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Research Article

Surgical Treatment Results of Young and Adult Cats with Pectus Excavatum

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Abstract

Pectus excavatum (PE) is an uncommon, congenital thoracic wall deformity that has been previously documented in a variety of species. Most of the time, the preferred treatment modality is surgical. External and internal splints may also be used according to the age of the patient and pliability of the sternum. In this study, the authors have aimed to share the clinical and radiographic results obtained in the treatment of PE by traditional external splintage, internal splintage and sternal turnover techniques in cats. For this purpose, PE was treated using the sternal turnover technique in 8 patients, internal splint in 1 patient and external splint in 9 patients. Ages of the patients varied between 2-24 months. The external splint technique was preferred to treat cats aged younger than 12 months. Frontosagittal indices (FSI), vertebral indices (VI) and clinical severity scores (CSS) were determined before and after surgical interventions. Mean FSI, VI and CSS values were 2.1, 10.0 and 0.8 and 1.8, 11.3 and 0.4 in external splint and sternal turnover groups, respectively. At the end of the study, FSI and VI values did not reach the reference interval, however, CSS values were improved in both the external splint and sternal turnover groups. In conclusion, results of the sternal turnover technique, used for the first time in feline patients with PE, were satisfactory even though complete recovery in FSI and VI values could not be achieved. Also, in the opinion of the researcher, results of using sternal turnover technique in feline PE patients younger than 12 months of age should be further investigated.

Keywords: *Pectus Excavatum, External Splint, Sternal Turnover, Cat*

Pektus Ekskavatum Hastası Genç ve Yetişkin Kedilerde Cerrahi Tedavi Sonuçları

Özet

Pektus ekskavatum (PE) farklı türlerde görüldüğü önceki yıllarda rapor edilmiş bir kongenital toraks duvarı deformitesidir. Tedavisinde çoğu zaman cerrahi yöntemler tercih edilir ve hastanın yaşı ve sternumun esnekliği göz önüne alınarak eksternal veya internal splintlerden faydalanılır. Bu çalışmada PE 'nin geleneksel eksternal ve internal splint uygulaması ve sternal döndürme teknikleri ile tedavisi ile elde edilen klinik ve radyografik bulguların paylaşılması amaçlanmıştır. Bu maksatla çalışmamızda PE, 8 hastada sternal döndürme, 1 hastada internal splint, 9 hastada ise eksternal splint kullanılarak tedavi edilmiştir. Hastaların yaşı 2 ila 24 ay arasında değişmekteydi. Oniki aylıktan küçük kedilerin tedavisinde eksternal splint tekniği tercih edildi. Frontosagital indeks (FSI), vertebral indeks (VI) ve klinik önem skorları cerrahi girişim öncesi ve sonrasında tespit edildi. Ortalama FSI, VI ve klinik önem skorları, eksternal splint ve sternal döndürme uygulanan gruplar için sırasıyla 2.1, 10.0 ve 0.8 ve 1.8, 11.3 ve 0.4 olarak hesaplandı. Çalışmanın sonucunda eksternal splint ve sternal döndürme grubunda FSI ve VI değerleri normal referans aralığa getirilemedi ancak klinik önem skorları iyileştirilebildi. Sonuç olarak kedilerde PE 'un tedavisinde ilk kez kullanılan sternal döndürme tekniği ile elde edilen sonuçlar her ne kadar FSI ve VI indeks değerleri normal sınırlara çekilemese de tatminkâr bulundu. Ayrıca araştırıcıların görüşüne göre, sternal döndürme tekniğinin 12 aylıktan küçük kedilerde PE 'un tedavisi için kullanılmasının ayrıca araştırılması gerekmektedir.

Anahtar sözcükler: *Pektus Ekskavatum, Eksternal Splint, Sternal Döndürme, Kedi*

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INTRODUCTION

Pectus excavatum (PE) is an uncommon congenital abnormality of the chest wall and it is characterised by a concave deformity of the caudal sternum and consecutive narrowing of the entire thorax [1,2]. This anomaly has been reported in humans, cats, dogs, cows, sheep, ruffled lemurs and sea otters. While the aetiology of PE is poorly understood, possible reasons have been reported as; shortening of the central diaphragmatic tendon, abnormal diaphragmatic musculature or abnormal intrauterine pressure, especially in the congenital form [3]. PE is inherited in humans, and the predisposition of Burmese kittens and brachycephalic dogs suggests a possible heritable basis in small animals [1].

