Management of sternal dislocation with and without surgery in cats: Owner-assessed long-term follow-up of two clinical cases

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ABSTRACT. The aim of this paper is to report two cases of sternal dislocation (SD) in cats and the long-term outcomes with and without surgery. In a cat with poly-traumatized SD (Case 1), mandibular, radial, and ulnar fractures were corrected first, and the SD was allowed to heal without intervention for 14 months. However, normal healing did not occur and sternal instability remained. Therefore, the SD was corrected surgically, and the cat recovered fully within 4 weeks. In a cat with isolated SD (Case 2), surgery was performed, and normal posture and gait were regained after 5 weeks. Furthermore, in both cases, no postoperative complications were observed during follow-up. Therefore, surgical correction of SD in cats is recommended.

KEY WORDS: cat, sternal dislocation, surgical management
rate (45–54 ml/kg/day). Hematology, serum biochemistry, electrocardiography (ECG), and blood pressure were obtained pre- and postoperatively.

**Case 2**: A 96-month-old neuter male domestic cat (5.27 kg) was presented to the clinic in respiratory distress. The owner revealed that the cat was sensitive to the sound of the vacuum cleaner, and when the owner started cleaning, the cat jumped on the furniture, fell down, and then displayed altered behavior. On presentation, the cat exhibited dyspnea (54 breath/min), tachycardia (225 beat/min), discomfort, and swelling of the ventral thorax. SD was suspected since abnormal movement of the sternum was visible, and instability was palpated. SD between the 4th and 5th sternebrae was confirmed on radiographs (Fig. 4).

Surgical repair of the SD was performed as described below. At 3 weeks post-surgery, the cat had not regained normal gait or posture; however, at 5 weeks post-surgery the cat had recovered and displayed normal cardiovascular parameters (including heart rate, rhythm and pulse quality) and respiratory rate. Telephone follow-up with the owner 19 months following the surgery revealed no abnormalities related to this incident.

In preparation for surgery, both cats were administered intravenous (IV) 0.9% normal saline (10 ml/kg/hr, CJ HealthCare, Eumseong-gun, Chungcheongbuk-do, South Korea), cephradine (30 mg/kg IV, bid; Panzedin Inj®, Hankook Korus Pharm. Co., Ltd., South Korea) and tramadol (2 mg/kg IV, tid, Maritrol Inj®, Jeil Pharmaceutical Co., Ltd., South Korea). General anesthesia was then induced with IV propofol (6–8 mg/kg, Provive®, Myungmoon Pharm. Co., Ltd., Seoul, Korea), the patient was intubated, and sevoflurane (1–5%; Abbott Korea Ltd., Seoul, Korea) was used to maintain anesthesia. Oxygen level and positive pressure were maintained, and ECG and CO₂ partial pressure were monitored by an automated anesthetic machine (Paieon,
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After shaving the entire affected sternal region, aseptic preparation and draping were performed, and the animal was positioned in dorsal recumbency. A midline longitudinal incision was made in the skin on the ventral aspect of the sternum, and the subcutaneous tissue was dissected to expose the dislocated sternal joint.

In Case 1, the fibrotic tissue and muscle were dissected, and the exposed ends of the affected sternebrae were scraped with a scalpel to expose fresh tissue in order to facilitate the healing process. The dislocation was then reduced using traumatic reduction forceps (Fig. 3) and stabilized and fixed with a compression LP and locking screws, taking care to avoid injury to the pleura or internal organs. In Case 2, after exposing the dislocated sternal joint, the ends were positioned using traumatic reduction forceps. Since the wound was acute, scraping with a scalpel was not performed (Fig. 5).

