PAPER

Thoracic bite trauma in dogs: a comparison of clinical and radiological parameters with surgical results

OBJECTIVES: **Canine bite wounds may cause severe underlying tissue trauma even with no clinically evident puncture wounds. In order to assess the ability of pre-operative diagnostic parameters to predict the extent of internal damage inflicted by a thoracic bite wound, the clinical, radiological and surgical data of 45 dogs that sustained thoracic bite trauma were recorded.**

METHODS: **Clinical, radiographic and surgical parameters from 45 dogs of various breeds with thoracic bite trauma, were analysed ($P<0.05$). All dogs were treated according to a previously described protocol and had exploratory surgery including a thoracotomy.**

RESULTS: **Mainly small-breed dogs were traumatised. Clinical and radiological data were suggestive of internal trauma but not reliable as accurate indicators for internal lesions. Only radiological evidence of lung contusion was significantly associated with the presence of surgically confirmed lung contusion ($P=0.006$). Dogs with postoperative wound complications had a significantly higher risk of dying than those without complications ($P=0.04$).**

CLINICAL SIGNIFICANCE: **This study concludes that according to protocol an optimal management of thoracic bite wounds in small dogs includes surgical exploration of the wound and the thoracic cavity in the presence of flail or pseudo-flail chest, fractured ribs, radiological evidence of lung contusion, pneumothorax or any combination of these.**

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INTRODUCTION

Bite wounds are common in dogs. A study of canine emergency admissions reported an incidence of up to 15 per cent of all cases (Kolata and others 1974). In a retrospective study of 185 canine bite trauma cases, the thorax was found to be the most important region of injury (Shamir and others 2002). Subdermal tissues, muscles and internal organs are often injured without appreciable superficial skin defects due to a combination of shearing, tensile and compressive forces of a bite and the mobility of overlying skin (Davidson 1998a). Laceration of internal organs may lead to life-threatening situations (McKiernan and others 1984, Davidson 1998b, Fossum 2002, Shamir and others 2002). Thoracic involvement is suggested to significantly increase the mortality rate (McKiernan and others 1984, Davidson 1998a, Shamir and others 2002).

Several authors have advocated exploratory surgery of all thoracic bite wounds after clinical and radiological examination (McKiernan and others 1984, Shahar and others 1997, Holt and Griffin 2000, Shamir and others 2002). Others, however, have suggested a more conservative treatment (Cowell and Penwick 1989, Davidson 1998a). McKiernan and others (1984) evaluated clinical and radiological parameters in 11 dogs with thoracic bite trauma; subcutaneous emphysema, pulmonary infiltrates, pneumothorax and rib separation were the most common radiographic findings. The question whether all dogs with thoracic bite trauma should be surgically explored could not be answered because clinical and radiological findings were not correlated to the surgical outcome.

The aim of this study was to document clinical, radiological and surgical variables in dogs with thoracic bite trauma and to compare the clinical and radiological parameters with the findings at surgery in order to analyse whether these clinical and radiological parameters are associated with severe internal trauma, which may require surgical intervention.

MATERIALS AND METHODS

The medical records of 45 dogs with thoracic bite trauma referred to the Utrecht University Department of Clinical Sciences of Companion Animals (UUCCA) between January 1995 and January 2003 were reviewed. All dogs were managed according to the bite wound protocol of the UUCCA (Table 1) and underwent an exploration of the thorax. Information