The major clinical symptoms in PE are growth retardation, exercise intolerance, cyanosis, tachypnea and vomiting [4]. Cardiac displacement, murmurs and cardiomegaly may occur in humans and small animals [5,6]. A diagnosis of PE can be made by palpation and radiography. The deformity may be evaluated objectively by measuring the fronto-sagittal and vertebral indices on thorax radiographs [7].

Animals with solely a flat chest may contour to near normal configuration, medical management could be prefered [2]. Surgical treatment of PE is indicated when cardiopulmonary signs are severe. In very young patients, when the tissues are still pliable, external splinting may be used [4,6,8]. Older animals usually require surgery on the hard or soft tissues of the thoracic wall to allow correction of the defects [9-13].

In this study, the authors evaluated the surgical treatment results of both young and adult cats with PE using external splint and sternal turnover technique.

MATERIAL and METHODS

Patient Selection and Preoperative Evaluation

All cats were brought with the complaint of respiratory distress. Cats with concave deformity of the caudal sternum determined during clinical examination were included in the study. Depending on respiratory rate and the severity of exercise intolerance and dyspnoea, clinical severity score (CSS) was rated between 0-5 during clinical examination. No clinical signs during examination was scored 0 and prolongesd periods of dyspnea with evidence of significant extrathoracic disease was scored as 5, according to previous study [14]. Radiographic examination of the thorax and blood tests were carried out routinely.

Frontosagittal (FSI) and vertebral indices (VI) were used to assess the severity of PE in all patients. FSI is the ratio of thoracic width at T10 level in dorsoventral radiography and the distance from the centre of the ventral surface of T10 or the vertebra overlying the deformity to the nearest point on the sternum in laterolateral radiography. VI is the ratio of the distance from the centre of the dorsal surface of the vertebral body overlying the deformity to the near point of the sternum and the dorsoventral diameter of the centrum of the same vertebra. FSI between 0.7-1.3 and VI between 12.6-18.8 were considered normal [14]. FSI >2 and VI <9 were considered as surgical candidates.

Surgery

Butarphanol (Butomidor®, Interhas) 0.4 mg/kg SC was used for preanesthethesia. Also we took precaution to avoid postoperative respiratory distress by the use of butarphanol at the same time. Anesthesia was induced with 2-4 mg/kg IV propofol (Pofol®, Sandoz) and maintained with isoflurane in oxygen. Non-rebreathing anesthesia circuit was used. Patients were positioned in dorsal recumbency and the ventral thorax was aseptically prepared for surgery. Perioperative fluid therapy consisted of Lactated Ringer's solution (10 mL/kg/h). Three different surgical treatment method were used depending on the pliablility of the hard and soft tissues. Ceftriaxone (Novosef® Zentiva) 50 mg/kg IV was administered 30 min before the operation.

External Splint Application

Preoperatively, a U-shaped, two sided splint made of PVC material was prepared by making holes at 1 cm intervals to include the sternum. The patient was positioned in dorsal recumbency. Non-absorbable monofilament no:1 suture material (Propilen®, Dogsan) was passed under the internal surface of the sternum starting from the caudal xiphoidea. Suture ends were left long and tagged with mosquito haemostats. All stay sutures were passed through the holes on the splint using an 18-gauge needle and then tied securely. The edges of the splint were padded. A bandage was applied lightly to cover the splint. The splint was removed three weeks post-surgery. After removal of the splint, normal thoracic depth was observed in physical and radiographic examinations.

Internal Splint Application

A medial ventral surgical approach to the sternum was used. Sternebrae were liberated from the superficial, deep pectoral and rectus thoracis muscle attachments by periosteal elevation [13]. Non-absorbable no:1 mono-filament sutures were passed under the sternebrae and costae and then were passed through the holes on the special design T-shaped plate (316-L steel) and finally tied securely. The skin was closed routinely *(Fig. 1)*.

