Clinical Management of Flail Chest in Dogs and Cats: A Retrospective Study of 24 Cases (1989-1999)

Cases of flail chest injury for 24 client-owned companion animals following various traumas were evaluated. Concurrently sustained injuries, initial emergency treatments, and definitive treatment and outcome for regimens that utilize stabilization of the flail segment were compared with cases treated with no stabilization.

Flail chest was confirmed in 24 animals: 21 dogs and three cats. There was an even division (12 each) of right and left flail segments. The median number of ribs involved was three (range, two to seven). Flail segment stabilization was performed in nine, and 15 were treated with no stabilization. Statistical analysis using multiple data permutations evaluating all combinations failed to reveal a significant difference in outcome between stabilized and unstabilized cases.

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Introduction

Flail chest exists when the intrinsic costal arch support of a section of the thoracic wall has been lost due to multiple (a minimum of two) fractures of at least two adjacent ribs. The section is said to "flail" asynchronously with the normal motion of the thorax during respiration. This "flailing" motion is paradoxic with normal thoracic wall movement and is characterized by inward displacement during inspiration and outward displacement during expiration. The clinical signs of difficult and exaggerated breathing that often accompany flail chest were thought for many years to be due, in large part, to the paradoxic movement of the flail segment.[1-7] The basis for this assumption was that pendulous airflow between lungs was thought to result from the loss of thoracic wall integrity (Pendelluft theory).[1,2,5,6] The theory states that air in the lungs beneath the flail segment would flow across to the lung in the opposite hemithorax during inspiration and then back again during expiration. The abnormal airflow was said to contribute to an increase in the physiological "dead space." When this is combined with decreased vital and functional residual capacities, decreased pulmonary compliance, and increased airway resistance resulting from the flail segment, severe respiratory distress may result. This thinking led to the widespread recommendation that the flail segment be stabilized as soon as possible, and in many instances this perspective still prevails.[3,4,8,9] Consequently, there have been many techniques described for stabilization—from procedures that place and maintain traction on the unstable ribs to internal fixation of the ribs in an effort to restore synchronous thoracic motion.[1,3,6-9]

Increased understanding of the pathophysiology of flail chest has redirected focus from the unstable flail segment to underlying pulmonary damage (e.g., contusion) as the primary cause of respiratory dysfunction.[1,2,5-7,10,11] Pulmonary contusions are commonly seen in cases of thoracic trauma.[12-17] When trauma is sufficient to result in solitary rib fractures or create a flail chest, pulmonary contusions are almost inevitable.[1-3,5-11,18] However, the dramatic appearance of a "flailing" chest wall may cause the less readily apparent pulmonary contusion to be overlooked. Pain is another component of the pathophysiology of respiratory distress that accompanies flail chest.[1,5,7,8,18] Pain impairs ventilation because of the reluctance to fully expand the thoracic wall. This results in hypoventilation, which can contribute to hypoxemia and pulmonary atelectasis, and also in a diminished cough reflex that leads to the accumulation of pulmonary secretions.[1,5,19,20] Medical treatment for flail chest often includes specific therapy directed at the pulmonary pathology that leads to inappropriate oxygen (O_2) exchange. This generally includes O_2 supplementation and drug therapy, but in very severe cases may also require positive-pressure ventilation with ventilator management and precautions taken to prevent iatrogenic barotrauma.[1,5,6,17] Pain management is another facet of flail chest treatment where medical therapy is focused.

The purposes of this retrospective study were to investigate flail chest trauma and concurrently sustained injuries; to evaluate initial emergency treatments used; to compare definitive treatment and outcome for regimens that utilize stabilization of the flail segment with those that direct therapy at accompanying pathology and do not stabilize; and to use the information obtained in an attempt to determine a preferred course of therapy.