Table 1. Management protocol for thoracic bite wounds at the UUCCA

- Emergency evaluation of the patient: airway, breathing and circulation protocol
  - Check for a clear airway passage and provide oxygen, intubate and ventilate if necessary
  - If pneumothorax is suspected, perform thoracocenthesis and routinely check breathing pattern. If pneumothorax persists, place a chest tube
  - Start iv infusion and adjust infusion rate to haemodynamic condition of the patient
  - Check neurological status
- Haematological, biochemical blood analysis
- Evaluation of bite wound(s); traumatised body surface are clipped and evaluated
- Cover open wounds with sterile bandage
- Thoracic radiographs if patient is stable; lateral and ventro-dorsal views
- Initial medical treatment for the patient
  - Prophylactic antibiotic treatment; 20 mg/kg amoxicillin-clavulanic acid three times a day iv
  - Preoperative pain medication: opiates and non-steroidal anti-inflammatory drug (the latter depending of haematological/biochemical blood values)
- Surgical exploration and debridement of all bite wounds within 24 hours
- Immediate thoracic exploration in patients with
  - Thoracic organs visible
  - Flail chest
  - Severe thoracic trauma including multiple rib fractures and pneumothorax
  - Visible deep penetrating trauma with possible visceral trauma
- Postoperative care at the emergency and critical care unit of the UUCCA

This management protocol is used in each thoracic bite wound patient in this consecutive order to facilitate a systematic and optimal treatment modality for each patient. The initial treatment is focussed on life-threatening problems and subsequently a profound wound assessment is performed. UUCCA; Utrecht University Department of Clinical Sciences of Companion Animals

was obtained from the medical records according to a standardised questionnaire and included signalment, clinical signs at time of initial examination, radiological results, intraoperative results, surgical management and postoperative data. The individual parameters analysed were scored binomially as present or absent.

Clinical parameters

The clinical parameters that were recorded were respiratory distress, presence of skin perforation, subcutaneous emphysema and flail chest or pseudo-flail chest. Respiratory distress was considered present if either dyspnoea or laboured tachypnoea was documented. Severe respiratory distress was defined as presence of cyanosis accompanying the tachypnoea. The emergency clinician recorded the presence or absence of skin perforation.

The wounds were classified pre-operatively as superficial when the dermis was not perforated and haematoma formations or tooth marks were present or perforative when the dermis was punctured or lacerated. Subcutaneous emphysema was documented when air was palpated in the subdermal tissues of the thoracic cavity. Flail chest was diagnosed by observing a paradoxical movement of a chest wall segment with multiple rib fractures, during respiration and by palpation. Pseudo-flail chest was defined as observing a paradoxical movement of a chest wall segment during respiration caused by a complete tear of the intercostal musculature with only one rib fracture or when no fractures were present at all.

Radiological findings

The specific radiological parameters that were documented were rib fractures, pneumothorax, pleural effusion, lung contusion and diaphragmatic hernia. A rib fracture was recorded as present when radiographic discontinuity of the cortex of a single or multiple ribs was observed. The presence of air or fluid in one or both pleural spaces resulted in the diagnosis of pneumothorax or pleural effusion, respectively. The radiological diagnosis of lung contusion was made when ill-defined, radiodense, patchy soft tissue opacities in the lung parenchyma were present. A diaphragmatic hernia was diagnosed radiographically when a discontinuation of the diaphragm was seen and abdominal organs were situated in the thoracic cavity.

Surgical findings

The specific surgical findings that were analysed were muscle laceration, lung contusion, lung lobectomy and diaphragmatic hernia. Surgical management was defined as an exploratory thoracotomy including debridement of the wound. Massive tissue trauma was present when disruption of normal anatomical structures and devitalised tissue were documented in the surgical report resulting in extensive wound debridement and reconstruction of the soft tissue structures.

Lung contusion was diagnosed if haematoma formation or a marked discoloration of lung parenchyma, sometimes accompanied with minor lacerations, were documented in the surgical report. The indication for lobectomy was based on the surgeon's opinion concerning the vitality of the lung parenchyma, in particular when a lung lobe laceration was present. A surgically confirmed diaphragmatic hernia was documented when a laceration of the diaphragm was observed during exploratory surgery.

In cases where multiple ribs were traumatised, stability of the thoracic wall was achieved by placing the ribs in a correct anatomical position and placing encircling synthetic monofilament absorbable sutures (polydioxanone, size USP 1 or 0) around consecutive pairs of adjacent ribs, starting with an intact rib cranial or caudal of the defect, respectively. This created a scaffolding for the overlying soft tissues. The remaining muscles and subcutaneous tissues were re-apposed with absorbable suture material, avoiding excessive tension. After surgery, an absorptive thoracic bandage was applied to decrease dead space, protect the chest tube and help stabilise the chest wall.

