Case Report

Case Report: Surgical Repair and Pericardial Drainage in a Scottish Fold Cat with Congenital Peritoneopericardial Diaphragmatic Hernia

Rutjathorn Maneewan Wijit Sutthiprapa Wutti Bunjerdsuwan Chaiyakorn Thitiyanaporn*

Faculty of Veterinary Medicine, Kasetsart University, Bangkok 10900, Thailand

***Corresponding author, E-mail address: chaiyakorn.t@ku.th**

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Abstract

Peritoneopericardial diaphragmatic hernia (PPDH) is the most frequently encountered congenital defect affecting the diaphragm and pericardium in cats. This report aimed to present the case of a 4-month-old intact male Scottish Fold cat that was diagnosed with PPDH, focusing on the surgical technique for pericardial drain insertion and the long-term outcome. The patient had a history of acute vomiting. Physical examination revealed abdominal breathing and mild abdominal discomfort upon palpation, with no history of dyspnea or cyanosis. Thoracic radiography confirmed the diagnosis of diaphragmatic hernia, while abdominal ultrasonography revealed displacement of parts of the liver and gallbladder into the pericardial space, along with thickening of the intestinal wall. Based on this investigation, congenital PPDH was diagnosed. Surgical repair of the PPDH was performed, and the hernial contents included the liver and gallbladder in the pericardial sac. The PPDH was closed with nylon No.3-0 using a simple continuous suture pattern. Air was aspirated from the pericardial sac to establish negative pressure by a pericardial tube. One year post-surgery, the cat exhibited normal breathing and regained overall health.

Keywords: Cat, Pericardial tube, Peritoneopericardial diaphragm hernia, Surgical treatment

รายงานสัตว์ป่วย: การผ่าตัดแก้ไขและการระบายเยื่อหุ้มหัวใจ โรคไส้เลื่อนกะบังลมเยื่อบุช่องท้องและเยื่อหุ้มหัวใจแต่กำเนิด ในแมวสกอตติช โฟลด์

รุจธร มณีวรรณ วิจิตร สุทธิประภา วุฒิธิ บรรเจิดสุวรรณ ชัยกร ฐิติญาณพร*

คณะสัตวแพทยศาสตร์ มหาวิทยาลัยเกษตรศาสตร์ กรุงเทพฯ 10900 ประเทศไทย

*ผู้รับผิดชอบบทความ E-mail address: chaiyakorn.t@ku.th

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บทคัดย่อ

โรคไส้เลื่อนกะบังลมเยื่อบุช่องท้องและเยื่อหุ้มหัวใจ (Peritoneopericardial diaphragmatic hernia: PPDH) เป็นความผิดปกติตั้งแต่กำเนิดที่ส่งผลกระทบต่อกะบังลมและเยื่อหุ้มหัวใจ พบได้บ่อยในแมว รายงานนี้มีวัตถุประสงค์เพื่อนำเสนอกรณีศึกษาของแมวสายพันธุ์สกอตติช โฟลด์ อายุ 4 เดือน เพศผู้ ยังไม่ทำหมันซึ่งได้รับการวินิจฉัยว่าเป็นโรค PPDH โดยเน้นที่เทคนิคการผ่าตัดที่มีการใส่สายสวนระบายเยื่อหุ้มหัวใจและผลลัพธ์ระยะยาว โดยสัตว์ป่วยมาด้วยอาการอาเจียนเฉียบพลัน โดยจากการตรวจร่างกายพบว่าสัตว์ป่วยมีการหายใจโดยใช้ช่องท้องและรู้สึกไม่สบายเล็กน้อยเมื่อมีการคลำบริเวณช่องท้อง และไม่พบประวัติของอาการหายใจลำบากและลักษณะเขียวคล้ำของเยื่อเมือกมาก่อน โดยจากการถ่ายภาพรังสีช่องอกช่วยยืนยันการพบภาวะไส้เลื่อนกะบังลมและจากภาพอัลตร้าซาวด์ช่องท้องพบการเคลื่อนของตับและถุงน้ำดีเข้าสู่ช่องเยื่อหุ้มหัวใจ พร้อมกับพบการหนาตัวของผนังลำไส้ จากผลการตรวจข้างต้นสัตว์ป่วยจึงถูกวินิจฉัยว่าเป็นโรค PPDH แต่กำเนิด และได้มีการผ่าตัดแก้ไขโรค PPDH โดยพบว่าอวัยวะที่เข้าไปอยู่ในเยื่อหุ้มหัวใจคือตับและถุงน้ำดี จากนั้นจึงได้ทำการเย็บปิด PPDH โดยใช้ไนลอนเบอร์ 3-0 โดยใช้เทคนิคการเย็บแบบต่อเนื่องจากนั้นมีการดูดอากาศออกจากเยื่อหุ้มหัวใจผ่านทางสายสวนระบายเพื่อสร้างแรงดันลบ หลังการผ่าตัด 1 ปี พบว่าแมวมีการหายใจเป็นปกติและมีสุขภาพโดยรวมที่ดี