The length and size of the plate and screws and the number of screws used were chosen and contoured based on the radiographs taken before surgery and considering the anatomic differences of the animal, position of the dislocation, and the thickness of tissue present to maintain adequate stability. The length of the plate was 120.72 mm with 16 holes and fixed with 13 screws (3 screws were 6 mm and 10 screws were 8 mm in length) for Case 1 (Figs. 1 and 3) and 77.06 mm with 10 holes and fixed with 8 screws (all were 8 mm in length) for Case 2 (Figs. 4 and 5). The width and thickness of the plates for both cats were 7 mm and 2.58 mm, respectively, and screw diameters were 1.5 mm. The plates and screws were purchased from BS.COREM (Wanju-gun, Jeollabuk-do, South Korea). The incision was then closed routinely and postoperative radiographs obtained to confirm successful alignment.

Postoperative pneumothorax was corrected by thoracentesis using the following technique as previously described [4]. After shaving and aseptically preparing the area of 7th and 8th intercostal space near the costochondral junction, a 19-gauge Echotip needle (Wilson-Cook, Winston-Salem, NC, U.S.A.) with an attached thoracic drain was carefully inserted into the pleural space using fluoroscopy guidance (OEC® 9800 Plus, GE OEC Medical System, Inc., Salt Lake City, UT, U.S.A.). The air was aspirated, and the needle was then removed.

The cats were kept in the intensive care unit (ICU) for 4 days after surgery for monitoring of vital signs and administration of analgesics and fluid therapy. Atropine (0.05 mg/kg, IV, p.r.n., Atropine Inj., Jeil Pharmaceutical Co., Ltd.), enrofloxacin (10 mg/kg IM, sid; Enrobac Inj®, CTC Bio, South Korea), cephradine (30 mg/kg IV, bid), and tramadol (2–3 mg/kg IV, bid or tid) were administered. A gastrointestinal protective agent (cimetidine 10 mg/kg IV, bid; Cimetidine Inj®, Dongkwang Pharm Co., Ltd., Seoul, South Korea) was also administered postoperatively.

The cat in Case 1 was released 28 days after surgery, and the cat in Case 2 was released at 35 days, fully recovered. The referring veterinarians conducted long-term follow-up for postoperative complications, morbidity, and recurrence of signs via

Fig. 4. Preoperative and postoperative radiographs of Case 2. (A–B) Preoperative radiographs illustrating the SD along with soft tissue density and swelling of the subcutaneous tissue. (C–D) Immediate postoperative radiographs show the plate and screw fixation as well as SD correction.

Fig. 5. Intraoperative images of Case 2. (A) Sternal dislocation. (B) Fixation of the 10-hole plate.
Blood cardiac troponin (cTnI) was analyzed on the i-STAT was centrifuged at 3,000 rpm and plasma biochemistry was measured using a Hitachi 7180 instrument (Hitachi, Tokyo, Japan). Blood anionic gap and osmolality were measured as described previously [13]. Blood anionic gap and osmolality were measured as described previously [13].

To the best of our knowledge, this is the first report on the clinical findings, diagnosis, and treatment of isolated and poly-traumatized SD in cats that also evaluated the short- and long-term outcomes with and without surgical management. Furthermore, this is the first report on the use of a LP for SD fixation in veterinary medicine. Even though cardiac and respiratory parameters were normal in the poly-traumatized cat, after 14 months the cat still displayed gait abnormalities and recovered smoothly after the surgical procedure. The isolated SD in the second case was corrected by surgery, and the cat recovered within 5 weeks.

Generally, conservative treatments for SD in humans are suggested [1]. The most common complication after an injury in

