

# Fatal congenital peritoneopericardial diaphragmatic hernia in a sable antelope (*Hippotragus niger*) calf

Rudolf Nel<sup>1</sup>, Alischa Henning<sup>1</sup> and Nicolize O'Dell<sup>1,2,\*</sup>

<sup>1</sup> Department of Paraclinical Sciences, Faculty of Veterinary Science, University of Pretoria, Onderstepoort, South Africa

<sup>2</sup> Centre for Veterinary Wildlife Studies, Faculty of Veterinary Sciences, University of Pretoria, Onderstepoort, South Africa

\*Correspondence

Nicolize O'Dell, Department of Paraclinical Sciences, Faculty of Veterinary Science, University of Pretoria, South Africa. Email: nicolize.odell@up.ac.za

## ABSTRACT

Congenital peritoneopericardial diaphragmatic hernia was diagnosed in a 2-week-old sable antelope (*Hippotragus niger*) calf with subsequent fatal acute heart failure. Histopathological examination of the lung, liver and heart revealed lesions supportive of acute heart failure that consisted of pulmonary oedema, periacinar hepatocellular necrosis and myocardial degeneration and necrosis. The external pressure on the coronary arteries by the liver and abomasum most likely resulted in ischaemic injury of the cardiomyocytes and the resultant acute heart failure.

**Keywords:** congenital, peritoneopericardial hernia, sable antelope

## BACKGROUND

Congenital peritoneopericardial diaphragmatic hernia is associated with the malformation of the pericardial sac and the diaphragm during embryonic development. The section of the diaphragm that separates the abdominal cavity from the pericardial sac is absent, and a communicating tract forms that allows organs from the abdominal cavity to herniate into the pericardial sac. This is a rare condition in humans and more so in animals. The few reported cases in animals were diagnosed in dogs and cats, calves, horses and alpacas.<sup>1-9</sup> This condition has not been reported to date in any wild counterparts, especially not in wild antelope species, as documented in this case.

In humans, peritoneopericardial diaphragmatic hernias are more commonly associated with diaphragmatic trauma.<sup>10</sup> The diaphragm is attached to the pericardial sac by means of a central tendinous aponeurosis that makes this specific area extremely vulnerable to rupture and herniation after a traumatic incident. There is however widespread interspecies variability with regard to the nature of this specific attachment in animals.<sup>11</sup> Similar to humans, pigs have a fixed attachment between the pericardial sac and the diaphragm.<sup>11</sup> In cats and dogs, a single ligament, the phrenicopericardial ligament, attaches the diaphragm to the pericardial sac. In ruminants and horses, the sternopericardial ligament is the sole attachment to the caudal part of the pericardial sac and ensures that traumatic causes of diaphragmatic rupture and herniation are unlikely.<sup>11</sup> The majority of the reported peritoneopericardial diaphragmatic

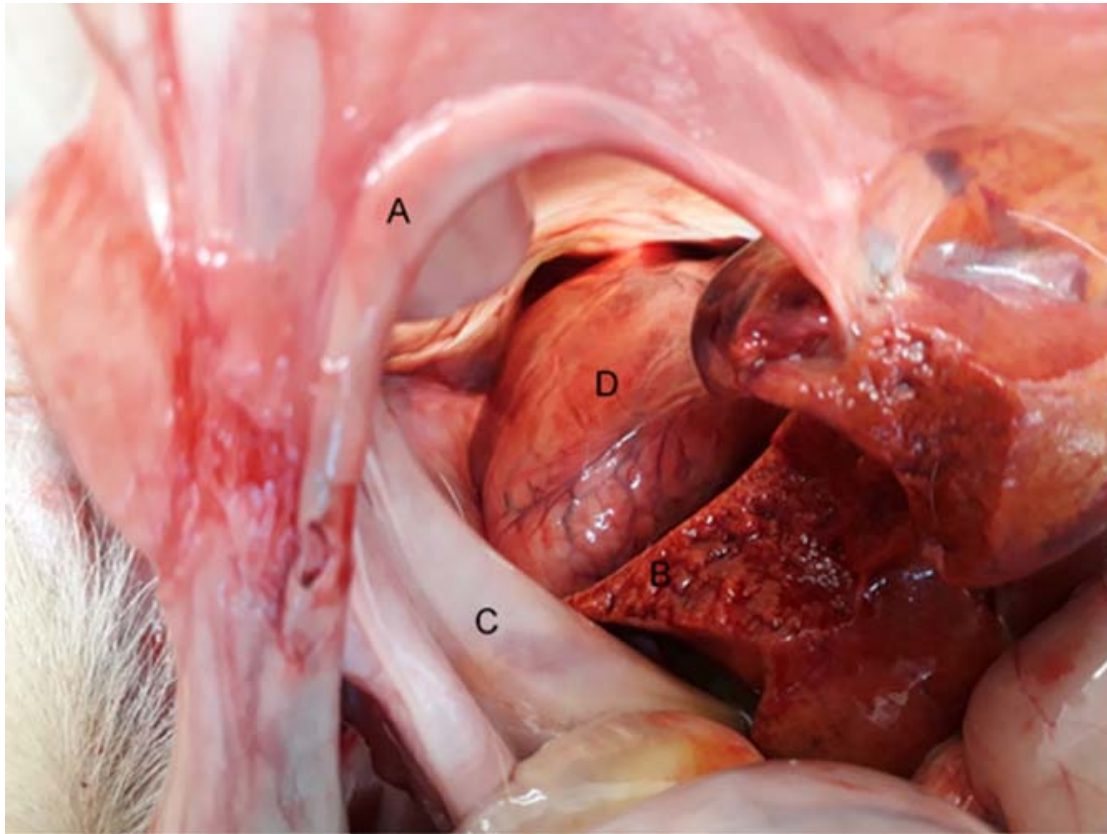
hernias in cats and dogs are due to developmental failure of the septum transversum.<sup>12</sup> Early injury due to trauma or defective development of the lateral pleuroperitoneal folds will also lead to the formation of a peritoneopericardial communicating tract in animals.<sup>13</sup>

