Median sternotomy and ventral stabilisation using pins and polymethylmethacrylate for a comminuted T5 vertebral fracture in a Miniature Schnauzer

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Keywords
Thoracic spine, vertebral fracture, ventral stabilisation, thoracotomy, bite wounds

Summary
A 2.9 kg Miniature Schnauzer was referred to our clinic, the Emergency & Critical Care Medicine Service at the Michigan State University Veterinary Teaching Hospital, following a dog fight. Physical examination findings upon admission included multiple thoracic wounds, absence of hindlimb deep pain, and marked Schiff-Sherington syndrome. Computed tomography imaging revealed thoracic wall penetration and a comminuted T5 vertebral fracture. Thoracic exploration and thoracic wall repair were performed through a median sternotomy. The vertebral fracture was exposed and stabilised intra-thoracically through the same approach using pins and polymethylmethacrylate. The pins were placed percutaneously into the vertebral bodies of the adjacent vertebrae. Recovery was uncomplicated and fracture healing was documented eight weeks post-operatively. Spinal trauma secondary to dog fights is relatively common. The presence of concurrent penetrating thoracic injury negatively affects prognosis and necessitates thoracic exploration as soon as feasible. The approach should allow complete thoracic exploration to repair parietal and visceral damage, thus indicating the need for median sternotomy rather than an intercostal approach. The present case report suggested that median sternotomy can be used to safely apply stabilisation devices for the treatment of concurrent spinal trauma. Direct visualisation of the vertebral bodies permitted optimal implant anchorange as compared to potentially more hazardous techniques such as dorsal pinning.

Case report
A one-year-old, 2.9 kg, neutered male Miniature Schnauzer was referred to the Emergency & Critical Care Medicine Service (ECCM) at the Michigan State University Veterinary Teaching Hospital for evaluation of bite wounds resulting from a dog fight with a German Shepherd. Initially, the dog had been presented to a local veterinary clinic where supportive care, including varying severity. In many instances, deeper structures including the musculoskeletal system, thoracic and abdominal cavities and their viscera may also be damaged. In a review of 196 dogs and cats which had suffered bite wounds, the thorax and the back were the most common body areas injured in small dogs (44% and 37% respectively) (2). Spinal trauma has been reported to occur in 3.8% to 14% of dogs and cats evaluated for bite wounds (3–7).

Treatment recommendations for patients with bite wounds include debridement of all wounds followed by primary closure, delayed primary closure, or second intention healing. In addition, surgical exploration of the thoracic or abdominal cavities is warranted if clinical signs or diagnostic information suggest thoracic or abdominal involvement (8–11). Guidelines for surgical intervention of spinal trauma integrate the location of the lesion, the severity and progression of any neurological deficits, and the degree of instability associated with the spinal lesion (4, 6, 12–17).

The purpose of this case report was to describe the management and outcome of a dog that was presented with bite wounds penetrating the thoracic cavity, a thoracic vertebral fracture, and profound pelvic limb neurological deficits. Thoracic exploration and ventral vertebral stabilisation were performed surgically in a single stage procedure using a median sternotomy approach.
crystalloid fluid therapy and buprenorphine, was administered. On presentation to the ECCM, the dog showed signs of severe depression, was in lateral recumbency, and displayed signs of extreme pain. Preliminary physical examination findings included pale mucous membranes, increased capillary refill time (3 seconds), hypothermia (36.8 °C), tachycardia (160 bpm), ta-chynpne (50 rpm), and dyspnoea. Indirect arterial blood pressure was 90 mmHg. Packed cell volume and total solids were 32% and 3.6 g/dL, respectively. Venous blood gas analysis revealed a metabolic lactic acidosis [pH 7.27 (7.38–7.45); lactate 3.5 mmol/L (0.3–3.2 mmol/L)]. Initial medical treatment following examination included oxygen supplementation (40% O₂ in oxygen cage), crystalloid administration (60 ml/kg bolus once followed by 10 ml/kg/hr), intravenous (IV) antibiotic medication (ampicillin sodium, 22 mg/kg), and opioids (fentanyl citrate, 3–5 µgr/kg/hr). Neurological examination revealed mentation and cranial nerve function to be within normal limits. The dog was non-ambulatory and exhibited a Schiff Sherrington posture. Deep pain perception was interpreted as absent in both pelvic limbs; however, the administration of buprenorphine two hours prior to presentation may have affected this finding. Restriction of manipulation was implemented using a rigid backboard and careful handling. Multiple puncture wounds were present over the lower cervical and thoracic regions, and were associated with severe subcutaneous emphysema and mild haemorrhage. The wounds were clipped, cleaned, and covered with sterile dressings.