| Clinical parameters       | Reference range | Case 1 Day 0 | Case 1 Day 7 | Case 1 Day 28 | Case 2 Day 0 | Case 2 Day 7 | Case 2 Day 35 |
|---------------------------|-----------------|--------------|--------------|--------------|--------------|--------------|--------------|
| RR (breath/min)           | 20–30           | 56           | 35           | 32           | 54           | 34           | 30           |
| Heart rate (beat/min)     | 140–200         | 168          | 173          | 178          | 225          | 188          | 182          |
| pH                        | 7.21–7.41       | 7.29         | 7.38         | 7.25         | 7.35         | 7.24         | 7.24         |
| pCO₂ (mmHg)               | 28–50           | 39.4         | 39.8         | 40.2         | 33           | 34.1         | 40.1         |
| pO₂ (mmHg)                | 24–48           | 73           | 52           | 71           | 43           | 61           | 74.2         |
| Na⁺                       | 148–157         | 161 (H)      | 159 (H)      | 155          | 157          | 157          | 148          |
| K⁺                        | 3.3–4.5         | 4.6          | 4.7 (H)      | 4.3          | 3.3          | 4            | 3.7          |
| Cl⁻                       | 117–127         | 123          | 120          | 125          | 116          | 118          | 113          |
| Ca²⁺                      | 1.11–1.38       | 1.4          | 1.37         | 1.34         | 1.29         | 1.3          | 1.24         |
| HCO₃⁻                     | 21–28           | 18.2         | 22.7         | 20.1         | 17.9         | 14           | 21           |
| cBase (B)                 | –2–3            | –7.4         | –1.4         | –6.3         | –6.3         | –12.2        | –13.2        |
| cBASE (B, ox)             | –2–3            | –7.6         | –1.8         | –7.5         | –6.8         | –12.5        | –10.2        |
| Angap (mmol/l)            | 7–16            | 22.8         | 16.3         | 9.9          | 23.1         | 25.0         | 14.0         |
| Osm (mOsm/l)              | 290–330         | 325          | 321          | 310          | 312          | 320          | 296          |
| Lactate (mmol/l)          | 0–2.7           | 5.2 (H)      | 3.8          | 2.8          | 4.2 (H)      | 2.4          | 2.5          |
| Hct (%)                   | 24–55           | 34.4         | 32.6         | 35.2         | 34.9         | 36.4         | 37.2         |
| Hb (g/dl)                 | 8–15            | 11.8         | 11.4         | 12.1         | 11.5         | 13           | 13.2         |
| RBC ×10⁶/µl               | 5–11            | 8.36         | 8.21         | 7.41         | 6.4          | 7.1          | 7.5          |
| WBC (×10³/µl)             | 5.5–19.5        | 35.09 (H)    | 8.11         | 10.2         | 21.48 (H)    | 20.4         | 14.2         |
| Neutrophil (×10³/µl)      | 2.5–12.8        | 28.67        | 23.67        | 11.2         | 20.14 (H)    | 16.96        | 10.23        |
| Monocyte (×10³/µl)        | 0.2–2           | 1.06         | 0.91         | 0.62         | 0.54         | 0.54         | 0.31         |
| PLT (×10³/µl)             | 150–500         | 599          | 667          | 281          | 326          | 273          | 272          |
| MPV (fl)                  | 5–20            | 10.4         | 10.8         | 11.3         | 17.3         | 17.6         | 17.1         |
| CK (UI/l)                 | 49–688          | 721 (H)      | 692 (H)      | 651 (H)      | 4,032 (H)    | 1,002 (H)    | 701 (H)      |
| ALT (UI/l)                | 12–130          | 25           | 9            | 15           | 138          | 102          | 108          |
| ALP (UI/l)                | 14–111          | 31           | 29           | 35           | 44           | 21           | 31           |
| AST (UI/l)                | 6–44            | 32           | 19           | 25           | 105 (H)      | 144 (H)      | 64 (H)       |
| cTnl (mg/ml)              | 0–0.09          | 0.06         | -            | 1.06 (H)     | 0.23         | 0.09         |
| TP (mg/dl)                | 5.7–8.9         | 7.4          | 8.4          | 8.2          | 6.7          | 7.4          | 7.2          |
| Albumin (mg/dl)           | 2.2–4           | 2.6          | 2.8          | 3.1          | 2.9          | 2.8          | 3.1          |
| BUN (mg/dl)               | 16–36           | 17.5         | 31.2         | 15.2         | 11           | 30.8         | 13           |
| CRE (mg/dl)               | 0.8–2.4         | 1.4          | 1.3          | 1.1          | 1.9          | 1.6          | 0.9          |
| Glucose (mg/dl)           | 74–159          | 117          | 176 (H)      | 144          | 131          | 137          | 135          |

