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Parasternal thoracotomy: a new minimally invasive approach to the pericardium

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Pericardiectomy is the preferred surgical procedure for the treatment of pericardial effusions with cardiac tamponade. Surgery is indicated in all cases of recurrent effusions after pericardiocentesis. In the literature, the most frequently used surgical procedure is subtotal pericardiectomy. More recently, minimally invasive techniques have allowed a reduction of morbidity compared to traditional procedures. Aim of this paper is to describe a new minimally invasive pericardiectomy technique and to document the results in a series of six cases. Six dogs underwent complete blood and urine tests, ultrasound examination, pericardiocentesis and CT scan. In all cases the pericardiectomy was performed via a left parasternal thoracotomy through the eleventh intercostal space. All the portions of resected pericardium were measured and histologically examined. Four dogs had a neoplastic mass at the base of the heart and no recurrence of the pericardial effusion. Two dogs had an inflammatory disease (pericarditis) and presented a clinically relevant pleural effusion after surgery, that required additional treatments. All dogs were discharged 24 hours after surgery. Parasternal pericardiectomy may be a good option for the minimally invasive treatment of recurrent pericardial effusions, particularly in the presence of neoplastic lesions of the heart base. The morbidity of the approach is similar to that of other known procedures but it is potentially faster and easier to perform. No dedicated instrumentation is required.

Key words: pericardial fenestration, minimally invasive surgery, parasternal access

INTRODUCTION

Pericardiectomy is the surgical procedure of choice in the treatment of recurrent cardiac effusions and tamponade unresponsive to medical therapy[1,2,3].

Several surgical techniques are reported in the literature, the most widely used being subtotal intercostal pericardiectomy throught the fifth right intercostal space or with a sternotomic approach[1,2,3].

Other less invasive procedures, such as percutaneous pericardiotomy[4], trans-diaphragmatic pericardiectomy[5] and especially thoracoscopic pericardial fenestration[6,7,8,9] have allowed a significant reduction of morbidity compared to traditional surgical techniques (in terms of extension of the surgical access, duration of the procedure, post-operative pain, prolonged recovery times).

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Pericardiectomy is the elective therapy for symptomatic relapsing cardiac tamponade. Subtotal pericardiectomy is the more commonly used procedure. When possible, a minimally invasive approach should be preferred.

Currently, the minimally invasive thoracoscopic approach is apparently the preferred one, despite the long learning curve and the relatively expensive surgical instrumentation that limit its use and spread in spite of its undoubted usefulness.
Aim of this paper is to assess the validity of a new minimally invasive access route to the pericardium, comparing it to known procedures through the analysis of the results in six clinical cases.

MATERIALS AND METHODS

Six dogs of different breeds and age (see table 1) were referred to our clinic for relapsing pericardial effusion and cardiac tamponade following treatment with pericardiocentesis. In the previous two weeks all the subjects underwent at least three pericardiocentesis procedures, with an interval ranging from 2 to 5 days. All patients underwent complete blood and urine tests, echocardiographic examination with pericardiocentesis, abdominal ultrasound examination and abdominocentesis; the samples obtained from the pericardial and abdominal effusion underwent chemical-physical examination (PS, PT, total nucleated cells, total red blood cells, PCV, comparison of all biochemical parameters with blood values) and cytological examination. After resolution of the acute signs all the dogs underwent a full body CT scan (Siemens-Somaton Definition Flash). Subsequently, a pericardiectomy was performed in all of the patients. A new surgical approach was proposed for this procedure, via a mini-thoracotomy in the left parasternal region. The owners were informed of the unconventional procedure and accepted by signing an informed consent. The time required for the entire procedure was recorded from the first incision until closure of the skin suture.

Parasternal thoracotomy is performed in dorsal decubitus, with a parasternal intercostal approach at the eleventh left intercostal space.