คำสำคัญ : แมว สายสวนระบายเยื่อหุ้มหัวใจ โรคไส้เลื่อนกระบังลมเยื่อบุช่องท้องและเยื่อหุ้มหัวใจ การรักษาโดยการศัลยกรรม

Introduction

Peritoneopericardial diaphragmatic hernia (PPDH) occurs when there is an abnormal connection between the pericardial sac and the abdominal cavity (Nikiphorou et al., 2016). In both cats and dogs, PPDH is linked exclusively to congenital defects (Banz and Gottfried 2010). It is hypothesized that incomplete midline fusion during embryonic development or prenatal trauma may contribute to the formation of PPDH (Margolis et al., 2018). As a result of this formation, abdominal organs can move into the pericardial space. The liver, gallbladder, and small intestines are the most commonly herniated organs (Lohinger et al., 2022). A thoracic radiograph is a common diagnostic tool for identifying this condition. Additional imaging techniques, such as positive contrast radiography using oral barium, ultrasonography, echocardiography, and computed tomography (CT), can also be used for diagnosis (Campanile et al., 2024).

PPDH is typically discovered incidentally in cats, often without specific clinical signs. In such cases, the absence of symptoms makes it challenging to justify surgical intervention (Linton et al., 2016). Surgical intervention is recommended for patients showing clinical signs and typically involves closing the congenital defect. During surgery, a tear in the pericardium leading to communication with the pleural cavity may result in postoperative pneumothorax (Hunt 2012). Additionally, the size of the diaphragmatic defect can affect the amount of air that accumulates in the pericardial sac, potentially causing postoperative pneumopericardium (Papazoglou et al., 2015). However, Pneumopericardium associated with PPDH repair has not been reported in the veterinary literature (Papazoglou et al., 2015). A thoracostomy tube is inserted when the pleural cavity is accessed and is typically removed either shortly after the patient recovers from anesthesia or within 12 hours after surgery (Banz and Gottfried 2010). Management of pneumopericardium is typically unnecessary unless the cardiopulmonary function is compromised due to significant air accumulation within the pericardial sac (Papazoglou et al., 2015).

PPDH in Scottish Fold Cats is uncommon. Normally, PPDH in cats is presented in long-haired breeds, including Persians, Himalayans, Maine Coons, and domestic long hairs (Margolis et al., 2018). In this case report, the surgical technique showed the success of PPDH management in cats using pericardial drain surgery. This case report describes clinical presentations, preoperative management, surgical technique, postoperative care, long-term follow-up, and outcome.

Case descriptions

A 4-month-old intact male Scottish Fold cat presented to the Kasetsart University Veterinary Teaching Hospital (KUVTH), Faculty of Veterinary Medicine, Kasetsart University, exhibiting acute vomiting. Physical examination revealed abdominal breathing and mild abdominal discomfort upon palpation, with no history of dyspnea or cyanosis. The cat had a complete vaccination history and lived in a closed-system environment. Hematology examinations showed mild anemia and leukocytosis. Blood chemistry showed increased alanine aminotransferase. Thoracic radiographs revealed an enlarged cardiac silhouette (Figure 1), while abdominal ultrasound showed a discontinuous diaphragmatic line, with both the liver and gallbladder located within the pericardial sac (Figure 2), leading to the suspicion of PPDH. Supportive treatment was administered continuously, including an omeprazole dose of 0.7 mg/kg was administered intravenously once daily, while a maropitant citrate dose of 1 mg/kg was administered subcutaneously once daily (Cerenia®, Zoetis), and an