Once the dog was haemodynamically stable, thoracic radiographs were obtained. Lateral views revealed the presence of extensive subcutaneous emphysema, mild pneumothorax, and soft tissue opacities at the periphery of the right lung lobes consistent with lung lobe atelectasis or pleural effusion (Fig. 1A). The length of the fifth thoracic vertebra (T5) was reduced when compared with the adjacent vertebral length. There was a fracture involving the body of T5 associated with narrowing of the spinal canal (Fig. 1A, B). After carefully sliding the dog into a foam V-shaped positioning device, a ventrodorsal view of the thorax was taken (Fig. 1C). Marked subcutaneous emphysema along the right thoracic wall was closely associated with an increased width of the fourth and sixth intercostal spaces. Mild pneumothorax and pulmonary atelectasis or pleural effusion were also confirmed on this projection. The T5 vertebral body fracture could also be seen on the ventrodorsal projection; however, complete evaluation of the fracture pattern could not be achieved using plain radiography. Thoracic spine computed tomography (CT) was then performed with the patient maintained under general anaesthesia. Two-dimensional reconstruction in the transverse and sagittal planes revealed the presence of a comminuted T5 body fracture, ventral displacement of T5 dorsal lamina and a T4-T5 subluxation (Fig. 2A-C). Three-dimensional reconstruction of the CT images using a software programme demonstrated compromise of the three compartments of T5 (Fig. 2D-F). Therefore, significant vertebral instability was expected at the fracture site (7). The diagnosis of penetrating chest wounds and unstable vertebral fracture supported the decision to proceed with thoracic exploration and vertebral stabilisation.

Following routine preparation and draping for aseptic surgery, a standard cranial median sternotomy was performed and extended to the caudal-most sternebra, thus preserving the xiphoid cartilage. Upon exploration of the thoracic cavity, all lung lobes were found intact with minimal contusions, and there was not any evidence of traumatic penetration of the lung parenchyma. At the level of the fourth and sixth right intercostal spaces, the thoracic wall musculature had full thickness lacerations which communicated with the skin lacerations. Following extensive lavage with warm saline, the thoracic wall defects were
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To close comminution with 2.0 metric polydioxanone circumcostal cruciate sutures placed from the inside of the thoracic cavity. After completion of the thoracic wall repair, a ventral intrathoracic approach to the fractured T5 vertebra was performed through the median sternotomy. The heart was gently retracted towards the right hemithorax, and the left cranial lung lobe was packed off caudally using a moist laparotomy sponge. A periosteal elevator was used to elevate the left ventrolateral aspect of the longus colli muscle from the fourth, fifth and sixth thoracic vertebral bodies. The exposure obtained of the comminuted T5 fracture (Fig. 3A) confirmed the feasibility of intrathoracic fracture stabilisation. A 25-gauge hypodermic needle was inserted into the intervertebral discs from T3/4 to T6/7 in order to determine the length of the intervening vertebral bodies. Four positive profile stainless steel pins and bone cement were used for vertebral body stabilisation. Two 1.5 mm pins were placed in the vertebral body of T4, and one 1.5 mm and one 1.2 mm pins were placed in the vertebral body of T6. The pins were inserted percutaneously through the left fourth or sixth intercostal spaces, directed across the left dorsal pleural space, and anchored into the vertebral bodies of T4 or T6 under direct intrathoracic visualisation (Fig. 3B). This percutaneous insertion method required the placement of the pins through the left dorsal-most aspect of the sterile field. Care was taken to avoid the neurovascular bundles at the caudal aspect of each rib. Following appropriate pin insertions, each pin was cut 1 cm from the vertebral body to allow anchorage in the bone cement and the transected end of each pin was pulled out through its skin insertion site. A self-retaining lamina spreader was secured between the two innermost pins adjacent to the vertebral bodies, and was used to distract the collapsed T5 vertebral body. Polymethylmethacrylate (PMMA) bone cement was prepared and mixed until a soft paste was obtained. The PMMA was then moulded around the pins and distraction was maintained until completion of the curing process. Saline lavage was used to minimise thermal injury to the surrounding tissue during PMMA polymerisation. The spreader was removed and the construct was assessed for stability, and to ensure the absence of sharp surfaces which