All the surgeries were performed by the same surgeon. The protocol for general anaesthesia was as follows: premedication with methadone at the dose of 0.2 mg/kg and dexmedetomidine at the dose of 1 microgram/kg IV; induction with fentanyl at the dose of 2 micrograms/kg and propofol at the dose of 3-4 mg/kg IV; maintenance with endotracheal inhaled isofluorane (1.3%). In all cases preoperative antibiotic prophylaxis (cefazolin at the dose of 20 mg/kg IV) was performed at the time of induction. The parasternal approach was performed through the eleventh left intercostal space, with the patient in dorsal decubitus and with the front limbs extended cranially.
The skin, the subcutaneous tissue and the cutaneous muscle of the trunk were dissected with an incision from the midline (sternum) towards the left side. The length of the incision was maintained between 2 and 3 cm, depending on the size of the subject. The rectus abdominis muscle was incised parallel to its fibres, in cranio-caudal direction.
The external and internal intercostal muscles and the parietal pleura were incised along the intercostal space. Two Gelpi retractors were inserted at 90° angle; in larger subjects a small-size Finocchietto retractor was used (cases 1 and 3, weight over 30 kg). The apex of the pericardium, which was always clearly visible in this case series, was identified. Adson forceps were used to exert traction on the pericardium and an incision was made using Metzembaum scissors with bevelled tips. After having established a secure grip of the pericardial tissue by means of Allis forceps an incision was made from the apex in cranial direction, using a harmonic scalpel (Harmonic, Ethicon) (cases 1, 3 and 4) or, in smaller subjects (cases 2, 5 and 6), straight Metzembaum scissors with bevelled tips.
The excised portion of the pericardial tissue included the phrenopericardial ligament caudally and the sternopericardial ligament cranially, always ventrally to the phrenic nerves which, in this case series, were always visible, despite the small aperture. In case number 1, the inside of the pericardial sac and the heart base were explored with the help of a rigid 2.7 mm, 30° lens, in order to directly visualize the mass on the right atrium.
The procedure was completed by closing the aperture with a routine approach. The intercostal incision was sutured with detached circumcostal polydioxanone stitches (from 2/0 to 0 depending on the size of the subject) while the muscular, fascial and subcutaneous planes were sutured with a continuous resorbable monofilament suture (glycomer 631).
The skin incision was closed with a continuous nonabsorbable monofilament suture (polyamide). In all subjects an adhesive skin patch was applied to protect the wound.

After surgery, a chest X-ray examination with two views was taken in all of the patients (latero-lateral view in right lateral decubitus and dorso-ventral view in sternal decubitus).

All the patients were discharged on the same day of surgery or on the next day (case number 2). At the time of discharge all subjects were assessed with the short form of the Glasgow composite pain scale[12,21] and plasma glucose and cortisol values were assayed[12]. Follow-up was planned as follows: clinical controls at 7 and 15 days after surgery and then at one, three, six and twelve months after surgery.

Blood and urine tests, radiographic examination with two orthogonal views of the chest and ultrasonography of the chest and abdomen were repeated at each follow-up visit.

The removed portions of pericardial tissue were measured in their full extension and histologically examined. The results of the measurements were related to the size of the subjects, arbitrarily divided into two groups, one under and one over 10 kg of body weight. A complete necropsy and histological examination of the mass at the base of the heart were performed in cases 1 and 2, as death occurred 12 and 5 months after surgery, respectively. In case number 2, a CT scan *ante-mortem*, performed on the day of demise, was also available.

RESULTS

In all of the subjects the symptoms present were weakness, abdominal distension, respiratory distress, weak and thin pulse, weakened heart noises at chest auscultation. Abdominal distension was, in all cases, caused by ascites due to decreased venous return consequent to the pericardial effusion. In the pericardial effusions the protein concentration was always higher than 3 gr/dl, while the cell count was variable between 2200 to 7000 cells/µl, with a mixed population of mesothelial/inflammatory cells.

A slight prevalence of neutrophils over other cell types was found in cases 3 and 5. In the peritoneal effusions the protein concentration always remained in a range between 2.5 to 3.5 gr/dl; in all cases the cell count was below 1000 cells/µl.

In 4 patients, in addition to pericardial and abdominal effusion ultrasonography detected the presence of a mass at the base of the heart. In the other 2 patients, instead, the ultrasound investigation detected diffuse thickening of the pericardium.