amoxicillin-clavulanic acid dose 20 mg/kg was administered intravenously every 8 hours (Cavumox®, Siam Bheasach). After two weeks of supportive treatment, a repeat of hematology and blood chemistry examinations showed improvement (Table 1). However, signs of abdominal breathing persisted. From this problem, the surgical correction of PPDH was recommended to the owner.

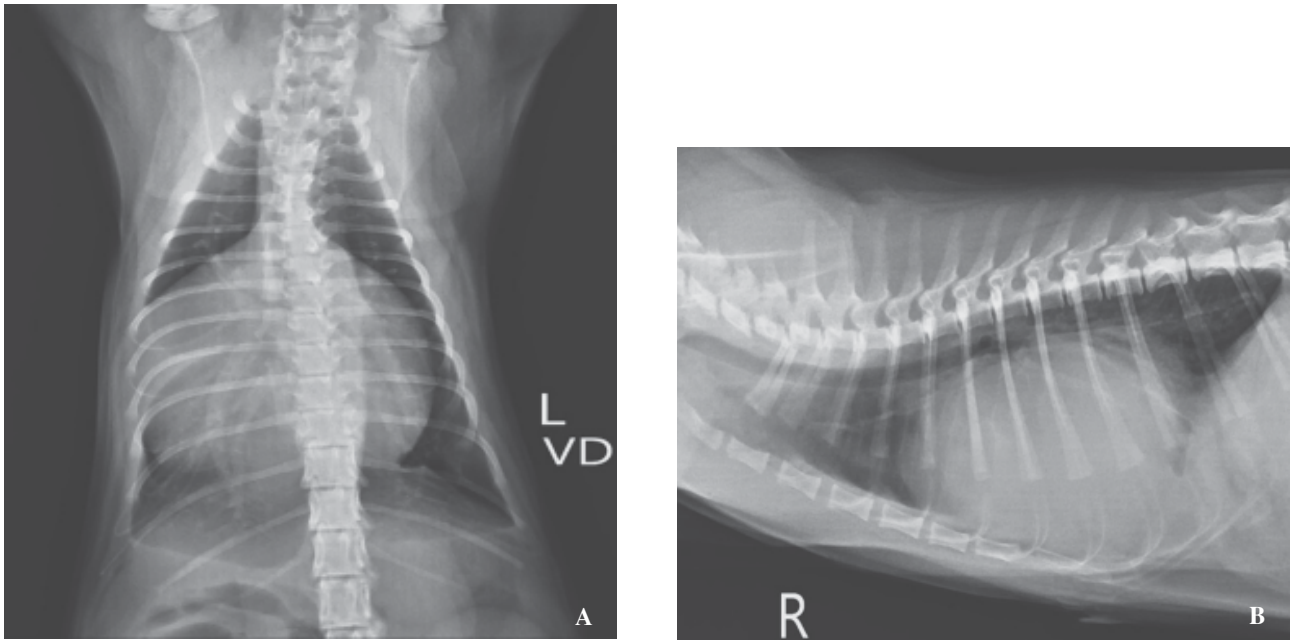


Figure 1. Thoracic radiographs of ventrodorsal (A) and lateral (B) views showing a severely enlarged cardiac silhouette with discontinuing of the ventral diaphragmatic line at the ventral region concurrent with small hepatic volume at the cranial abdomen.