Clinical parameters Reference range | Case 1 Day 0 | Case 1 Day 7 | Case 1 Day 28 | Case 2 Day 0 | Case 2 Day 7 | Case 2 Day 35 |

RR, respiratory rate; pCO₂, partial pressure of carbon dioxide; pO₂, partial pressure of oxygen; Hct, hematocrit; Hb, hemoglobin; RBC, red blood cell; WBC, white blood cell; PLT, platelets; MPV, mean platelet volume; Angap, anionic gap; Osm, osmolality; CRE, creatinine; BUN, blood urea nitrogen; ALT, alanine aminotransferase; AST, aspartate aminotransferase; ALP, alkaline phosphatase; CK, creatinine kinase; cTnl, cardiac troponin-I; TP, total protein; H, higher than reference level. In the first case, the data presented here include pre- and post-SD correction.

Laboratory tests (hematology, serum biochemistry) and patient information (breed, age, sex, and body weight) from the medical records are presented in Table 1. EDTA samples were analyzed using ADVIA 2120i™ (Siemens Healthcare Diagnostics, Vienna, Austria) for hematology, and blood gas, electrolytes, and lactate were analyzed using an ABL80 FLEX BASIC blood gas analyzer (Radiometer Medical, Brønshøj, Denmark). Blood anionic gap and osmolality were measured as described previously [13]. Blood was centrifuged at 3,000 rpm and plasma biochemistry was measured using a Hitachi 7180 instrument (Hitachi, Tokyo, Japan). Blood cardiac troponin (cTnI) was analyzed on the i-STAT®1 stall-side analyzer (Abbott, Kyoto, Japan) according to manufacturer instructions. Radiographs were obtained using Titan 2000, (COMED Medical Systems Co., Ltd., Seoul, Korea) and interpreted by an experienced (10 years) radiologist for both animals. CT imaging was performed using an ECLOS 16-row detector CT scanner (Hitachi) to exclude other pathological abnormalities. Respiratory rate was recorded by the movement of the abdominal and chest wall (breath/min). ECG was performed with a Cardiofax ECG-9020 electrocardiograph (Nihon Kohden, Tokyo, Japan), and heart rate was recorded.

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Generally, conservative treatments for SD in humans are suggested [1]. The most common complication after an injury in
patients with isolated sternal fractures is pain, and up to two-thirds of patients are managed with analgesia alone. Surgery is only suggested in human trauma medicine when there is marked displacement, uncontrolled pain, cardiorespiratory disturbances, or clinical non-union [11]. In Case 2, there were significant alterations in cardiac (heart rate was 225 beat/min and ST interval was elevated transiently) and respiratory parameters (respiratory rate was 54 breath/min); therefore, open reduction and lock and screw plate fixation was performed.

No major complications occurred in the first case; the cat had abnormalities in gait for 3 weeks and recovered completely by 4 weeks, as evidenced by radiographs, normal gait, and normal hematology and serum biochemistry results. The clinical signs of SD in humans are associated with type of injury, position, and degree of displacement [8]. The second case in this study had associated signs of dyspnea, tachycardia and thoracic pain/discomfort.

Several fixation techniques are applicable in human medicine, such as stainless-steel wires, Steinmann pins and wire, dynamic compression plates (DCP), sternal lock plates, T-shaped compression-tension stainless steel plates and screws, titanium mandibular plates, cervical plates, and titanium LPs [5]. In one reported canine case, a SD was stabilized using a DCP [13]. In the current report, the appropriate length of LP was contoured and fixed (Figs. 1 and 3–5) carefully by evaluating the tissue and anatomic location, and was matched with the appropriate number and length of screws to induce maximum stability. Sternal function in cats is important as they lie down on the sternum, so appropriate contouring is important. LP may provide better countering in cats than DCP. Furthermore, LP technology protects against plate-screw strain, which is beneficial in cancellous bone [5].