In compliance with the ultrasound results, in four cases (numbers 1, 2, 4 and 6) CT confirmed the presence of a mass at the base of the heart and in two cases (numbers 3 and 5) the presence of diffuse thickening of the pericardium, suggestive of an inflammatory disease (pericarditis). CT scans also allowed a more specific characterisation of the type of neoplasm present: in case number 1 the diagnostic suspicion was of haemangiosarcoma of the right atrium; in case number 2 the images suggested the presence of a primary lung tumour of the left caudal lobe with lymph node involvement (middle and left tracheobronchial lymph nodes) as well as of the entire pericardium; finally, in cases 4 and 6, the findings were suggestive of a chemodectoma originating from the aortic arch. In case number 3 a cystic prostatopathy with organomegaly was observed.

Cytology was found to be compatible with the diagnosis of benign prostatic hyperplasia. In no other subjects were other pathological findings encountered, other than the abdominal effusion.

In no case have intraoperative complications occurred. In all subjects no signs of pneumothorax were present at the post-operative radiographic examination.

Hospitalization time varied between 10 and 24 hours. In all cases the surgical wounds healed without complications.

The mean duration of surgery was of 22 minutes and 45 seconds (range from 20 to 25 minutes). The Glasgow pain score at the time of discharge was in all subjects between 2 and 5 (range 0-24); plasma glucose and cortisol concentrations were normal (glucose: mean 111, minimum 100, maximum 120, reference interval 90-120 mg/dl; cortisol: mean 7.58, minimum 2.35, maximum

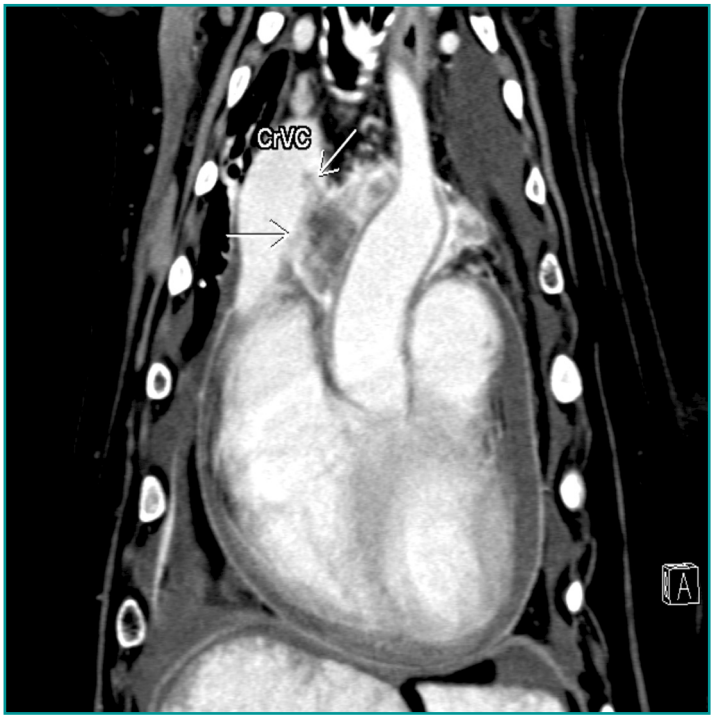

Figure 1 - Chemodectoma with invasion of the vena cava (CT: coronal scan).