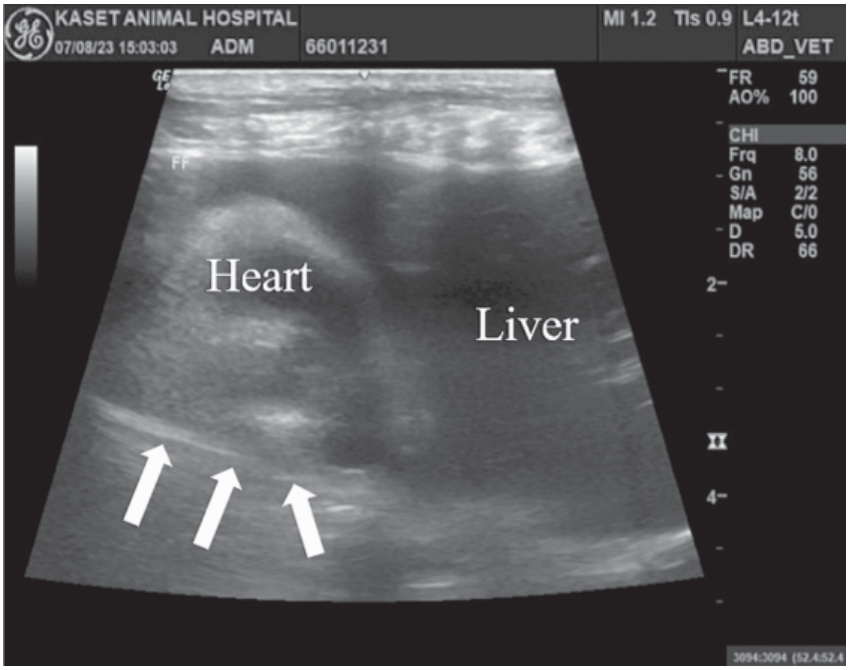


Figure 2. Thorax and abdominal ultrasound revealed a part of the liver displaced into the pericardial sac. The white arrows indicated the boundary of the pericardial sac.

Table 1. Complete Blood Count and Serum Biochemistry results before and after supportive treatment.

Parameter	Before supportive treatment	After supportive treatment	Reference range*
Hemoglobin	9.1	11.5	9.8-15.4gm%
Hematocrit	24	34	30-45%
RBC	6.61	8.66	5-10fL
WBC	13.77	21.65	5.5-19 x 10^3/μL
SEGS	49	30	2.5-12.5 10^3/μL
LYMPH	38	63	1.5-7 10^3/μL
RETICS	0.18	0.19	0-0.6%
Platelets	64	477	200-500 x 10^3/μL
Plasma protein	7.0	7.0	5.8-7.8 gm%
BUN	22	30	15-34 mg/dL
Creatinine	1.1	1.01	0.5-1.8 mg/dL
ALT	574	74	28-80 U/L
Albumin	3.1	3.3	2.3-4 gm%
Total protein	6.3	6.3	5.8-7.8 gm%

*Reference ranges used at the Laboratory of Veterinary Diagnostic Unit, Faculty of Veterinary Medicine, Kasetsart University, Thailand; RETICS = Reticulocyte; RBC = Red blood cell; WBC = White blood cells; SEGS = Segmented neutrophils; LYMPH = Lymphocytes.

*Reference ranges of serum parameters analyzed by IDEXX VetTest Chemistry Analyzer, BUN = Blood urea nitrogen; ALT = alanine aminotransferase.

Preoxygenation and electrocardiogram (ECG) monitoring were performed. ECG revealed a normal electrocardiographic pattern. For anesthetic induction, propofol was administered intravenously at a dose of 8 mg/kg. Maintenance of anesthesia was achieved using sevoflurane at 1.3-1.5% of the minimum alveolar concentration (MAC = 2.6) via inhalation. Pain management included morphine at a dose of 0.3 mg/kg intramuscularly, followed by an intravenous loading dose of fentanyl at 2 mcg/kg. Continuous rate infusion (CRI) of fentanyl was administered intravenously at a rate of 10 mcg/kg/hr. The cat was positioned in dorsal recumbency for the preparation of the surgical site, which included hair clipping and scrubbing routinely with a 2% chlorhexidine scrub and 70% isopropyl alcohol.