Sternal Turnover Technique

The cat was positioned in dorsal recumbency, and both the ventral aspect of the thorax and the abdomen were prepared aseptically for surgery *(Fig. 2-A)*. A midline skin incision was made extending from the manubrium of the sternum to 2 cm cranial to the umbilicus *(Fig. 2-B)*.

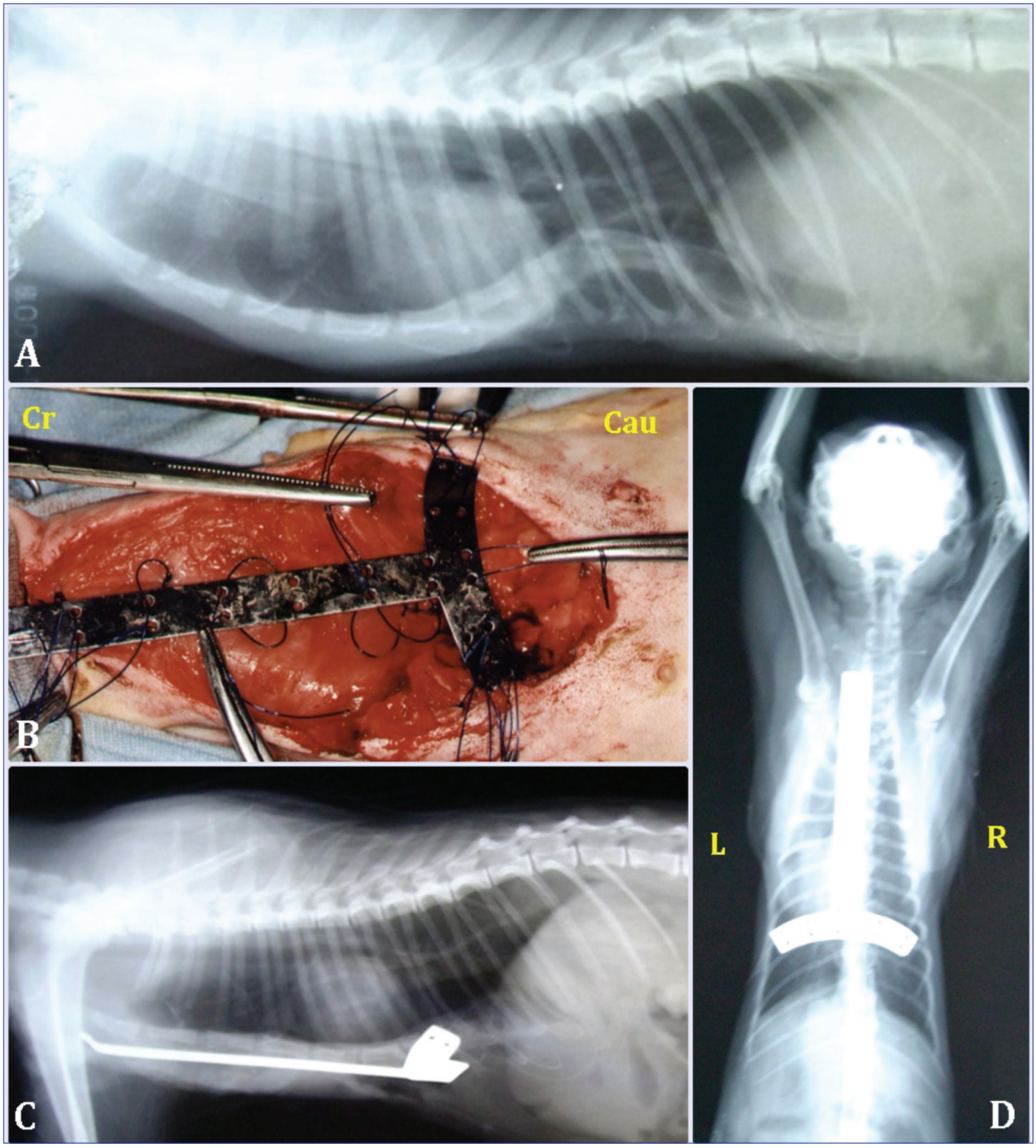

Fig 1. Internal splint application, case no 2. Preoperative lateral radiographic view, **A**; Placement of internal splint to ventral thorax by circumcostal and circumsternal sutures, **B**; Postoperative lateral radigraphic view, **C**; Postoperative dorsoventral radiographic view, **D**; *Cr*, cranial; *Cau*, caudal; *L*, left; *R*, right