Materials and Methods

Medical records from five separate veterinary medical facilities (i.e., Kansas State University, Virginia Tech, University of Georgia, Colorado State University, and Michigan State University) were searched over a 10-year period (1989-1999) to locate cases of flail chest. Flail chest was ascertained by radiographic confirmation of rib fractures that resulted in a clinically apparent loss of thoracic wall continuity. At least two adjacent ribs with fractures at different levels (i.e., dorsal and ventral) were noted by evaluation of thoracic radiographs. Information derived from the search included signalment of the animal, cause of trauma, location and number of ribs involved in the flail segment, concurrent radiographic findings, and the emergency therapy utilized. Additional information included whether or not the flail segment was stabilized and, if so, what method was used. If there was no stabilization of the flail segment, the methods utilized for patient care were recorded. The duration of time in an intensive care unit (ICU) and total hospitalization were noted. Complications encountered and the final outcomes were also determined.

The primary criterion used to divide the cases into two groups was whether or not the flail segment was stabilized. Both groups were then evaluated and compared to determine if differences existed between the apparent extent of the injuries (such as number of ribs fractured, location, and other significant injuries) and clinical presentation. Also, differences in the treatment regimens, duration of hospitalization, complications, and outcome were evaluated. Statistical analysis was performed using Pearson's chi-square test and Fisher's exact test with multiple permutations of the data. Significance levels were established at $P \leq 0.05$.

Results

Flail chest was confirmed in 24 patients: 21 dogs and three cats. Canine males (n=15) were more common than females (n=6), and intact dogs were more common than neutered, with 12 intact males and four intact females. Of felines, two were female (one intact; one neutered) and one was male (neutered). Median age among canines was 5 years (range, 8 months to 13 years), and median age for felines was 1 year (range, 1 to 11 years). There was an even division (12 each) of right and left flail segments. The median number of ribs involved was three (range, two to seven). Dog-bite trauma was the most common cause, with nearly twice as many cases (n=13) as the next most-common cause, automobile trauma (n=7). Other causes included kicked by a horse, gored by a bull, a fight with a bear, and unknown trauma with one case each. Stabilization of the flail segment was performed in nine cases, and 15 were treated conservatively with no stabilization. Methods of stabilization were divided into two general categories. The first category included all techniques involving percutaneous placement of sutures that encircled ribs within the flail segment, then securing the sutures to some form of external brace that used the adjacent intact thoracic wall to provide countertraction for stabilization. Five of the nine stabilized cases utilized this method of fixation. The four remaining cases were viewed in a second category that included all methods of internal surgical fixation of the ribs. A summary of flail segment stabilization techniques is provided in Table 1. Median total days of hospitalization were 6 (range, 1 to 16 days) for stabilized cases and 5 (range, 1 to 14 days) for nonstabilized cases. Median days in ICU were 5 (range, 1 to 9 days) for stabilized cases and 3 (range, 1 to 14 days) for nonstabilized cases. Pulmonary contusion, subcutaneous emphysema, and pneumothorax were the most prevalent additional radiographic abnormalities noted, regardless of the group. A greater percentage of the cases in the nonstabilized group exhibited the additional radiographic abnormalities. A summary of all additional radiographic findings with a group breakdown is given in Table 2.

Emergency therapy at presentation, regardless of flail segment stabilization status, consisted of intravenous (IV) fluid administration at or near accepted rates for shock (16/24), supplemental O_2 (13/24), thoracocentesis for pneumothorax (12/24), analgesic drug administration (9/24), and a chest bandage (7/24). Assisted ventilation was provided only in cases undergoing surgical stabilization (and then only during the procedure and not as an initial emergency therapy).

Following initial emergency treatment and patient stabilization, the most common therapies utilized for cases managed without flail segment stabilization included IV fluids

Table 1

Methods of Flail Segment Stabilization

Stabilization Methods	No. of Cases
External thoracic brace	5
Internal fixation:	
Intramedullary pins	1
Interfragmentary wire	2
Suture approximation	1

(10/15), pain management (10/15), antimicrobial drugs (9/15), and supplemental O_2 (6/15). Common therapies for flail segment stabilized cases after initial emergency treatment included supplemental O_2 (7/9), IV fluids (6/9), and chest tube placement (6/9).

Short-term complications, identified after initial patient care, were limited to ventricular premature contractions in two of the unstabilized cases and one stabilized case, and atelectic lung fields with one case from each group. Long-term complications noted were limited to the nonstabilized group and consisted of a persistent, slight chest wall deformity in two cases and slight paradoxic movement in one case. These long-term complications were not deemed to be clinically significant.