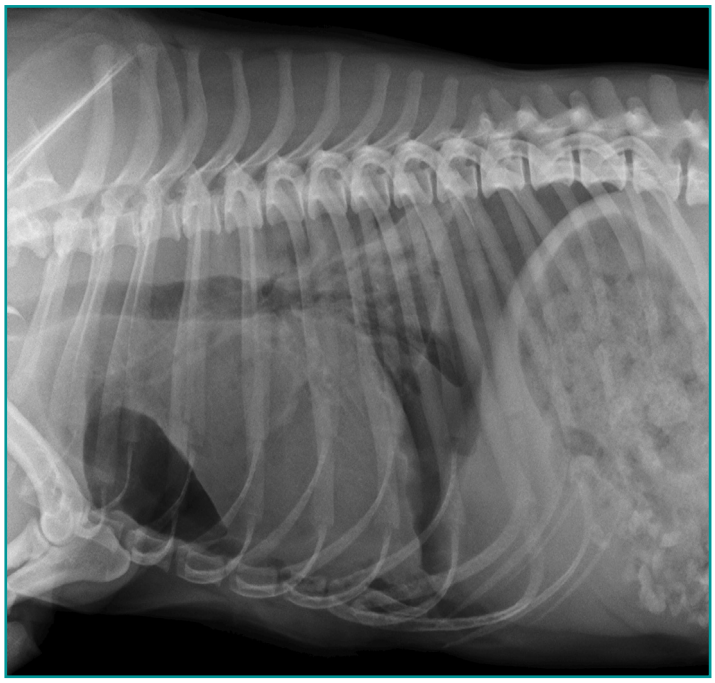

Figure 2 - Post-operative chest X-ray (case number 5), latero-lateral view in right decubitus; no signs of pneumothorax are present.

12.40, reference interval 1.10-13.3 µg/dl). Recurrence of the pericardial effusion was absent in the four dogs with neoplastic masses (cases 1, 2, 4 and 6).

Subject number 1 died one year after surgery of gastric torsion; a complete necropsy and histological examination of the mass were performed, which confirmed the diagnostic suspicion of haemangiosarcoma of the right atrium.

Patient number 2 died five months after surgery of an intracranial neurological syndrome. Also in this case additional investigations were performed, including an *antemortem* CT scan and a complete necropsy with histological examination that confirmed the diagnosis of lung carcinoma with lymph node and cerebral metastases. Subjects number 4 and 6 are alive and asymptomatic at more than 12 months after surgery.

In patient number 3, follow-up ultrasonography showed signs of constrictive pericarditis at the heart base, associated with a moderate and mildly symptomatic recurrent pleural effusion (polypnoea). In view of this, periodic thoracocentesis was necessary, performed with a frequency below one every 2-3 months.

Parasternal thoracotomy is faster and easier to perform, it does not require the use of specific instrumentation and the results are comparable with those of thoracoscopic procedures.

The patient is still alive more than a year after surgery.

In the post-operative follow-up of patient number 5, recurrent symptomatic pleural effusion was found, which required an additional surgical procedure of total pericardiectomy (ventrally and dorsally to the phrenic nerves) via a median sternotomy. The procedure was performed about 3 months after the first surgery and resulted in complete resolution of the effusion. The patient is still alive more than a year after the second operation and does not present any symptoms referring to the pleural or pericardial effusion. All the removed portions of the pericardium were measured in their full extension. The mean surface area of the resected pericardial membrane was of 27.83 cm^2 (15 to 42 cm^2). In subjects weighing more than 10 kg the mean was of 40 cm^2 (from 36 to 42 cm^2) while in subjects weighing less than 10 kg the mean was of 15.66 +/- 1 cm^2. The mean size was found to be significantly different in the two groups ($p<0.05$). All the removed portions of pericardium were histologically examined.

In subjects number 1, 4 and 6 the histological diagnosis was of lymphoplasmacellar pericarditis with medium grade fibrosis; in subject number 2 pericardial carcinomatosis was detected as an extension of the primary lung cancer; finally, in subjects number 3 and 5 the histological diagnosis was of chronic, severe lymphoplasmacellar and macrophagic pericarditis, with intense fibrosis and mesothelial reaction.

DISCUSSION

The mean duration of this new surgical procedure resulted to be lower compared to what reported in the literature for the more invasive open surgery procedures and for thoracoscopic fenestration[1,2,3,4,5,6,7,8,9,10].

No specific instrumentation was required. The execution of the procedure by a single surgeon may be a limitation of the study, as the results may have been influenced by the experience of the surgeon who ideated the procedure and hence may have not shown the real difficulties of the technique.

Hospitalization time and postoperative pain were comparable to those observed with thoracoscopic procedures, both in our experience and if compared to what reported in the literature[6,7,8,9,10,12]. The short form of the Glasgow composite pain scale and blood concentrations of glucose and cortisol were selected as criteria for the assessment of post-operative pain in accordance with what reported in the literature[12,21].

At the time of the evaluation none of the subjects were under treatment with analgesics.