Following this, the sternum was transected just above the point where it begins its posterior displacement. Costal cartilages and medial ends of the intercostal muscles were then resected en bloc *(Fig. 2-C,D)* [15]. The sternum was freed from its dorsal attachments, turned over and attached to its cranial part using Kirschner wires *(Fig. 2-E,F,G,H)*. Next, the lateral and caudal parts of the sternum were attached to muscles and other soft tissue structures using no:0 monofilament absorbable suture material (Tekmon®, Dogsan) in a simple interrupted fashion *(Fig. 2-I)*. Skin and subcutaneous tissues were closed using 2/0 monofilament non-absorbable suture material (Propilen®, Dogsan) *(Fig. 2-J)*. Laterolateral and dorsoventral thorax radiographs were taken and evaluated in the pre- and post-operative periods and also following removal of the Kirschner wire *(Fig. 3)*.

Postoperative Management and Evaluation

Patients were placed in an oxygen tent and respiratory rate, mucous membrane colour and existence of dyspnoea was

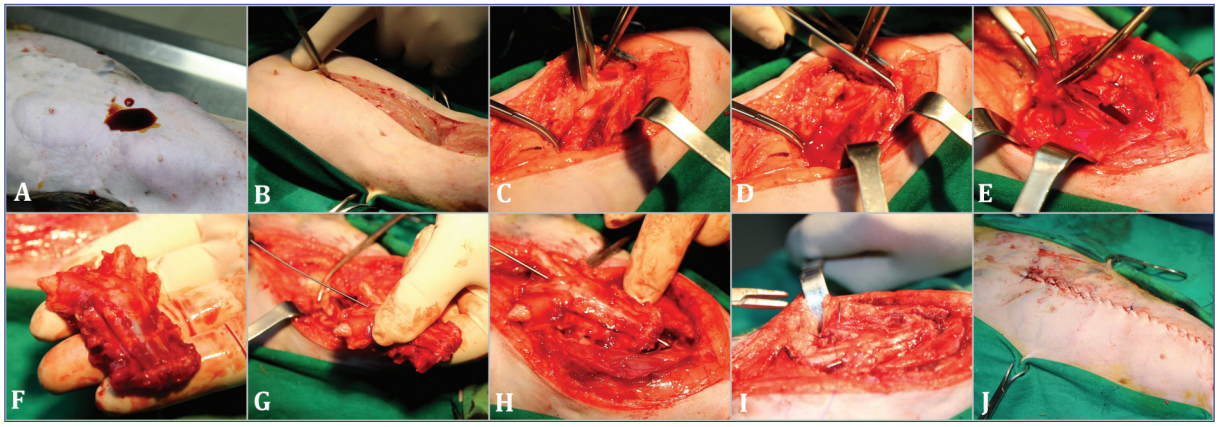

Fig 2. Operation stages of the sternal turnover technique. Patients were positioned in dorsal recumbency and ventral thorax was aseptically prepared, **A**; Median skin incision was made from manubrium to the caudal of xyphoid process, **B**; Costal cartilages and the medial ends of the intercostal muscles were then resected en bloc, **C**; Sternum was transected just above the point where it begins its posterior displacement, **D**; Sternum was freed from its dorsal attachments, **E-F**; Sternum was turned over 180° and ø 1.5 kirshner wire was passed through the centre of the sternebrae, **G-H**; Next, sternum was attached to its cranial part by kirchner wire and lateral and caudal parts of sternum were attached to muscles and other soft tissue structures using no:0 monofilament absorbable suture material, **I**; Subcutaneous tissues and skin were closed routinely, **J**