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Fig. 2 Preoperative spinal computed tomography (CT) scan; two-dimensional sagittal, transverse, and coronal sections (A-C) and three-dimensional (3D) reconstruction (D-F): The sagittal section (A) and lateral 3D view (D) show the presence of a mild dorsal displacement associated with a malalignment of the spine due to the compression fracture of the fifth thoracic vertebral body. There is a large comminuted vertebral body fragment, displaced laterally and ventrally, visible on both the transverse section (B) and on the 3D model (D-F). The dorsal lamina and the articular facets display multiple fractures (B, E) associated with a ventral displacement of the spinous process of T5, resulting in vertebral canal narrowing. Finally, the level of comminution of the T5 compression fracture is responsible for severe shortening of the spinal column between T4 and T6. There was not any evidence of traumatic disc herniation based on the plain CT scan images.
could damage the left lung lobes (Fig. 3C). A 16 French thoracostomy tube was inserted into the left hemithorax and secured to the body wall. Thorough lavage with warm saline was performed prior to routine closure of the sternotomy with 3.0 metric polypropylene simple interrupted sutures. The pectoralis muscles and subcutaneous layers were closed with a simple continuous pattern using 2.0 metric and 1.5 metric poliglecaprone 25, respectively. The skin was apposed with staples. Finally, the multiple cutaneous puncture wounds were debrided and left open to heal by second intention.

Postoperatively, the patient’s cardiovascular and respiratory parameters, including heart rate and rhythm, pulse quality, mucous membrane colour, capillary refill time, respiratory rate and respiratory pattern were carefully observed. Electrocardiogram, central venous blood pressure, indirect arterial blood pressure and pulse oximetry were closely monitored. Half a unit of packed red blood cells was administered to treat a marked anaemia (postoperative PCV of 14% compared to preoperative PCV of 32%) resulting from the combination of blood loss associated with the trauma, fluid administration to replace volume loss, and minimal intraoperative haemorrhage. Supportive care included crystalloid fluid therapy (2.5 ml/kg/hr), aspiration of the thoracostomy tube at least every four hours, and wound management. Antibiotics were continued intravenously (ampicillin sodium, 22 mg/kg IV Q8 hr) until oral medication could be given. As part of the postoperative care, physical rehabilitation including manual urinary bladder expression, pelvic limb passive range-of-motion, massage, and neuromuscular electro-stimulation was implemented.