Tabella 1 - Summary of clinical cases

Case	Breed and sex	Age (years)	Weight (kg)	Ultrasound and CT diagnosis	Histopathology (pericardium)	Histopathology (tumour)	Pericardial surface-area removed (cm^2)
1	Sterilized female Labrador retriever	13	33	Right atrial mass	Lymphoplasmacellular pericarditis with medium grade fibrosis	Hemangiosarcoma of the right atrium	42
2	Sterilized female mongrel	16	10	Pulmonary mass, left caudal lobe, lymphadenomegaly and pericardial thickening	Carcinomatosis	Pulmonary carcinoma with lymph node metastases	15
3	Intact male Labrador retriever	12.5	45	Pericardial thickening, no masses	Severe lymphoplasmacellular and macrophagic pericarditis, severe fibrosis and mesothelial reaction	Not applicable	42
4	Sterilized female Basset Hound	14	25	Mass at the base of the heart (suggestive of chemodectoma of the aortic arch)	Lymphoplasmacellular pericarditis with medium grade fibrosis	Not applicable	36
5	Intact male Jack Russel terrier	5,5	6,5	Pericardial thickening, no masses	Severe lymphoplasmacellular and macrophagic pericarditis, severe fibrosis and mesothelial reaction	Not applicable	16
6	Intact male French Bulldog	10	8,5	Mass at the base of the heart (suggestive of chemodectoma of the aortic arch)	Lymphoplasmacellular pericarditis with medium grade fibrosis	Not available	16

In none of the cases was the pre-operative antibiotic prophylaxis continued in the post-operative period. These last two observations may support the impression of a low morbidity of the procedure. In none of the patients treated was a thoracic drainage used. Although the use of pleural drainage after thoracic surgery is recommended in the literature, based on our previous experience with pericardiectomy - but performed with other minimally invasive techniques not included in this case series – the decision was taken to standardize the surgery with a minimally invasive approach, without applying thoracic drainage. This may have had a significant impact on both the short duration of hospitalization and on the extent of post-surgical pain. In no case was pneumothorax detected. This was probably due to the surgeon's ability in not damaging the visceral pleurae lining the lungs during dissection of the pericardium. The absence of complications during the procedures is probably related to the small number of cases and should therefore be considered with caution.

Potential complications could include bleeding of intercostal blood vessels, of the epicardium and of the coronary vessels, pneumothorax in case of extensive dissection of the ventral mediastinum, iatrogenic damage to the phrenic nerves, seroma/ haematoma and infection of the surgical wound. In our study, the survival time of patients with neoplastic disease was comparable to the one reported in the literature for the same type of cancer (particularly long in the case of chemodectoma)[13,14,15,16].

In these patients the pericardial effusion relapse rate was zero, supporting the hypothesis that in such cases this procedure can be used advantageously. On the contrary, the pleural effusion relapse rate in subjects with inflammatory disease was extremely high and certainly higher than what reported in the literature for more invasive procedures such as subtotal or total pericardiectomy[1,2,3], but very similar to the rate observed with minimally invasive procedures in the same type of patients[5,6,7,8,9,10,17].

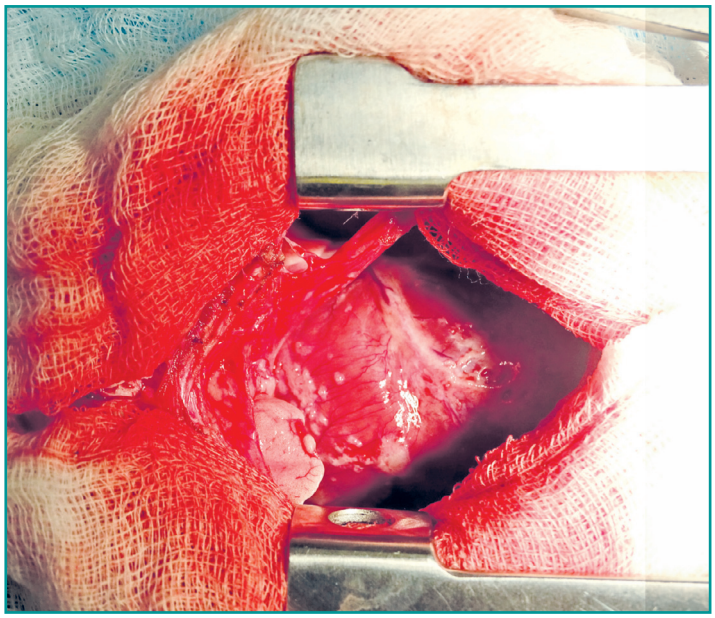

Figure 3 - Extension of the excised portion of pericardium (case 5: intraoperative view during revision) (cranial to the left, caudal to the right).