A laparotomy was performed by a longitudinal incision along the cranial midline of the abdomen from the xiphoid cartilage to the umbilicus. The peritoneum was dissected away from the muscular part of the diaphragm using Metzenbaum scissors (Figure 3). The gallbladder, right lateral, and right medial liver lobes were found in the pericardial sac as hernial contents and passed through the opening of the ventral third of the diaphragm. The visceral organs and pericardial sac showed no adhesion. The herniated organs were returned to their original positions, and herniorrhaphy was performed using a simple continuous suture pattern with a monofilament, non-absorbable suture (Dafilon® 3-0, B Braun, Spain).

After suturing, a pericardial drainage tube (silicone oval-shaped DEK eyes, open-ended tube, non-toxic and medical-grade materials, size 6 French; manufactured by K.F. Medical Co., Ltd., Thailand) was placed into the pericardium, passed through the ventrally of the herniorrhaphy site, and exited externally through the abdominal wall at the left paramedian (Figure 4). The abdominal cavity was closed using a simple continuous suture pattern with monofilament, absorbable sutures (PDS™II 3-0, Ethicon®, USA). Air from the pericardial sac was aspirated to achieve negative pressure. The drainage tube was left in place to enable postoperative air and fluid removal. The skin was closed with a monofilament, non-absorbable suture, and cross mattress pattern (Dafilon® 3-0, B Braun, Spain). Postoperative radiographs of the thorax in the ventrodorsal view and lateral view showed no evidence of pneumopericardium and pneumothorax (Figure 5). The pericardial drainage tube was removed immediately after the thoracic radiograph. ECG monitoring in the recovery room after tube removal showed no abnormalities.

The cat was admitted to the critical care unit to observe the clinical signs of respiration. Oxygenation was provided continuously after recovery. The oxygen support was discontinued for 48 hours postoperatively. Amoxicillin-clavulanic acid dose of 20 mg/kg was administered intravenously every 8 hours (Cavumox®, Siam Bheasach) for infection control. This treatment was continued for 1 week following a 2-week course of supportive treatment. For pain control, a morphine dose of 0.2 mg/kg was administered subcutaneously every 8 hours, and a gabapentin dose of 7 mg/kg was administered by peroral route every 8 hours for 1 week. The cat was discharged from the hospital 1 week after surgery. A month after surgery, the cat showed normal vital signs and maintained a good appetite. However, thoracic radiographs revealed that the heart shadow remained enlarged, with a vertebral heart scale (VHS) of 9.5. As a result, a transthoracic echocardiographic examination was performed using a phased array probe of Mindray M9 ultrasound system with 12 MHz frequency to examine cardiac function. Measurement was performed in parasternal long

and short-axis views with the patient positioned in lateral recumbency and without the administration of sedation. The echocardiographic examination result is described in Table 2. The left ventricular wall structure and function were evaluated using two-dimensional and M-mode echocardiographic measurements, which revealed a normal left ventricular size and overall heart function. At the six-month follow-up appointment, no complications were noted, and the cat was living a normal life without any signs related to the digestive or respiratory systems.