Six (66.7%) of the surgically stabilized cases survived, whereas 14 (93.3%) of the conservatively managed cases survived. Overall success was 20/24 (83.3%), and mortality was 4/24 (16.7%). Statistical analysis using multiple data permutations was performed looking at all combinations. Regardless of the permutation, statistical analysis failed to demonstrate significant differences in the extent or number of injuries sustained, hospitalization duration, complications, and final outcome between stabilized and nonstabilized flail chest (P=0.1304).

Discussion

Treatment of flail chest in veterinary medicine is largely extrapolated from therapeutic recommendations in the human field. A plausible explanation for the dependence on the human field is the paucity of cases in veterinary medicine. Other reports concerning thoracic trauma have found that flail chest is an uncommon condition in veterinary patients.[1,4,6] This retrospective study concurs. Despite searching medical records of five university teaching hospitals for a 10-year period, only 24 cases were found. Perhaps these selected teaching hospitals had low numbers of flail chest simply by chance, and other institutions may have had higher numbers of cases. Various authors have proposed possible explanations for the low number of veterinary cases. The anatomical configuration and potentially increased pliant nature of the small animal thoracic cage are speculated to be reasons that flail chest is uncommon.[1,13,15] Another potential explanation is that the degree of trauma necessary to create a flail chest may also be rapidly fatal; therefore, the diagnosis is never made.[3,15]

The number of dogs diagnosed with flail chest was considerably greater than cats. When the most common etiologies of flail chest (namely, dog-bite trauma and automobile impact) are considered, some possible explanations become apparent. Dogs have a tendency to be very interactive when another dog is encountered, and this increases the potential for adverse contacts. When one dog is considerably larger, severe trauma such as bite wounds to the chest and vicious shaking can occur. Cats, as opposed to dogs, do not have the innate tendency to interact with dogs; this likely decreases the potential for adverse contacts, although every case of feline flail chest in this study was caused by a dog attack. Impact to the thoracic area by an automobile is more likely to occur in the dog simply because of the size of

Table 2

Additional Radiographic Abnormalities Identified in Patients With Flail Chest and Number of Cases Affected in Each Group

Abnormality	Nonstabilized*	Stabilized†	Total
Pulmonary contusion	14	4	18
Subcutaneous emphysema	12	4	16
Pneumothorax	12	2	14
Pneumomediastinum	3	1	4
Pleural effusion	3	1	4
Pulmonary collapse	2	0	2

* Nonstabilized cases: n=15
† Stabilized cases: n=9

some breeds. Larger dogs may also be propelled away from the car following impact, as opposed to being run over, which may influence survival and subsequent presentation for medical therapy. Seven of the canine cases in this study were hit by cars, and of those seven, all but one was ≥27.3 kg. The smallest of the seven was a 7.3-kg, mixed-breed dog. As mentioned previously, it is reasonable to speculate that the trauma likely to cause flail chest has a high possibility of being fatal for smaller dogs and cats.[15]

The distribution of affected dogs according to gender is similar to another study of trauma.[15] Twice as many sexually intact than neutered animals were included in the population. Intact male dogs comprised 57% of the population, while intact females comprised 19%. Roaming behavior of intact animals, specifically males, is thought to contribute to the increased potential of traumatic incidents.[15]

Previous reports have indicated that flail chest may occur more commonly in older animals because of the increased brittleness of the bones.[6,21] The results obtained from this retrospective study do not support this point. Seventeen of the 24 animals were ≤5 years of age, and 10 were <3 years of age. One credible explanation for young animals having an increased incidence in this study is that younger animals are involved in trauma incidents more frequently than older animals.[15,22] Possible reasons for the increased incidence are offered; namely, younger animals may not be as familiar with surroundings and vehicular traffic, and they may have an increased inclination to roam.[15] The tendency for roaming may also be tied to the reproductive status of the animal, as previously suggested. Therefore, the type of trauma that leads to flail chest may have more to do with occurrence than with the physical characteristics of the bones. However, it is also possible that older animals may not have survived the severe trauma because of concurrent age-related health problems and are therefore under-represented in the study.