These data are in agreement with what has been observed in the literature regarding pericardial inflammatory disorders, whose resolution depends on the amount of pericardial tissue removed as the amount of fluid produced is strictly related to the amount of residual pericardium[10]. According to the data available in the literature, the mean surface area of pericardium removed was higher compared to other fenestration techniques[6,7,8,9,10], lower compared to more invasive open surgical techniques[1,2,3,17] and similar to the one observed with transdiaphragmatic pericardiectomy[5].

The difference in the mean surface area of pericardial tissue removed in the two patient groups (weight over and under 10 kg) may suggest that the amount of pericardium that can be removed with this technique is influenced by the size of the subject involved (larger subjects would allow for a more extensive removal). However, the finding is apparently of little clinical or practical significance.

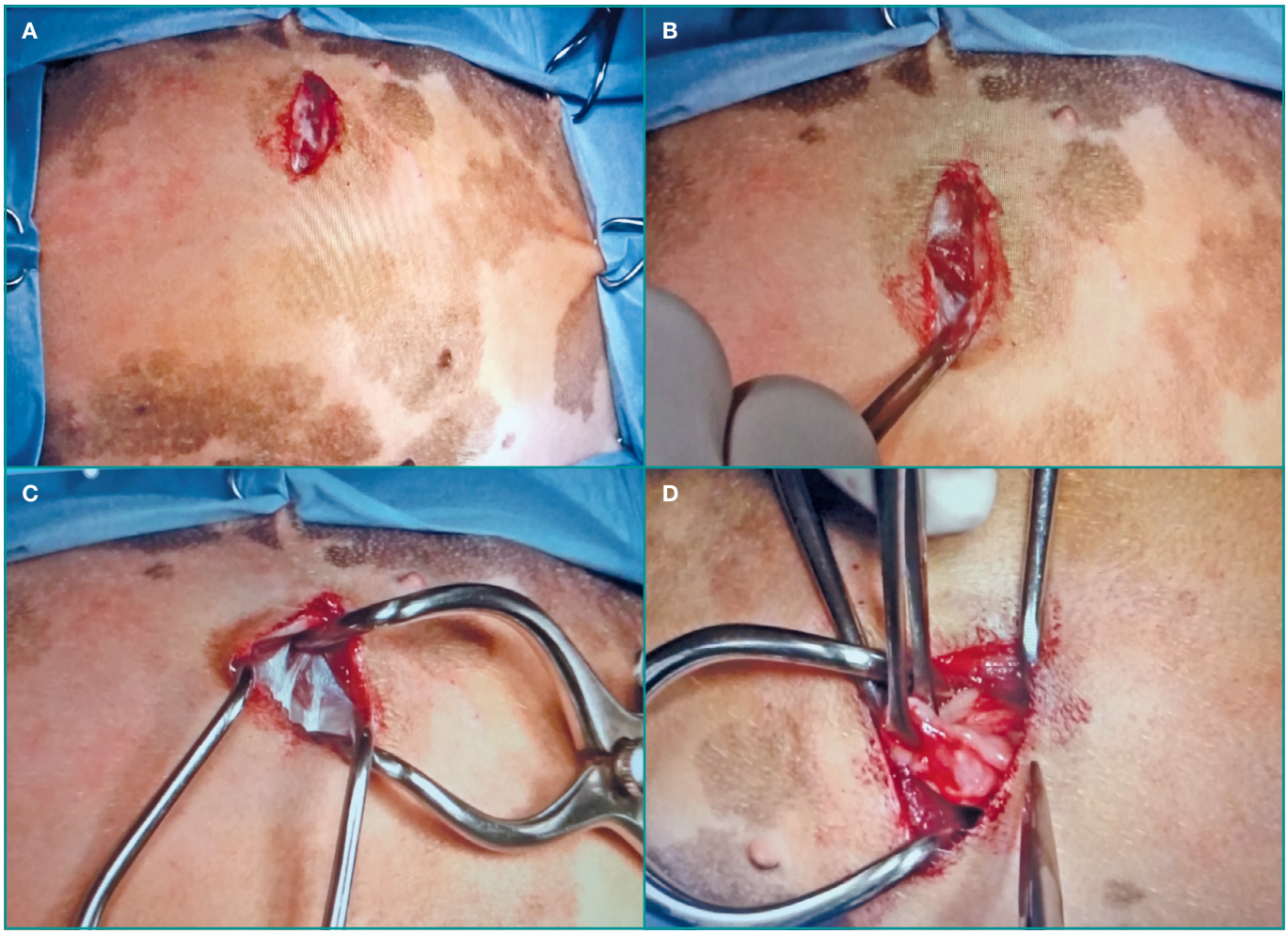

Figure 4 - **A)** Skin incision (cranial to the left, caudal to the right). **B)** Incision of the rectus abdominis muscle (cranial to the left, caudal to the right). **C)** Positioning of Gelpi retractors (cranial to the left, caudal to the right). **D)** Visualization and traction of the pericardium (cranial to the left, caudal to the right).

Parasternal thoracotomy is a valid alternative to thoracoscopic procedures in the treatment of pericardial effusions with cardiac tamponade, particularly if of neoplastic nature. Careful patient selection is required.

As the study was not performed *ex-vivo*, it was not possible to evaluate the percentage of pericardium removed; however, in the two deceased subjects (cases number 1 and 2) necropsy allowed a subjective evaluation of this percentage as being of approximately 40% (a value comparable to what found in the literature for transdiaphragmatic pericardiectomy)[5].

In conclusion, in the authors' opinion parasternal intercostal pericardiectomy can be considered a valid alternative to thoracoscopic fenestration procedures in the treatment of symptomatic and relapsing pericardial effusions, particularly when caused by neoplastic disease at the base of the heart.