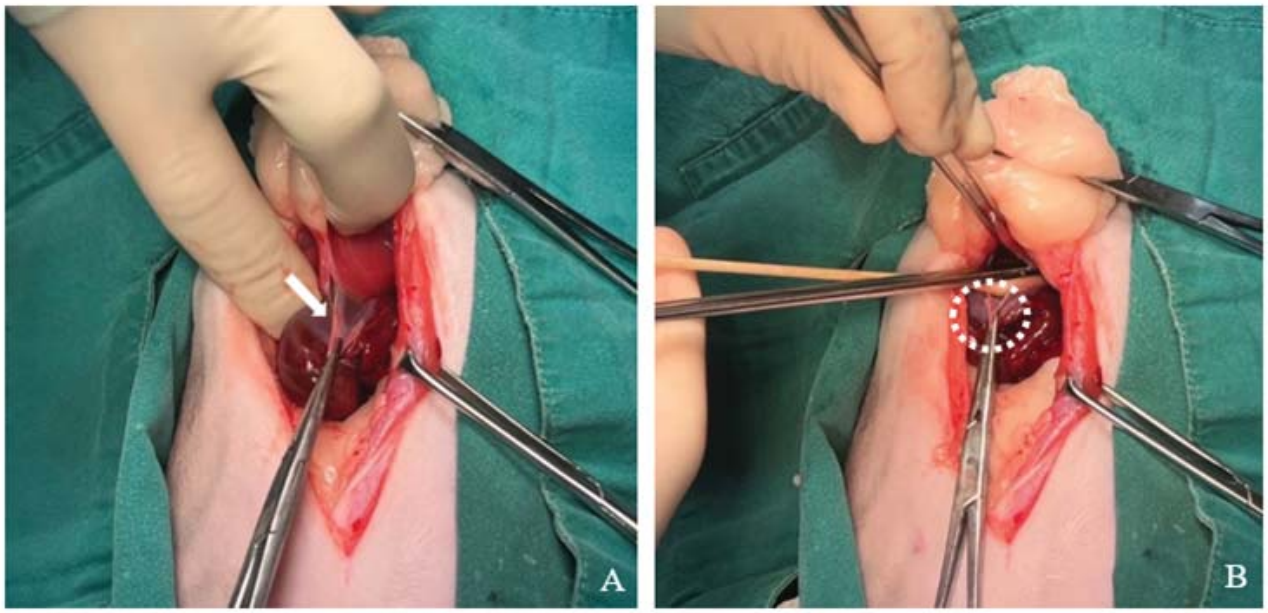


Figure 3. The white arrow highlights the adhesion between the peritoneum and the muscular part of the diaphragm (A), and Metzenbaum scissors were used to cut and separate the adhesion (B; white circle).



Figure 4. The distal end of the pericardial tube exits through the abdominal wall at the left paramedian position (Black arrow).