Postoperative assessment

The patients recovered at the intensive care unit at UUCCA. The postoperative data that were analysed were wound complications and mortality. Postoperatively, wound complications were recorded when clear, progressive signs of inflammation were present (redness, wound swelling, pain, dehiscence and purulent exudate). Postoperative death was considered related to the initial trauma if it occurred within 14 days after surgery.

Statistical evaluation

In order to determine whether an individual clinical or radiological variable was

associated to trauma of the lung parenchyma requiring lobectomy, the presence of each clinical or radiological parameter was compared to the intraoperative findings of lung contusion or the necessity to perform a lobectomy. Statistical evaluation was performed using the chi-squared test. Significance was determined at $P<0.05$ (SPSS version 9.0; SPSS, Chicago, IL, USA).

RESULTS

Signalment

All patients were small to middle-sized breed dogs (mean bodyweight 5·2 kg, range 3·0 to 10·4 kg) with a wide range of ages (mean age 5·1 years, range 4 months to 12 years). The Yorkshire terrier (12 of 45, 27 per cent), Maltese (10 of 45, 22 per cent) and Jack Russell terrier (9 of 45, 20 per cent) were the most common breeds represented. Of the 45 dogs, 37 (82 per cent) were male (97 per cent of them entire) and 8 (18 per cent) were female (75 per cent of them entire).

All defined clinical, radiological and surgical parameters are summarised in Table 2.

Clinical data

Fifty-three per cent of all cases (n=24) were recorded with all clinical parameters, documented in Table 2. In 36 per cent of the patients, the skin was not perforated and only bruising or tooth marks could be seen in the traumatised skin. A flail chest or pseudo-flail chest was diagnosed in 35 dogs, of which nine dogs had severe dyspnoea. Of the 35 dogs with a flail chest, 26 had a true flail chest segment and nine had a pseudo-flail chest. There was no statistically significant association between any of the recorded clinical parameters and surgically confirmed lung contusion, or the necessity to perform a lung lobectomy. Two dogs also had other clinical findings. One dog was lame in one front leg due to a scapula fracture, and one dog had a Schiff-Sherrington posture. However, the severe paresis of the hindlimbs and the rigid extension of the forelimbs gradually disappeared within five days after the initial trauma.

Table 2. Cross table of clinical, radiological, surgical and postoperative parameters

	Total	Sev resp stress	Perf	SC emph	Flail	Rib Fx	Rx pneu	Rx liq	Rx cont	Rx diap hr	S muscle	S cont	S lobect	S diaphr	W compl	Mort
Total	**45**	**11**	**29**	**45**	**35**	**40**	**31**	**10**	**30**	**1**	**44**	**25**	**12**	**3**	**5**	**9**
Sev Resp stress	**11**		8	11	9	11	8	4	9	0	11	8	4	0	0	2
Perf	**29**			29	24	26	21	6	20	1	28	16	6	3	3	6
SC emph	**45**				35	40	31	10	30	1	44	25	12	3	5	9
Flail	**35**					31	22	7	22	1	35	18	9	2	4	6
Rib Fx	**40**						25	10	25	1	39	21	10	1	4	8
Rx Pneu	**31**							9	23	1	30	18	8	3	3	6
Rx Liq	**10**								9	0	10	7	3	0	1	2
Rx Cont	**30**									1	29	**21***	9	2	3	8
Rx Diap hr	**1**										1	0	0	1	1	1
S Muscle	**44**											24	12	3	5	9
S Cont	**25**												12	0	2	5
S Lobect	**12**													0	1	2
S Diaphr	**3**														1	1
W Compl	**5**															**4***
Mort	**9**															