Complications occur in 16% of human patients due to intraoperative errors during implant fixation, including the use of the wrong size plate, screws that are too short, and those that do not have adequate spanning segments (empty screw holes) over the fracture site [16]. We were conscious of this and carefully evaluated the length and thickness of the sternebrae on the radiographic images in order to select the correct size of implant and screws (6–10 mm). Post-operative radiographs confirmed the appropriate positioning of the plate and screws.

The success of orthopedic surgery also depends on the skill of the surgeon [12]. Therefore, the surgeries were performed by same surgeon, Dr. In-Seong Jeong. Long term follow-up radiographs were not obtained in either cat, so union could not be evaluated. However, pathology-related alterations in the hematology and serum biochemistry results (Table 1) returned to normal levels or near normal levels, and normal posture behavior was observed. The cats were considered to have recovered normally, and the owners reported no long-term complications on the questionnaire regarding appetite, gait and posture, temperament, respiratory rate, body temperature, defecation, and urination (Table 2). The limitation of this report is the lack of follow-up radiographs, due to unwillingness of the owners.

The most common cause of sternal fractures and dislocation in humans is blunt anterior chest trauma in traffic accidents (67%), although there are many case reports available related to other traumatic and spontaneous events [6]. Falling may be a common cause of SD in cats, as the SD in both of these cases resulted from a fall. Similar findings were also reported in a dog by Serra et al [15]; however, the limitations of these small studies indicate that these findings should be interpreted cautiously.

In conclusion, surgical repair of feline SD had excellent clinical outcomes in these two cases; therefore, surgical correction of SD in cats is recommended.

Table 2. Questionnaire for owners regarding long-term outcomes of sternal dislocation surgery in the cats

| Question                                                      | Options                  | Selection |
|---------------------------------------------------------------|--------------------------|-----------|
| 1 What was the condition of eating?                          | Normal, Decreased, Increased |           |
| 2 What was the condition of drinking water?                  | Normal, Decreased, Increased |           |
| 3 Did you observe any weakness/ lethargy/depression?         | Yes, No                  |           |
| 4 Did the cat move comfortably with all four legs?           | Yes, No                  |           |
| 5 Did the cat spend time lying down on its chest?            | Yes, No                  |           |
| 6 Did you observe hyper-excitability or abnormal movements?  | Yes, No                  |           |
| 7 Did you hear any abnormal sounds or vocalizing?            | Yes, No                  |           |
| 8 What was the respiratory rate?                             | Normal, Decreased, Increased |           |
| 9 What was the body temperature?                             | Normal, Decreased, Increased |           |
| 10 What was the condition of the feces?                      | Normal, Constipation, Loose or Diarrhea |           |
| 11 How many times has the pet urinated or defecated today?   | One time, Two times, 3 or more |           |

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   ■ Normal  ■ Decreased  ■ Increased
2 What was the condition of drinking water?
   ■ Normal  ■ Decreased  ■ Increased
3 Did you observe any weakness/ lethargy/depression?
   ■ Yes  ■ No
4 Did the cat move comfortably with all four legs?
   ■ Yes  ■ No
5 Did the cat spend time lying down on its chest?
   ■ Yes  ■ No
6 Did you observe hyper-excitability or abnormal movements?
   ■ Yes  ■ No
7 Did you hear any abnormal sounds or vocalizing?
   ■ Yes  ■ No
8 What was the respiratory rate?
   ■ Normal  ■ Decreased  ■ Increased
9 What was the body temperature?
   ■ Normal  ■ Decreased  ■ Increased
10 What was the condition of the feces?
    ■ Normal  ■ Constipation  ■ Loose or Diarrhea
11 How many times has the pet urinated or defecated today?
   ■ One time  ■ Two times  ■ 3 or more
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