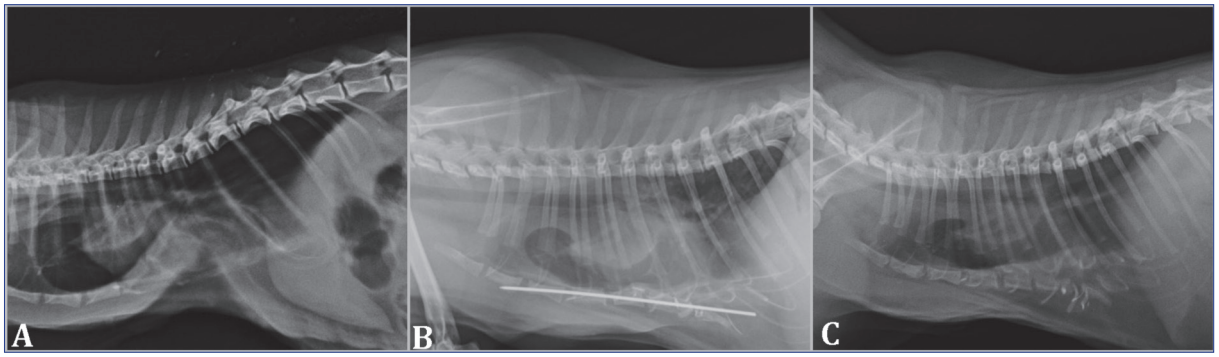

Fig 3. Preoperative and postoperative control radiographs of a cat (Case no: 6) in the sternal turnover group. Preoperative view of the sternal concavity, **A**; Changes in the sternal concavity immediately after operation, **B**; Lateral thorax radiography of the same cat 2 months after the operation, immediately after removal of the kirschner wire, **C**

observed at regular intervals. Administration of antibiotic and analgesic medications (Ceftriaxone and butarphanol) were continued for 7 days. External splints were removed 20 days after the operation and control radiographs were taken. In patients treated using the sternal turnover technique, Kirschner wires were removed 1.5-2 months postoperatively. FSI and VI values were recalculated in external splint and sternal turnover groups on radiographs taken 20 days and 1.5-2 months postoperatively, respectively. CSS was reevaluated and recorded at the same time.

RESULTS

The material of this study comprised a total of 18 cross bred cats (10 male and 8 female). Their ages varied between 2 and 24 months (average 11.1 months). During this study PE was diagnosed in 2 littermates from the same mother. Case no 16 and 17 were brothers and external splint application was carried out. Clinical signs included palpable abnormality of the sternum, as well as exercise intolerance and dyspnea in all of the patients. CSS was evaluated in both the preoperative and postoperative period. Patient were split into groups according to their age at the time of admission. While the external splint technique was used in cats younger than 12 months old, the sternal turnover technique was used in cats older than 12 months of age.

PE was treated using the sternal turnover technique in 8 patients, internal splint in 1 patient and external splint in 9 patients. One of the patients (case no: 7) treated with an external splint died in the acute postoperative period due to respiratory distress. Also another patient in the external splint group (case no: 4) was presented to the clinic with a complaint of severe dyspnea one week after removal of the external splint. Control radiography revealed that the concave deformity of the sternum had worsened after splint removal. The external splint was reapplied. The internal splint application in one patient (case no: 2) failed. A reaction occurred between the soft

Table 1. *Signalment, preoperative and postoperative FSI and VI indices and CSS, surgical techniques used and complications including information belonging to the patients*