Thoracic radiographs (Fig. 4) were not obtained immediately postoperatively to shorten anaesthetic time for this trauma patient. Thoracic radiographs obtained two days after surgery revealed that all four pins were placed in the vertebral bodies of T4 and T6 without obvious penetration into the vertebral canal. The PMMA column was visible along the left ventro-lateral surface of the fourth, fifth and sixth thoracic vertebral bodies incorporating the extra-osseous portion of the fixation pins. Pneumothorax had resolved and pleural effusion was minimal. Following radiology, the thoracostomy tube was removed and a CT scan (Fig. 5) was performed under sedation to further assess the degree of vertebral canal reduction and pin placement. A direct comparison was made between the preoperative and postoperative images measuring both spinal canal diameter at its narrowest portion and length of longitudi-
nal collapse. The spinal canal diameter increased from 3 mm to 4 mm postoperatively. Similarly, the longitudinal collapse distance as measured by the distance between the cranial aspect of T4 and the caudal aspect of T6 increased from 21.0 to 22.2 mm.

The day following surgery, deep pain perception was present in both pelvic limbs with absent motor function. Although mildly improved, the thoracic limb hyperextension was still present. Voluntary motor function was recovered four days after surgery. On day seven, the patient was ambulatory and thus discharged from the hospital. Oral medications included the administration of tramadol (2 mg/kg PO Q8 hr) for five days and amoxicillin with clavulanic acid (12.5 mg/kg PO Q12 hr) for ten days. Cage rest was recommended for eight weeks with the exception of simple rehabilitation exercises including passive range-of-motion and sling assisted walking four times a day for 15 minutes. Professional physical rehabilitation was performed semi-weekly at the Advanced Rehabilitation Center in our institution (Michigan State University Veterinary Teaching Hospital).

The dog was re-examined eight weeks postoperatively. No neurological deficits were evident and thoracic radiographs showed complete resolution of the subcutaneous emphysema and pneumothorax. While no implant failure or migration could be appreciated on these images, it was difficult to evaluate bone healing at the fracture sites. Thoracic spine CT and magnetic resonance imaging (MRI) were performed under general anaesthesia. The spinal CT scan allowed for the best evaluation of the implant position and healing process (Fig. 6). On the transverse images, all pins appeared well-seated in the vertebral bodies without any penetration into the spinal canal. A bone callus was bridging the right dorsal lamina fracture, and bone healing and remodelling had occurred in the vertebral body of T5. Reduction in the vertebral canal diameter at the level of the vertebral body of T5 was minimal compared to the diameter at the level of the adjacent vertebrae. Despite the presence of a callus over the dorsal lamina of T5, the vertebral canal diameter was equivalent (4.1 mm) to that measured immediately after surgery. The MRI images obtained using an attenuation protocol failed to improve visualisation of the spinal cord at the level of the fracture due to extensive implant artefacts (18).

Discussion

Bite wounds in dogs and cats constitute a common medical emergency, representing...
10% to 15% of all veterinary trauma cases (1). Small and miniature breeds are over-represented and the wide variety of clinical signs associated with this trauma are often referred to as the ‘big dog/little dog’ syndrome. As seen in this case report, severity of internal injury resulting from tearing, crushing, and shaking by the attacking dog is often not correlated with the extent of cutaneous damage (1, 2, 8). The thorax is the most common anatomical region injured in dog fights, and patients with thoracic bite wounds should be carefully evaluated for extra- and intra-thoracic lesions (2, 8, 19).

Treatment approach for penetrating thoracic injuries has been controversial. While few authors have advocated conservative management with wound care and thoracostomy tubes in the past, currently the most commonly accepted approach is surgical intervention as early as possible following the traumatic event (2, 8, 9, 19, 20). In some institutions, including ours, thoracic exploration is considered a ‘standard of care’ for patients with penetrating thoracic injuries, and is performed as soon as the patient is haemodynamically stable (8). In the case presented in this report, the severity of the respiratory signs, the presence of deep penetrating thoracic wounds, and abnormal radiographic findings triggered the decision to perform an exploratory thoracotomy. A median sternotomy was chosen over a lateral intercostal thoracotomy approach. The median sternotomy approach allowed exposure of most thoracic structures, as compared to a more limited exposure provided by a lateral thoracotomy. Sternotomy also permitted stabilization of the vertebral fracture without changing patient positioning during surgery and eliminated the need for use of an intercostal retractor that might have induced displacement of the unstable fracture of the T5 vertebral body. Lateral intercostal approach has been successfully used in the treatment of a T11 vertebral body fracture (12, 21). However, a lateral thoracotomy at the level of the vertebral fracture may produce iatrogenic fracture displacement and induce further spinal cord trauma. Biomechanical testing would be necessary to validate this statement and establish guidelines for the treatment of such fractures. The intra-thoracic wall repair did not present major difficulties. Thoracic lavage was performed to assess integrity of the lung parenchyma and to decrease bacterial contamination. After closure of the thorax, the external wounds were explored, debrided, and left open to heal by second intention.