Congenital peritoneopericardial diaphragmatic hernias are probably the most common reported congenital abnormality of the pericardium in cats and dogs.<sup>12</sup> Maine coon cats, Himalayan cats and Weimaraner dogs showed an abnormal high prevalence for this abnormality, indicating the possibility of a heritable predisposition for this condition in these breeds.<sup>3</sup> Congenital peritoneopericardial diaphragmatic hernias in cats and dogs are often reported in conjunction with a variety of co-existing congenital defects, that is, skeletal and cardiac abnormalities.<sup>3, 7</sup> Reports on species, other than companion animals, with congenital peritoneopericardial diaphragmatic hernias are limited to calves, alpacas and horses.<sup>4-6, 14</sup> Therefore, information with regard to clinical manifestation, pathological findings and the sequel of congenital peritoneopericardial diaphragmatic hernia in other species, specifically ruminants, is limited.

This report describes a case of a 2-week-old sable antelope calf with a congenital peritoneopericardial diaphragmatic hernia that resulted in acute heart failure and death. To the authors' knowledge, this is the first report of its kind in a wild antelope species and specifically in sable antelope and one of few that resulted in the death of the animal.

## **CASE PRESENTATION**

On 30 October 2018, a 2-week-old sable antelope calf presented to the Faculty of Veterinary Science at the University of Pretoria for a post-mortem examination, after it was found dead in a breeding group camp. The owner was unable to comment on any clinical signs prior to death since the carcass was discovered in an extensive system, and sable antelope are known for hiding their calves for the first few weeks post-partum. On gross examination, the carcass displayed mild post-mortem changes and moderate congestion throughout. Upon opening of the thorax, the pericardial sac was distinctly enlarged. Prior to the removal of the abdominal and thoracic organs, an incision into the pericardial sac illustrated the abomasum and left liver lobe adjacent to the heart within the pericardial space. On further inspection from the abdominal side, a large diaphragmatic opening that connected the abdominal cavity and pericardial sac was evident (Figure 1). This opening was large enough to allow for the easy movement of the liver and abomasum between the abdominal cavity and pericardial sac. The edges of the diaphragmatic opening were smooth and appeared typical for a chronic hernia (Figure 1). Mild ascites and hydropericardium were present and characterised by a small amount of serous fluid that could move freely between the abdominal cavity and the pericardial space which was connected by the large diaphragmatic opening. After removal of the liver from the pericardial sac, a mild zonal pattern could be observed. The lungs displayed multifocal to coalescing areas of atelectasis, especially in the caudo-ventral area adjacent to the pericardial sac. A small umbilical hernia was also present.