Intrathoracic injuries concurrent with flail chest that were noted are very consistent with other studies of thoracic trauma. Pulmonary contusions were diagnosed in 75% of the cases and likely would have approached 100% if additional thoracic radiographic studies had been performed.[13,17] It has been shown in both veterinary and human investigations that diagnosis of thoracic injuries can be complicated, because many patients are able to compensate for severe injury due to a significant pulmonary reserve, thereby diminishing the severity of clinical signs.[13,15] Additionally, the small tidal volumes of many small animal patients can complicate diagnosis of pulmonary injury via auscultation.[13,15] The possibility that clinical signs may be minimal offers an explanation for the diagnosis of contusion to be <100%. One of the best methods for diagnosing pulmonary contusions is radiography, but it is well known that radiographically visible evidence of contusions may not be seen for 4 to 6 hours.[15,17,23] Therefore, radiographic findings early in the course of evaluation may be regarded as negative for pulmonary contusions. Had additional radiographs been taken after 24 hours, the rate of diagnosis would likely have been increased.

Pneumothorax and subcutaneous emphysema were diagnosed 58% and 67% of the time, respectively. Pneumothorax is commonly diagnosed when thoracic trauma is significant enough to cause pulmonary contusion, and the occurrence in this study is somewhat higher than that found in other investigations.[13,15-17,24] A possible explanation for the higher rate is that the trauma resulting in flail chest is greater than the trauma resulting in contusions without rib fractures. Closed pneumothorax can be caused when a fractured rib fragment lacerates the pulmonary parenchyma or an airway and air escapes from the laceration. Rupture or tearing of the lung can also occur because of a rapid increase in airway pressure secondary to blunt impact. The pressure change may be so rapid and of such a magnitude that local tissue failure occurs.[3,25] Another potential cause is shear forces within the lung tissue that result when there is an abrupt change in velocity, such as might be expected in severe trauma. Tissue of different densities would have differing rates of acceleration and deceleration, and shear forces between them would result in tears and escaping air.[3] Laceration of pulmonary parenchyma can also result when there is penetration of the thoracic wall by the teeth of an attacking animal, creating an open pneumothorax. When considering open pneumothorax caused by bite wounds and the stabilization of the thoracic wall, it is interesting to note that seven of the nine stabilized cases were from bite trauma while only six of 15 nonstabilized cases were from bite trauma. It is reasonable to suggest that the increased rate of stabilization in cases caused by bite trauma may be due to the higher probability of having an open pneumothorax that required closure, and that during wound debridement and thoracic wall closure the flail segment was also stabilized. This course of action would be prudent as an attempt to restore normal thoracic wall form and function.

The occurrence of subcutaneous emphysema was considerably higher in this study than in other studies of thoracic trauma where it is mentioned only briefly, if at all.[16] The most common cause of flail chest in this study was dog-bite wounds. The tissue disruption from the bite could allow air accumulation from the external environment as well as from perforation of the thorax and lung and allow air to escape from the pulmonary tissue and pleural space into the disrupted tissues. There are other plausible explanations for such a high incidence. Air that escapes from the lungs because of tears or rupture of the parenchyma or airways could pass from the pleural space in cases of pneumothorax and infiltrate disrupted tissue planes that result when multiple ribs are fractured in multiple locations. When the pleura has not been torn, escaping air can migrate through the pulmonary interstitium along the bronchi to the mediastinum and eventually reach the subcutaneous tissues and cause emphysema.

Other conditions that accompanied the flail chest were pneumomediastinum, pleural effusion (both approximately 17%), and pulmonary atelectasis (approximately 8%). Pneumomediastinum and pleural effusions have been mentioned in previous studies regarding thoracic trauma, but at similar or lower rates of occurrence.[13,15,24] Possible explanations for the increased incidence are similar to those for pneumothorax. Despite radiographic diagnosis of these accompanying complications, there were no immediate attempts made in those cases to treat the condition. This would infer that the problems were not considered sufficient to contribute to the clinical condition. Lung-lobe atelectasis was the least common of the intrathoracic injuries, and this is similar to the findings of other investigators.[15]