The numbers in the cross-table represent the number of canine patients who were recorded with both specific parameters
Sev resp stress Severe respiratory distress, Perf Perforating wound, SC emph subcutaneous emphysema, Flail flail/Pseudo-flail chest, Rib Fx Radiographic rib fracture, Rx pneu Radiographic pneumothorax, Rx liq Radiographic liquothorax, Rx cont Radiographic lung contusion, Rx diap hr Radiographic diaphragmatic hernia, S muscle Surgical muscle laceration, S cont Surgical lung contusion, S lobect Surgical lobectomy, S diap Surgical diaphragmatic hernia, W compl Wound complications, Mort Mortality
Radiographic lung contusion and surgical lung contusion, as for wound complications and mortality were significantly associated *$P<0.05$

Radiology

The most common radiographic signs were rib fractures (88 per cent), pneumothorax (69 per cent), pulmonary contusions (67 per cent) and pleural effusion (22 per cent) (Figs 1 and 2). Forty-two per cent of the patients had three or more of these radiological findings consistent with severe thoracic trauma. Five out of 12 patients that underwent lung lobectomy showed all former mentioned radiological findings, whereas three of them had only one radiographic abnormality (pneumothorax n=2, rib fracture n=1). The radiographical finding of pulmonary contusion was statistically significantly associated with the intraoperative presence of pulmonary contusion (P=0·006), but not with the necessity to perform a lung lobectomy. There was no statistical significant association between any of the other radiographic findings and the presence lung contusion or lung lobectomy. Other radiological findings included a scapula fracture in one dog, a pneumomediastinum in two dogs, a traumatic lung bulla (for example, a clearly defined lucent area within contused lung parenchyma) in one dog and a subluxation of the thoracic vertebrae at T12 and T13 in one dog. This dog was the one that was presented with a Schiff-Sherrington posture.

Surgical data

Exploration of the bite wounds documented massive subcutaneous trauma in all but one patient. This dog had a perforative skin wound with only minor subdermal trauma and no flail chest, but had surgically confirmed lung contusion that did not need surgical intervention. In all cases except this former one, the intercostal musculature was traumatised. Evaluation and debridement of the intercostals musculature resulted in an open thorax in almost all cases. If the thoracic cavity was still not opened by this procedure the pleura was incised and an exploratory thoracotomy was performed. Nine out of 16 patients that did not have any perforation of the skin had a flail chest or pseudo-flail chest and massive subcutaneous tissue damage and muscle lacerations at exploratory surgery.

Lung lobe contusion was surgically confirmed in 25 dogs, six of which had non-perforating wounds and one dog had only one fractured rib but no radiological signs indicating visceral trauma. This dog needed a lung lobectomy because of the parenchymal damage present. In total, lung lobectomy was performed in 12 dogs. Eight of these had a true flail chest and one a pseudo-flail chest. In only three of these cases did severe dyspnoea accompany the flail chest.

Besides pulmonary trauma, diaphragmatic lesions were documented at surgery in three dogs. In only one of these dogs, abdominal organs were actually in the thoracic cavity. This was the patient in which the diaphragmatic hernia was diagnosed at the time of radiographic examination. The other two patients had a 2 to 3 cm laceration of the diaphragm without herniation of abdominal organs. Other miscellaneous findings included a laceration of the main right bronchus requiring a lobectomy of the right cranial lung lobe, a laceration of the pericardium and a haematoma in the cranial mediastium. The latter two did not need surgical intervention.