Case No	Age (month)	Breed	Sex	Technique	Preop CSS	Postop CSS	Preop FSI	Postop FSI	Preop VI	Postop VI	Complications
1	6	Cross bred	Female	External Splint	3	1	3.2	2.1	5.3	7.5	
2	12	Cross bred	Male	Internal Splint	3	3	2.1	N/A	8.2	N/A	Seroma formation and soft tissue reaction. Splint was removed
3	18	Cross bred	Male	Sternal Turnover	4	1	3.3	2.1	3.2	11.7	
4	2	Cross bred	Female	External Splint	3	2	3.1	2.4	4.4	7.1	Respiratory distress, external splint was removed and reaplicate 1 month later
5	7	Cross bred	Male	External Splint	4	0	3.0	1.2	7.1	11.9	
6	14	Cross bred	Female	Sternal Turnover	3	0	2.6	1.4	7.5	12.4	
7	4	Cross bred	Male	External Splint	4	N/A	3.1	N/A	7.3	N/A	Died
8	19	Cross bred	Male	SternalTurnover	3	0	2.6	1.9	7.9	11.1	
9	9	Crossbred	Female	External Splint	3	1	2.6	1.9	7.9	12.2	
10	8	Cross bred	Male	External Splint	3	0	3.1	2.5	6.1	9.1	
11	16	Cross bred	Female	Sternal Turnover	3	0	2.5	1.7	7.7	10.3	
12	14	Cross bred	Male	Sternal Turnover	2	0	4.5	1.4	5.7	12.9	
13	19	Cross bred	Female	Sternal Turnover	2	0	2.2	1.5	6.9	10.8	
14	20	Cross bred	Male	Sternal Turnover	3	1	3.4	1.7	7.1	10.6	
15	24	Cross bred	Female	Sternal Turnover	3	1	3.5	2.2	7.4	10.9	
16	3	Cross bred	Male	External Splint	3	1	3.1	1.8	6.8	12.2	
17	3	Cross bred	Male	External Splint	3	1	3.8	2.4	6.4	8.8	
18	3	Cross bred	Female	External Splint	4	1	3.2	2.4	8.1	11.2	Relapse of respiratory signs and rising the concave deformity of thorax after removing the external splint- reoperated

FSI: frontosagittal indices; ***VI:*** vertebral indices; ***CSS:*** clinical severity score; ***N/A:*** not applicable

Table 2. *Evaluation of the postoperative mean FSI, VI and SCC values of the patients in sternal turnover and external splint groups*

Groups	Mean FSI	*sd*	Mean VI	*sd*	Mean CSS	*sd*
Sternal Turnover Group (n=8)	1.8	*0.3*	11.3	*0.8*	0.4	*0.5*
External Splint Group (n=8)	2.1	*0.3*	10.0	*1.5*	0.8	*0.4*

FSI: *frontosagittal indice;* ***VI:*** *vertebral indice;* ***CS:*** *clinical severity score;* ***sd****= standart deviation*

tissue and the plate and the material had to be removed *(Table 1)*.

When the external splint and sternal turnover groups were evaluated separately, the improvement in FSI and VI values in the postoperative period were different. Mean FSI and VI values were 2.1 and 10.0 in the external splint group and these values did not reach the reference interval. On the other hand, general clinical condition and CSS (mean 0.8) values were satisfactory in the external splint group when compared to the preoperative period. FSI and VI values were close to the reference interval in the sternal turnover group (FSI, mean 1.8; VI, mean 11.3) at 1.5-2 months postoperatively and general condition and CSS (mean 0.4) values had improved as much as the external splint group *(Table 2)*.

Postoperative skin abrasions, suture abscesses, and dermatitis-like complications were rarely observed and any additive evaluation was not required.

DISCUSSION

Pectus excavatum, also known as funnel chest or trichterbrust, is a skeletal abnormality of the sternum characterised by dorsal deviation of the sternebrae and resultant dorsoventral compression of the thorax [3]. Aetiology of the congenital form is poorly understood. Theories such as; shortening of the central diaphragmatic tendon, abnormal diaphragmatic musculature or abnormal intrauterine pressure have been put forward [6]. Predisposition in Burmese cats suggests that this developmental defect

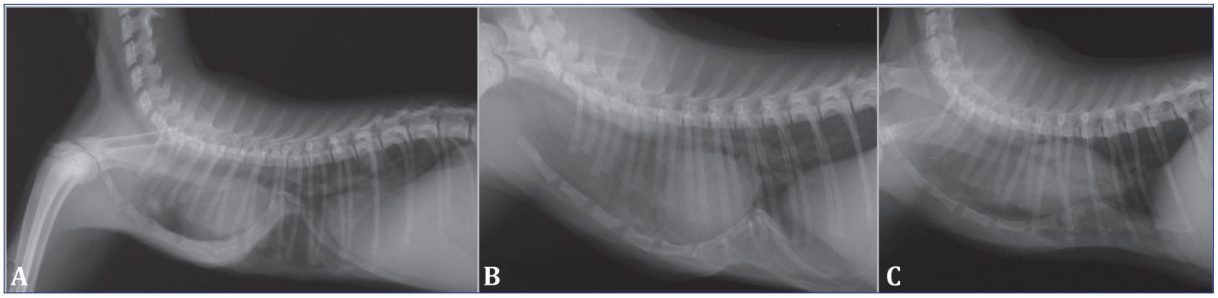

Fig 4. Case no: 4. Preoperative radiography, **A**; One week after removal of external splint, **B**; One month after second external splint application, **C**

may be heritable in some cases [16]. In this study, PE was determined in 2 littermates. Although no genetic tests have been performed, it has been suggested that PE may be heritable in such cases.