Therapeutic recommendations in veterinary medicine for many years have largely involved surgical stabilization of the flail segment. As a result, there are many different methods described for stabilization.[1,3,4,6-9] An interesting finding in this retrospective study is that despite the many recommendations for immediate stabilization of a flail segment, the majority of cases (15/24) were treated without any form of stabilization. This suggests that some clinicians, based on extrapolated evidence and experience, may have realized that stabilization is not always necessary when the underlying pulmonary damage is treated appropriately. One interesting finding in this series is the relatively low use of analgesics for pain management. Only two-thirds (16/24) of all the cases received drugs for pain management at some point during treatment. This was evident during the initial emergency stabilization period, where only nine out of all cases were treated with analgesic drugs. After the cases were separated into the two categories, only three of the nine stabilized cases and 10 of 15 nonstabilized cases received drugs for pain control. The reasons for the apparent lack of use of analgesic drugs are difficult to elucidate from this study. One possible explanation is failure to properly record all medications used during hospitalization. Emergency situations may contribute to this failure because of increased levels of stress and activity. Should this be the case, it emphasizes the need for a conscious effort to assure the accuracy of the recorded therapies. Another possible reason is the changing perception of the need for pain control during the time period of the study. Approximately 87% of the cases treated with analgesic drugs were presented from 1993 to 1999, whereas 55.5% of the cases presented from 1989 to 1992 apparently had no analgesic medications provided. The higher percentage of pain management during the later years of the study may be a reflection of this altered perception.

Initial evaluation of stabilized and nonstabilized flail chest data seems to suggest important differences in the method of therapy. There was a slight difference between the groups as far as time spent in the ICU and hospital. Nonstabilized cases had a trend for less time spent in the ICU and overall hospitalization. Also, approximately 67% of those stabilized survived, whereas 93% of the conservatively managed cases survived. Nevertheless, statistical analysis could not detect any significant differences in hospitalization or survival times between treatment modalities. The apparent lack of difference is difficult to interpret because of the low population number. If additional cases were obtained, a significant difference might be found; but it is also feasible that there may indeed be no difference in hospitalization times and survival rates. Another potential reason for the apparent difference in hospitalization and survival is that those stabilized were clinically in more critical condition. This possibility exposes an inherent weakness in a retrospective study where clinical status cannot be accurately ascertained or comparisons between different cases be made. Even though additional abnormalities, such as pulmonary contusions and pneumothorax, were found to be more common in the nonstabilized cases, the severity of the injury cannot be determined. However, as indicated by this finding, cases afflicted with multiple problems may be treated without thoracic wall stabilization. This, however, does not suggest that aggressive therapy utilizing analgesic drugs, O_2 therapy, and even ventilatory support should be withheld if they are clinically indicated. Appropriate fluid therapy with isotonic or hypertonic crystalloids or colloids should also be utilized when indicated, and great care should be taken to avoid fluid overload that would aggravate respiratory compromise.

The overall mortality in this retrospective study was 16.7%, which compares favorably to the highly variable rates of up to 40% published in some of the human literature.[5,26] While this number is somewhat encouraging, it is difficult to determine from this study whether any specific emergency or definitive therapy has contributed to the relatively good success rate. Conversely, since the exact cause of mortality (e.g., respiratory or cardiovascular arrest) was not recorded in the four cases, it is difficult to say if the degree of trauma was of sufficient magnitude to lead to death or if excessive therapy may have contributed to death. When initial emergency and definitive therapies for all cases are scrutinized, it becomes apparent that there is no standard protocol that is routinely followed for every case.

Conclusion

This retrospective study indicates that flail chest is an uncommon condition. Therapy must be directed at all facets of this complex condition. The results of this study also indicate that there was no demonstrable difference in the outcome of stabilized versus nonstabilized cases. The results of this study clearly indicate that a specific treatment applicable to every case of flail chest does not exist. The clinician must be prepared to evaluate each aspect of the flail chest syndrome for each case individually and then use the clinical findings to determine the optimal course of therapy. Failure to recognize this point and simply applying the same therapy to every case would result in inadequate treatment for some and excessive treatment for others, which in either case could lead to a poorer outcome as a direct consequence of the therapy.

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