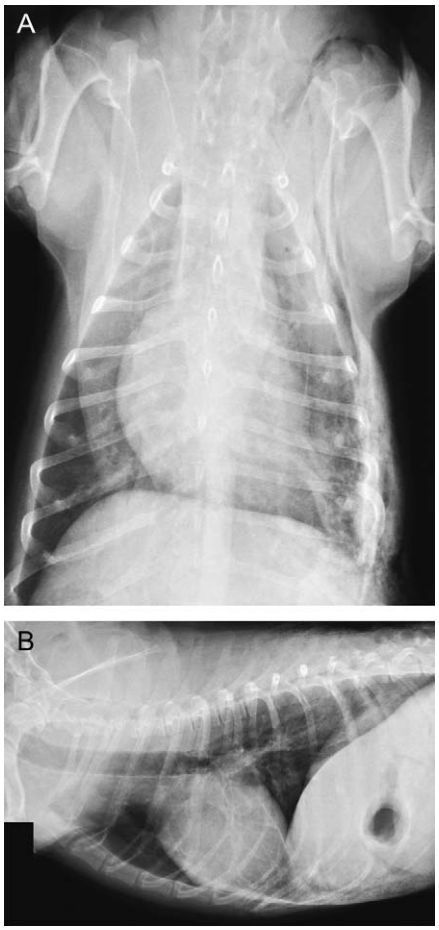

FIG 1. (A) Dorsoventral and (B) lateral radiographs of a patient with thoracic bite wounds. The radiographs reveal massive left-sided subcutaneous emphysema and fractures of the eighth and ninth ribs. Pleural fluid density (presumably haemorrhage) and an alveolar infiltrate of the periphery of the left caudal lung lobe (presumably lung contusion) are present at this site (courtesy of the Division of Diagnostic Imaging, Faculty of Veterinary Medicine, Utrecht University)

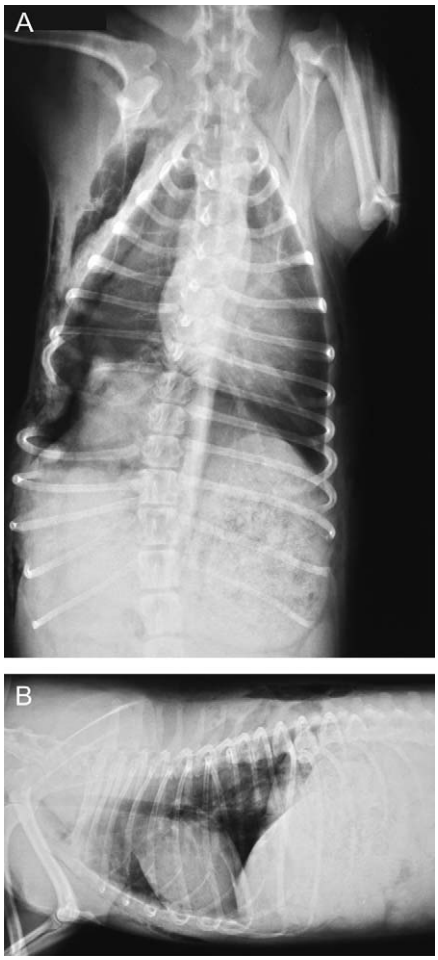

FIG 2. (A) Dorsoventral and (B) lateral radiographs of a patient with a severe traumatised thorax caused by a bite wound. Massive right-sided subcutaneous emphysema, fracture with severe dislocation of the eighth rib and dislocations of ribs nine to 12 are visible. Furthermore, a right-sided pneumothorax can be seen, as well as an increased opacity of the lung parenchyma of the right caudal lung lobe, which is compatible with lung contusion (courtesy of the Division of Diagnostic Imaging, Faculty of Veterinary Medicine, Utrecht University)

Postoperative data

No dogs died during surgery or during the recovery from anaesthesia. Seven dogs died or were euthanased during hospitalisation

(mean 2·9 days, range 1 to 6 days). Post-mortem examination was permitted in only one dog. This patient had been showing signs of progressive anaemia and thrombocytopenia and prolonged clotting times consistent with disseminated intravascular coagulation.

A perforated gastric ulcer was found upon post-mortem examination. Two dogs died at home, one of which was euthanased after a second bite trauma incident, 13 days after the initial bite wound. This dog was excluded from the mortality analysis, because death was not caused by the initial disease. The other dog died at home, 10 days after surgery. Post-mortem examination was not performed. Postoperative wound complications developed in five dogs; four of these died within six days after surgery. In two of the dogs with a wound complication a bacterial culture was performed. In one dog *Pseudomonas* was cultured and the other dog had a wound infection caused by *Escherichia coli*.