PE has been reported in Bengal, Main Coon, Burmese, domestic shorthair and domestic longhair cats [4,8,14,16,17]. Domestic shorthair and domestic longhair cats are cats of mixed ancestry and thus not belonging to any particular recognised cat breed [18], in other words cross bred. In the present study, all of the cats were cross bred. When the authors analyzed previous studies, PE was commonly seen in cross bred cats. The breed distribution of cats in this study is compatible with previous cases and studies.

External splint application to the ventral aspect of the thorax is the most common technique used to correct PE defects in small animals. However, the external splint technique can be used in young animals due to the pliability of the costal cartilage and sternum, and the thorax can be reshaped by applying traction to the sternum using sutures [2]. Although some studies suggest that external splintage should be used before 4 months of age [4], it is also known that this technique can be used in older animals and FSI and VI could be improved [8]. In this study, the external splint technique was used in cats older than 4 months old (oldest 9 months-old). Postoperative mean FSI and VI values did not reach the normal reference ranges but respiratory and cardiopulmonary signs had regressed. Body weight was increased and exercise intolerance and high respiratory rates were decreased in most of the patients in the postoperative period. Mean CSS in this group was 0.8. One patient (case no:18) was brought to the clinic 1 month after removal of the external splint, with complaints of a relapse of the respiratory signs and an increase in the concave deformity of the sternum. In this case, the external splint was reapplied and removed 3 weeks later as usual *(Fig. 4)*. It is known that, the ensuing costal mineralisation provides sufficient rigidity to maintain the costal arch and sternum in their final correct shape after removal of the external coaptive device [13]. Ongoing contraction of the central diaphramatic tendon, especially in ages 2 to 4 months may be the reason of the rising concavity after removal of the external splint in this case. According to the authors' observations, external splint was considered to be better tolerated in 5 to 9 month-old cats in terms of postoperative adaptation and respiratory signs regressed more rapidly. On the other hand, the reanimation period was longer and respiratory distress-like complications were more common in cats younger than 4 months of age in the external splint group in this study.

In adult cats, the sternum is less pliable and the external splint technique may not be sufficient enough to correct sternal abnormality. Because of this, instead of external splints, the plate and Kirschner wire were both used to correct sternal deformity in cats older than 4 months [12,13]. In this study, the researchers used a special design T-shaped plate to correct sternal deformity in a 12 month-old cat as an internal splint but the results were not satisfactory. In this case, the plate was placed on the sternum and attempts to stabilise were made using circumsternal and circumcostal sutures. In this case, poor stabilization of the plate resulted in soft tissue reaction and seroma formation under the skin. The plate was removed and no other treatment options were applied since consent was not given by the owner.

Sternal turnover technique was first described in 1965 for the treatment of PE in human patients [10]. Satisfactory results using this technique were obtained in 97% of the 199 patients in the 15-year experience. Despite the excellent results and the appeal of such a direct method of repair, experience with sternal turnover has been limited even in human medicine until the 1980s [11]. In this study, the researchers preferred to use this technique to treat PE in cats older than 12 months. When preoperative and postoperative FSI and VI values were examined, it was determined that FSI and VI values close to normal chest conformation could be reached in the sternal turnover group. In addition, postoperative CSS values were between 0-1 in all of the patients in the postoperative period. Although sternal turnover has some disadvantages, such as a long operation time and more invasive surgical technique when compared to other internal splint methods, results were satisfactory. On the other hand, sternal turnover technique may give better results, if this

technique is used in cats younger than 12 months of age, since the cats continue to grow.

In conclusion, the results achieved by the authors suggest that, sternal turnover technique may be used successfully to correct sternal deformity in PE in cats older than 12 months of age. Also, results of using the sternal turnover technique in PE patient cats younger than 12 months of age should be further investigated.

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