs were
257 performed, would have resulted in exploratory thoracic surgery in 16/18 cases. In
258 actuality, eight of these 16 cases underwent exploratory thoracic surgery, four
259 underwent wound exploration, one was managed conservatively and three were
260 transferred to their primary care practice. Of the five cases that underwent wound
261 exploration only or were managed conservatively, that is to say, the cases that were
262 not managed according to the aforementioned recommendation, only one did not
263 survive to discharge. Our results suggest that thoracic exploratory surgery (i.e.
264 thoracotomy/sternotomy) may have been unnecessary in some of these cases.

265 Pseudo-flail chest was present in 9/20 cases in this study. Seven underwent thoracic
266 exploration and pseudo-flail repair, one was transferred to the primary care practice
267 and one underwent wound exploration, pseudo-flail repair and was found not to
268 have a penetrating injury. A retrospective evaluation of management of flail chest in

dogs and cats, caused by various traumatic events, did not reveal a significant difference in outcome between surgically and conservatively managed cases.[10] The previously mentioned study evaluating dogs suffering thoracic bite wounds revealed that 35% of dogs with flail chest required lung lobectomy.[9] As a result they also advocated surgical exploration in cases of flail- or pseudoflail-chest. Although only one case in our population required lung lobectomy the vast majority of cases with pseudo-flail (7/8) were found to have penetrating injuries, warranting exploration, debridement and lavage. The flail segment was surgically addressed in all eight cases. This would support the recommendation of surgical exploration in all cases of pseudo-flail.

Although no set protocol exists at the study institution, surgical exploration is advocated for a number of reasons. Bite wounds are inoculated with bacteria from the patient's skin and the attacking dog's mouth.[3,4] Additionally the resultant injury can cause ischemia and necrosis of surrounding tissue, leading to increased susceptibility to infection.[15,16] Publications evaluating bacteriology of dog bite wounds in a dog population reported positive culture results in 52-80% of cases, which is higher than our study.[7,17] In contrast to the aforementioned publications, at our institution intra-operative swabs are obtained following lavage, which may be associated with the lower rate of positive culture results in our study. The most commonly cultured bacteria in these studies included *Escherichia Coli*, *Staphylococcus*, *Streptococcus-*, *Enterococcus-* and *Pasteurella-* species, of which 85.4-100% were susceptible to amoxycillin-clavulanate. Although two culture results in the current study revealed organisms non-susceptible to amoxycillin-clavulanate, our results

suggest that this is an appropriate empirical choice, while being in-keeping with responsible antimicrobial stewardship.[18] Additionally, the leading cause of death in our population was due to sepsis/SIRS. For these reasons, debridement and removal of bacterial contamination is advocated in all bite wounds. An additional advantage of surgical intervention is that it allows underlying injury to be identified and addressed as necessary.

Interestingly, a recent publication evaluating cats surgically managed for thoracic trauma (of varying aetiology) found a significant difference in animal trauma triage (ATT) score of survivors versus non-survivors and an overall mortality rate of 13%.[19] Evaluation of ATT scores was not possible in our study, but could be considered in future investigations.

Mortality rates of 12.5-27% have been reported in dogs and cats suffering from dog bite wounds.[6,8,9] One study reported a mortality rate of 11% in dogs and 27% in cats and included patients that had suffered dog bite wounds to any area of the body. To the authors' knowledge, there are two studies specifically evaluating dog bite wounds to the thorax. One of these included only dogs and reported a mortality rate of 17.7% while the other reported an overall mortality rate of 15.4%.[8,9] The latter study included only eight cats, of which seven survived to discharge (equating to a feline mortality rate of 12.5%). Overall mortality rate in our study was 27%. This is within previously reported values in patients suffering from bite wounds and is higher than that reported for surgically managed feline thoracic trauma of varied aetiology. This could be reflective of the severity of bite injury versus other injury

and we also speculate that the smaller body size of cats could mean that they are susceptible to more severe injuries than dogs.

There are limitations to this study, predominantly concerning the retrospective nature and limited case number. Reliance on case records was necessary, including classification of wound depth as described by the treating veterinary surgeon. There is potential for inherent bias in the determination of wound depth in the conservatively managed cases, as these were presumed to be less severely affected, without definitive surgical assessment being carried out. Cases were managed by various veterinary surgeons, meaning potential variability between assessments and treatment. Some cases were transferred to their primary care practice, meaning further evaluation was not possible and long-term follow-up was not performed.

Conclusions

Thoracic bite wounds are challenging cases to manage as they are susceptible to injury of underlying structures, despite absence of externally evident injuries or clinical signs. Moreover, inoculation of bacteria and multifaceted tissue damage mean that these patients are at risk of developing wound infection with potentially fatal consequences. Presence of $\geqslant$3 radiographic lesions should raise suspicion of penetrating injury and may be suggestive of injury requiring a greater level of intervention. Although an association is reported, radiographic findings should not be relied upon solely for determination of severity of injury. Given the limitations of assessing wound severity based on clinical and radiographic findings, the authors advocate surgical exploration of all thoracic dog bite wounds in cats. The treating

veterinarian should have a high index of suspicion for penetrating injury and ought to be prepared in case extension to thoracic exploratory surgery is necessary.

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Conflict of Interest

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Figure 1: Flow chart illustrating case progression.