There was a statistically significant association between postoperative wound complication and mortality (P=0·004). Neither wound complication nor mortality was significantly associated to any of the other clinical, radiological or surgical variables.

DISCUSSION

All traumatised animals were small- to medium-breed dogs. Shamir and others (2002) showed that this particular group of dogs had a higher risk of being bitten and is likely to sustain more severe trauma resulting in a higher mortality rate when the thorax or abdomen is involved. The massive trauma to the subdermal tissues, the high numbers of flail chests and lung contusions and the mortality rate of 18 per cent found in the study reported here, corresponds to their findings.

Surgical exploration of the bite wound, including thoracotomy, has therefore been advocated in more severely traumatised patients to optimally assess and treat the damage (McKiernan and others 1984, Shahar and others 1997, Holt and Griffin 2000, Shamir and others 2002). However, the necessity for surgery in bite trauma cases has also been debated, as other studies favour conservative therapy (Cowell and Penwick 1989, Davidson 1998a,b). One of the reasons to perform an exploratory surgery is that not all internal visceral lesions are associated with radiographic signs of pneumothorax or pleural effusion (Holt and Griffin 2000). The study reported here confirms this suggestion because there was no statistically significant association of any of the clinical or radiographic parameters with the thoracic trauma documented during surgery. Therefore, it is not possible to predict if internal thoracic trauma is present without doing an exploratory surgery.

In the UUCCA all thoracic bite wound patients are surgically explored according to a standardised bite wound protocol (Table 1), including a thoracotomy. This assures the uniformity of the variables for evaluation, in contrast to other studies (McKiernan and others 1984, Cowell and Penwick 1989, Shamir and others 2002). Treating patients according to this protocol implied that no patients were treated conservatively, therefore no control group was available for comparison. A double-blind case controlled study to answer the questions as to whether exploratory surgery is warranted in all thoracic bite trauma cases would be the optimal setting, however this would be difficult to perform and certainly cause ethical dilemmas for the treating veterinarian. The use of a thoracic bite wound protocol requiring a thoracotomy for all patients is justified at the UUCCA because of the relative seriousness of lesions found in the dogs referred to this institution, as reflected in the surgical findings of this study.

Surgical exploration of bite wounds is generally accepted as the appropriate management in order to debride devitalised tissue and reduce the degree of contamination (Davidson 1998a,b, Holt and Griffin 2000). During exploration, severe subdermal trauma was found in 44 out of 45 dogs, even when perforative skin lesions were not present. This finding can be attributed to the unique characteristics of a canine bite in combination with the elasticity of the canine skin, inflicting minor skin puncture wounds with extensive underlying subcutaneous trauma and intercostal muscle injury below the skin surface (Cowell and Penwick 1989, Davidson 1998a). In dogs with disruption of the intercostal musculature, superficial wound exploration automatically results in opening the thoracic cavity. Thoracotomy in these cases is, therefore, only an extension of routine exploration of the bite wound.

Although 50 per cent of the patients had multiple clinical or radiological signs suggestive of internal trauma, none of the parameters was sufficient to determine if surgery was necessary. Even dogs with non-perforating skin wounds or mild dyspnoea may have severe injury to internal tissue necessitating a lobectomy. Although diagnostic imaging is warranted in all thoracic bite wound cases, imaging techniques will not always provide a complete inventory of the visceral damage, as lung lobectomy was necessary in a case where only a rib fracture was present, and herniorraphy of the diaphragm was indicated in three cases. Rib fractures, lung contusion or a pneumothorax were seen in most cases where a lobectomy was indicated. However, a combination of all these parameters was only documented in five patients. Unfortunately, no radiological parameter was significantly associated with damage to lung parenchyma requiring lung lobectomy. This means that without surgical exploration severe internal trauma can be missed and large areas of devitalised muscle, fractured ribs, pneumothorax, haemothorax and internal organ damage may then be left untreated (McKiernan and others 1984, Shahar and others 1997, Holt and Griffin 2000). Therefore, the data presented suggest that in the presence of either fractured ribs, radiological evidence of lung contusion, pneumothorax, or any combination of these, surgical exploration of the bite wound should be extended into the thoracic cavity, especially in cases where massive subdermal trauma is found. Using these guidelines, only one dog in this study, which featured minor subdermal trauma combined with radiological evidence of lung contusion, would have undergone an unnecessary thoracotomy.