The absence of signs of deep pain at the time of presentation to the ECCM service raised major concerns regarding functional recovery of the pelvic limbs. The administration of buprenorphine two hours prior to clinical evaluation may have altered the neurological evaluation, and deep pain perception tests could have been falsely negative. However, we believe the neurological status of the patient was profoundly affected with either paralysis and loss of motor function, or paralysis with loss of deep pain perception (grade 1 to 3) (6).

General indications for surgical management of spinal trauma include 1) minimal voluntary motor function or complete paralysis, 2) clinical or radiographic evidence of highly unstable fractures, and 3) progression of neurologic signs despite appropriate nonsurgical treatment (22). The case presented here displayed the first two of the above criteria in support of surgical intervention. As emphasised in the first section of this discussion, it is important to address all life-threatening conditions prior to performing neurosurgery. Several treatment options to stabilise the vertebral fracture were considered during the surgical planning. Exploration of the fracture site during the primary thoracic procedure and stabilisation of the vertebral fracture from a ventral approach was elected. The goal of neurosurgery in this case was to (1) realign the vertebrae, (2) decompress the spinal cord, and (3) stabilise the vertebrae to allow fracture healing. While decompression procedures are not possible through a ventral approach in the thoracic region, the vertebral bodies are accessible allowing direct implant anchorage. Numerous fixation methods have been proposed for the treatment of thoracic and lumbar vertebral fractures or luxations, including both ventral and dorsal techniques. Dorsal techniques using pins or screws with PMMA, or external skeletal fixators, are often chosen in the thoracolumbar area even in the presence of fractures involving the ventral compartment of the vertebra. The placement of the implants through a dorsal approach raises concerns for both the amount of bone purchased by the fixation device, and the potential for creating trauma to important structures in the lumbar and thoracic regions (21, 23). A recent study suggested that the use of intraoperative fluoroscopy may allow more consistent implant placement to optimise bone purchase and implant anchorage (23). Ventral stabilisation techniques including vertebral body plat-
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Disclosure
The authors have no disclosure to report for this manuscript.

Conclusion
In conclusion, ventral vertebral stabilisation of mid-thoracic fractures is possible through a median sternotomy approach and was associated with a favourable outcome in this case despite profound preoperative neurological deficits. While this case report is encouraging, in vitro or in vivo evaluation of ventral stabilisation of thoracic vertebral fractures is necessary to define its advantages and limitations. Careful patient evaluation and assessment of conventional fixation techniques should be performed before considering this method as a primary treatment option. The main benefits of the ventral approach are ideal visualisation and maximised implant anchorage in the transverse plane of the vertebral bodies. The use of a thoracotomy to stabilise thoracic vertebral fractures and luxations must be carefully evaluated as potential risks of intrathoracic complications may outweigh the benefits in cases lacking concurrent thoracic trauma or displaying only mild neurological deficits.

Acknowledgements
The authors would like to acknowledge Genia Smith, LVT, CCRP from the advanced rehabilitation center at Michigan State University for her active participation in the postoperative care and rehabilitation of this patient, and Christine Warzee, DVM, DACVS for her contribution in this manuscript.

Disclosure
The authors have no disclosure to report for this manuscript.
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