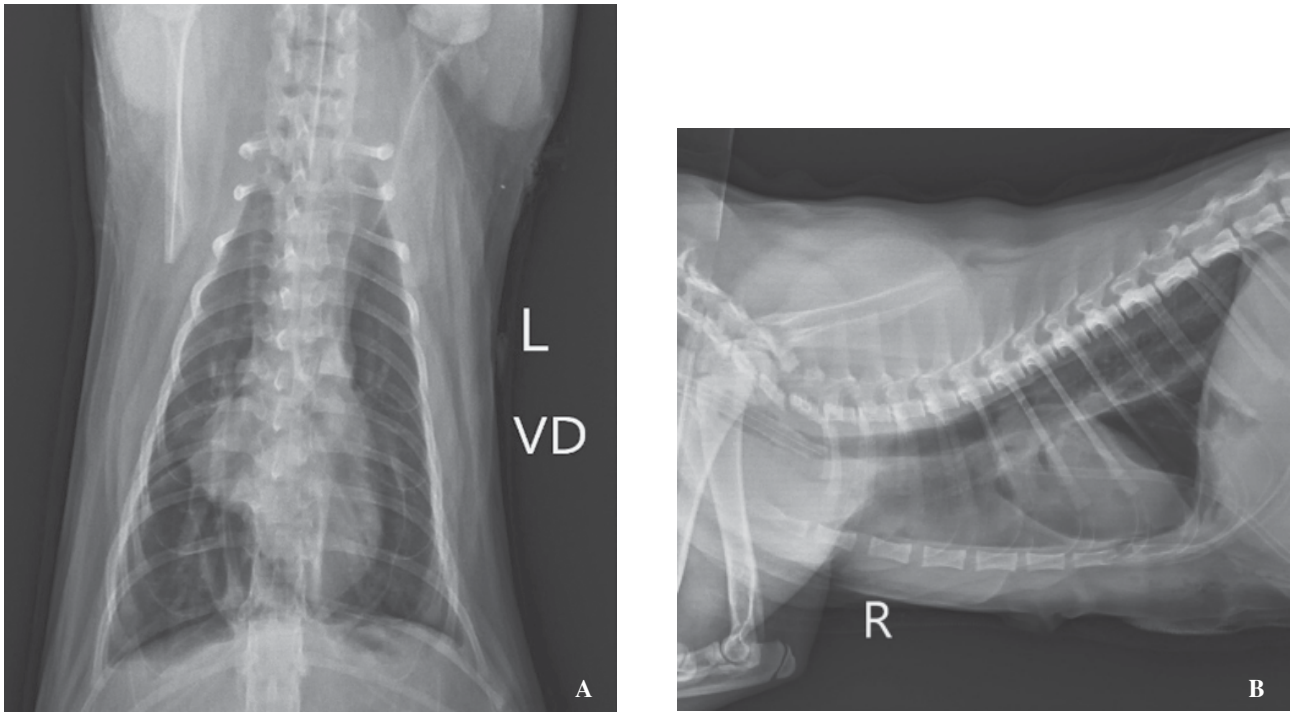


Figure 5. Postoperative thoracic radiographs of ventrodorsal (A) and lateral (B) views showed no evidence of pneumopericardium.

Table 2. Echocardiography parameters after surgical repair of PPDH in a Scottish Fold cat.

Echocardiography Parameter	Value	Reference range
IVSs (mm)	7.5 mm	4.4-8.7 mm
IVSd (mm)	5.1 mm	2.9-5.1 mm
LVIDs (mm)	7.7 mm	5.7-13 mm
LVIDd (mm)	15.3 mm	12.7-19.8 mm
LVFWs (mm)	6.7 mm	5.4-8.1 mm
LVFWd (mm)	3.9 mm	2.2-4.4 mm
FS	49.51%	28-62 %
LA:Ao	1.22	0.88-1.43
LA	10.8 mm	8.2-14.5 mm
Ao	8.9 mm	7.5-11.9 mm

*Reference ranges used at the Cardiovascular center, Faculty of Veterinary Medicine, Kasetsart University, Thailand.

IVSs, interventricular septum systole; IVSd, interventricular septum diastole; LVIDs, left ventricular internal diameter systole; LVIDd, left ventricular internal diameter diastole; LVFWs, left ventricular free wall systole; LVFWd, left ventricular free wall diastole; FS%, fractional shortening; LA:Ao, left atrial to aortic ratio; LA, left atrial diameter; and Ao, aortic diameter.

Discussion

PPDH is one of the congenital defects that present in cats over 2 years old. The prevalence of PPDH in cats (0.062%) is significantly higher (P = 0.04) compared to dogs (0.015%). More than 100 cases have been reported in domestic cats, with approximately 50% being found incidentally (Burns et al., 2013). A previous study reported that Persians and other long-haired breeds (domestic long-hair and Himalayans) have a higher predisposition to PPDH (Reimer et al., 2004). Similar to a report in 2004, the prevalence of PPDH was high in long-haired cats, particularly Maine Coon, and Persians when compared to domestic cats (prevalence = 0.062-0.59%) (Margolis et al., 2018). However, PPDH in short-haired cats such as Scottish Fold cats has rarely been reported in the last decade (Burns et al., 2013). Clinical signs of PPDH in short-haired and long-haired cats are similar signs. The commonly reported clinical signs include asymptomatic cases, muffled heart sounds, respiratory distress, and gastrointestinal symptoms like regurgitation, anorexia, or vomiting (Margolis et al., 2018). In this case, the cat exhibited clinical signs including abdominal breathing and gastrointestinal symptoms.

The liver is the most commonly herniated organ in PPDH cases (Sicoe et al., 2019). When the liver becomes trapped within the pericardial sac, it can lead to inflammation, which may result in elevated liver enzyme levels in blood tests (Linton et al., 2016). Additionally, other organs such as the stomach, small intestine, and pancreas can also herniate. Inflammation of these organs may cause conditions such as leukocytosis and anemia (Lee and Kim 2014). However, patients with PPDH do not consistently exhibit anemia, leukocytosis, or elevated liver enzymes. Blood test changes often depend on the specific pathological conditions present at the time. In this case, the elevated liver enzyme levels are likely due to inflammation caused by the liver's displacement into the pericardial sac. As for the anemia and leukocytosis, they may be related to concurrent gastroenteritis or other underlying conditions occurring simultaneously.

The treatment approach for PPDH can be either surgical or conservative, with both options offering good long-term survival rates (Morgan et al., 2020). Conservative treatment is usually performed in asymptomatic cases, while surgical intervention is recommended for symptomatic patients. Surgical correction is generally recommended for the treatment of PPDH and should be performed as early as possible in young animals (Fossum 2018). In this case, the surgery was conducted at 4 months old, which likely contributed to the absence of adhesions.