Ventilation is compromised when multiple rib fractures result in a flail chest. However, not all dogs were severely dyspnoeic and needed immediate stabilisation. This finding was documented in a study where no significant difference in outcome

was observed between surgically stabilised and unstabilised flail chests (Olsen and others 2002). In the study reported here, rib fractures and pulmonary contusions were seen in more than 50 per cent of the patients with a flail chest. This resulted in a lobectomy in 35 per cent of the dogs. This is in accordance with the human literature in which a flail chest is an important marker for high kinetic energy absorption, associated with pulmonary contusion, pneumothorax and haemothorax (Ciraulo and others 1994).

Another reason for surgical exploration in dogs with flail chest is the fact that flail segments are the result of multiple rib fractures, which in their turn can cause damage to the lung parenchyma by puncturing it. In some cases only a single rib was fractured or no fractures were present at all; however, a flail segment was recognised. Due to massive intercostal muscle damage the rigid thoracic wall is damaged, resulting in a local non-rigid segment that will be displaced during respiration. Therefore, even in cases where a pseudo-flail chest is diagnosed, lungs can be damaged extensively warranting a lung lobectomy, as is documented in this study. The authors strongly recommend surgical exploration in bite trauma cases with a flail or pseudo-flail chest.

All bite wounds should be considered contaminated and, if left untreated, may result in infection (Cowell and Penwick 1989, Davidson 1998b). The study of Holt and Griffin (2001) documented that severe bite wounds have a high rate of bacterial contamination at presentation. The use of a proper surgical technique, radical debridement of devitalised tissue, wound lavage, drainage and bandaging is warranted in order to reduce the risk of wound infection (Davidson 1998b).

Although antibiotic therapy remains controversial and no single antibiotic is effective against all bacteria cultured in a bite wound (Shahar and others 1997), amoxicillin clavulanate potassium has been used successfully as initial prophylactic therapy (Lewis and Stiles 1995). All the patients in the current study were treated with a broad-spectrum antibiotics (for example, amoxicillin combined with clavulanic acid) to reduce the risk of bacterial infection. As mortality was significantly associated to the wound complication rate, a combination of medical management and thorough wound debridement and drainage is advisable to reduce the mortality rate in patients with thoracic bite wounds. Postoperative wound complications occurred in five out of 45 dogs in this study (11 per cent). This is comparable to the results of a study of postsurgical wound infections in contaminated wounds (Brown and others 1997). If recurrence of infection is diagnosed, renewed wound debridement and medical management based on bacterial culture and sensitivity is recommended.

The mortality rate (8 of 45) reported in our study is similar to previously documented mortality rates after surgical intervention of thoracic bite trauma (McKiernan and others 1984, Shamir and others 2002). This is in contrast to the mortality rate presented by Cowell and Penwick (1989), who reported a 100 per cent death rate after thoracotomy. Exploratory thoracotomy did not significantly alter the prognosis in a study by Shamir and others (2002); however, this was not based on statistical analysis comparing dogs that underwent thoracotomy and dogs that did not. Thoracotomy was thus recommended in all severe cases of thoracic bite trauma.

Conclusions

The study reported here suggests that in the presence of either flail or pseudo-flail chest, fractured ribs, radiological evidence of lung contusion, pneumothorax, or any combination of these, surgical exploration of the bite wound should be extended into the thoracic cavity, especially in cases were massive subdermal trauma is found. Benefits of surgery in these patients include an optimal assessment and management of all thoracic injuries and reduction of the risk of wound complications resulting in a lower mortality rate.

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