Being a minimally invasive technique - similarly to thoracoscopic fenestration - in the presence of occasional masses at the base of the heart that have not yet caused a tamponade the procedure may be also considered as a preventive surgical intervention. The technique is potentially fast and easy to learn and execute; it presents low risks of complications and does not require dedicated instrumentation. A careful selection of the patient is advisable, based on the following inclusion criteria: A) presence of symptomatic relapsing pericardial effusion; B) need for a minimally invasive approach and for a short duration of the anaesthesia (high anaesthesia risk based on the subject's general conditions, ASA classification and potential risk resulting from iatrogenic pneumothorax caused by thoracoscopic procedures); C) non-resectability of the neoplastic mass (if present) based on the CT examination; D) thoracic exploration and/or pleural biopsies judged unnecessary for the diagnostic approach; E) type of disease (inflammatory versus neoplastic). In selected cases the procedure can be used to collect pericardial biopsies. It should not be considered as a first-choice procedure in case of inflammatory diseases, similarly to other minimally invasive techniques; in the authors' opinion in such cases total and/or subtotal pericardiectomy are the first-choice procedures, as the *a priori* distinction between neoplastic or inflammatory effusion, although not always possible, must be based on the identification or not of a mass and on the histological examination of pleural and pericardial biopsies.

The limited number of patients in our study makes further investigations appropriate, especially for the evaluation of complications (e.g., role of the procedure in a large number of cases with inflammatory disease, comparison between parasternal thoracotomy and thoracoscopic fenestration in control groups without prior patient selection, execution of the procedure by different surgeons).

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KEY POINTS

- Minimally invasive procedures are to be preferred to traditional ones, especially in elderly patients and for palliative surgery.
- Parasternal thoracotomy has never been previously described, neither in veterinary nor in human medicine.
- The speed and simplicity of execution together with the fact that no dedicated instrumentation is required are valid reasons to prefer one surgical technique over another and to favour its spread, results being equal.

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