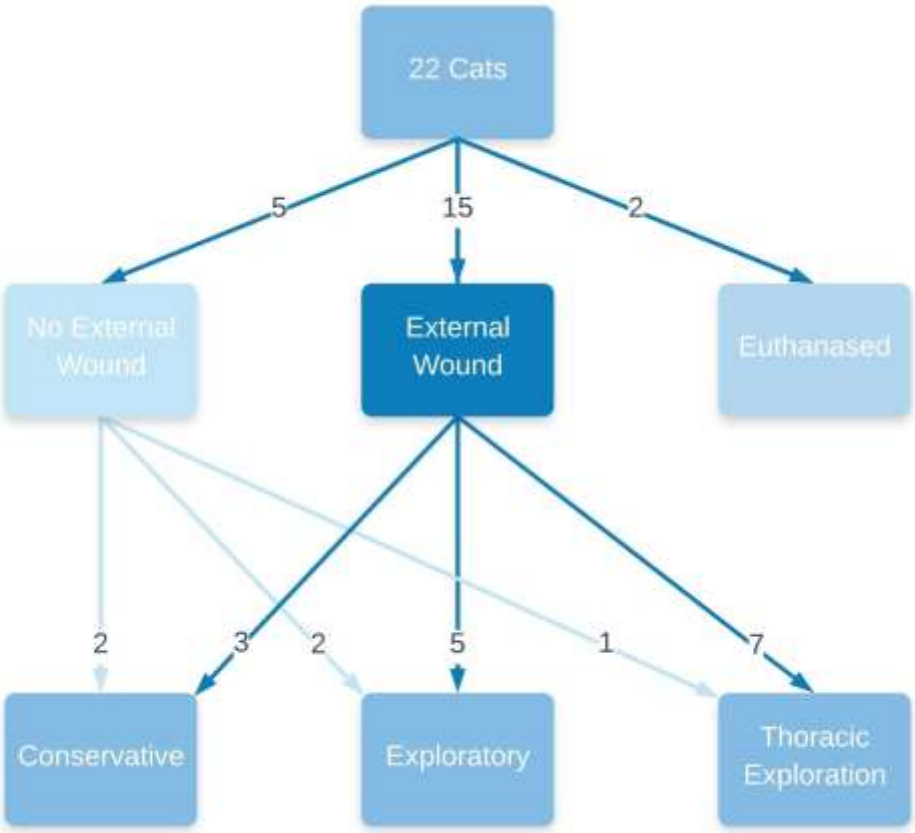

Table 1. Table detailing respiratory status, number of radiographic lesions, wound depth, wound management and progression of each case.

Case No	Abn. Resp	No. of Rad Lesions	Wound Depth	Wound management classification	Findings/treatment	Outcome
1	+	3	4	Thoracic exploration	No external wound. Pseudo-flail (intercostal muscle avulsion) and penetration into thorax. Thoracic wall repair.	Died (euthanased)
2	+	4	4	Thoracic exploration	Penetration into thorax. Pseudo-flail (thoracic wall defect) repair and lung lobectomy.	Survived
3	+	3	4	Thoracic exploration	Pseudo-flail with penetration into thorax. Diaphragmatic rupture and liver lobe rupture. Exploratory coeliotomy (diaphragmatic rupture repair) and thoracic wall repair.	Survived
4	–	n/a	2	Wound exploration	Local debridement.	Survived
5	+	2	3	Wound exploration	Local debridement of thoracic wound. Diaphragmatic rupture and abdominal wall defect. Exploratory coeliotomy (diaphragmatic rupture repair) and abdominal wall repair.	Died (euthanased)
6	+	0	1	Wound exploration	Local debridement.	Survived
7	+	1	1	Conservative	n/a	Survived
8	+	2	1	Wound exploration	Local debridement.	Survived
9	+	1	2	Wound exploration	Local debridement.	Died
10	+	2	2	Conservative	n/a	Transferred. Survived
11	+	3	4	Wound exploration	Local debridement and open wound management. Pyothorax with bilateral chest drain placement.	Survived
12	+	2	4	Thoracic exploration	Debridement and flushing of thoracic cavity and chest drain placement. Exploratory coeliotomy	Died (euthanased)

					(unremarkable) and open wound management of some wounds.	
13	–	2	3	Conservative	n/a	Transferred. No further treatment at primary care practice. Survived
14	–	n/a	2	Conservative	n/a	Survived
15	+	4	4	Thoracic exploration	Pseudo-flail (intercostal muscle avulsion,) lung contusions. Exploratory coeliotomy (abdominal wall repair) and pseudo-flail repair.	Survived
16	+	3	3	Wound exploration	Pseudo-flail repair (no penetration into thorax).	Survived
17	–	3	1	Thoracic exploration	Penetration into thorax. Pseudo-flail repair.	Survived
18	+	n/a	–	–	n/a	Died (euthanased)
19	+	3	4	Thoracic exploration	Intercostal muscle avulsion. Thoracic wall and rib reconstruction.	Died
20	+	n/a	1	–	n/a	Died (euthanased)
21	+	4	4	Thoracic exploration	Sternal luxation repair.	Died
22	+	3	1	Conservative	n/a	Transferred. Declined follow-up
Case No = case number. Abn Resp = abnormal respiration. No. of Rad Lesions = total number of radiographic lesions. Wound Depth 1 = no external wound 2= superficial, 3 = deep, 4 = penetrating.						

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