In terms of the PPDH surgical technique, the cranial midline celiotomy approach is the most popular. In addition, caudal median sternotomy can be performed when adhesions are present between the liver or intestines and the pericardium (Burns et al., 2013). In the final step of the procedure, the air should be evacuated from the pericardial cavity using a drainage tube to prevent the limited expansion of the lung (Lohinger et al., 2022).

The incidence of pneumopericardium after surgical correction of PPDH is not frequently reported in veterinary literature. However, complications such as pneumothorax or pneumopericardium may occur due to the surgical procedure's invasive nature and manipulation of thoracic and pericardial structures (Less et al., 2000). During surgery, accidental tearing of the pericardium may occur, potentially leading to pneumothorax. Therefore, placing a pericardial drainage tube can help ensure that no air remains in the pleural cavity postoperatively and confirm the integrity of the pericardium. This technique is simple, requires minimal equipment, and has relatively low complication rates. Potential

complications include malposition, tube blockage, and subcutaneous air leakage (Heier et al., 2022). In this case, a pericardial drainage tube was inserted into the pericardium, with the distal end routed through the abdominal wall. The tube placement was intended to be temporary, with the drain removed once postoperative chest radiographs confirmed the absence of pneumopericardium and pneumothorax. Exiting the tube through the abdominal wall facilitated easier removal and minimized trauma compared to routing the tube through the intercostal muscles.

Severe injuries and significant intrathoracic trauma during surgery can lead to delayed recovery from anesthesia in animals (Imazio and Hoit 2013). These injuries can increase the risk of postoperative complications and contribute to higher mortality rates, ultimately resulting in prolonged hospitalization (Legallet et al., 2017). In the current case, no tears in the pericardium extending into the thoracic cavity were observed during surgery. The surgeon placed a pericardial drainage tube to remove the air from the pericardial sac and maintained drainage until a postoperative thoracic radiograph confirmed the absence of pneumopericardium and pneumothorax (Figure 5). This procedure can contribute to a shorter postoperative hospitalization and a favorable long-term outcome.

In this case, one month after surgery, thoracic radiographs revealed a persistently enlarged cardiac silhouette. However, echocardiogram findings indicated that the size of the cardiac muscle was within normal limits. It might be because, after PPDH surgery, there might be a shift of internal organs or residual tissue from the healing process, which could create a silhouette resembling cardiomegaly on radiographs without reflecting the actual cardiac size (Fossum 2018). Additionally, thoracic radiographs only provide a two-dimensional view, which may not show the heart's structure as clearly as echocardiography, which gives a three-dimensional view of its function and anatomy (Häggström et al., 2016).

Long-term follow-ups of cats that underwent surgical treatment indicated that owners were generally satisfied with the outcomes of the procedure (Reimer et al., 2004). Prognoses following surgical repair of PPDH are typically favorable, with survival rates ranging from 86% to 97% (Burns et al., 2013). Most cats receiving surgical intervention for PPDH displayed prominent clinical signs, such as respiratory difficulties or other abnormalities, which improved significantly after surgery (Reimer et al., 2004). In this case, a year follow-up revealed that the cat showed no respiratory or gastrointestinal symptoms and maintained a quality of life comparable to that of a healthy cat.

In conclusion, the current case details the successful surgical repair of a congenital peritoneopericardial diaphragmatic hernia (PPDH) in a Scottish Fold cat, utilizing a pericardial drain to prevent postoperative pneumopericardium and verifying the integrity of the pericardium. Using a pericardial drain technique ensured the immediate evacuation of air from the pericardial space, minimizing potential complications such as cardiac tamponade. The surgical outcome was favorable, with no respiratory or gastrointestinal symptoms observed during the long-term follow-up. This case shows the importance of careful postoperative management in PPDH cases and demonstrates that the use of a pericardial drain may improve recovery and prevent complications. Moreover, this report adds to the limited information on PPDH in Scottish Fold cats and provides evidence for the successful long-term prognosis following surgical treatment.

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