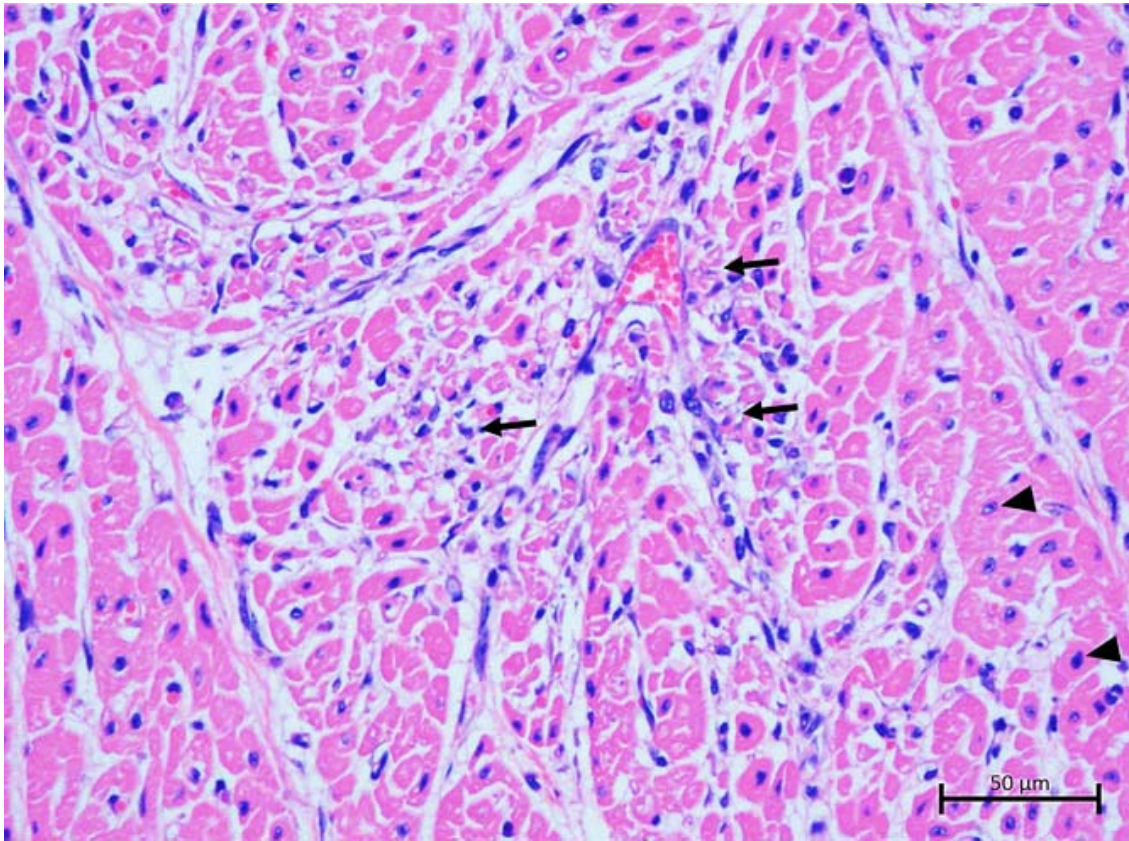
**FIGURE 1.** Opened thorax of the sable antelope (*Hippotragus niger*) calf with a peritoneopericardial diaphragmatic hernia viewed from caudal to cranial. The peritoneopericardial diaphragmatic hernia (a) can be seen with herniation of the liver (b) and abomasum (c) next to the heart (d) in the pericardial space

Tissue samples from the lungs, liver, heart and all the other major organs were fixed in 10% buffered formalin and routinely processed, embedded and sectioned for histopathological evaluation. Histopathological examination of the heart revealed multifocal areas of moderate, acute, myocardial degeneration and necrosis. The cardiomyocytes in these areas displayed cytoplasmic hypereosinophilia with loss of striations and nuclear karyolysis with occasional perinuclear clearing (Figure 2). Examination of the lungs revealed multifocal to coalescing atelectasis as well as moderate pulmonary oedema. Atelectasis was characterized by collapsed alveolar walls and the subsequent absence of air-filled alveoli (Figure 3). Pulmonary oedema was evident by the eosinophilic fluid (protein-rich transudate) within alveolar spaces and the presence of occasional intra-alveolar macrophages (Figure 3 inset). The liver revealed mild to moderate, acute, multifocal areas of periacinar hepatocellular necrosis characterized by karyorrhexis, karyolysis and dystrophic calcification. Mild to moderate areas of haemorrhage and scattered neutrophils were present in the areas of necrosis (Figure 4).

#### **LEARNING POINTS/TAKE-HOME MESSAGES**

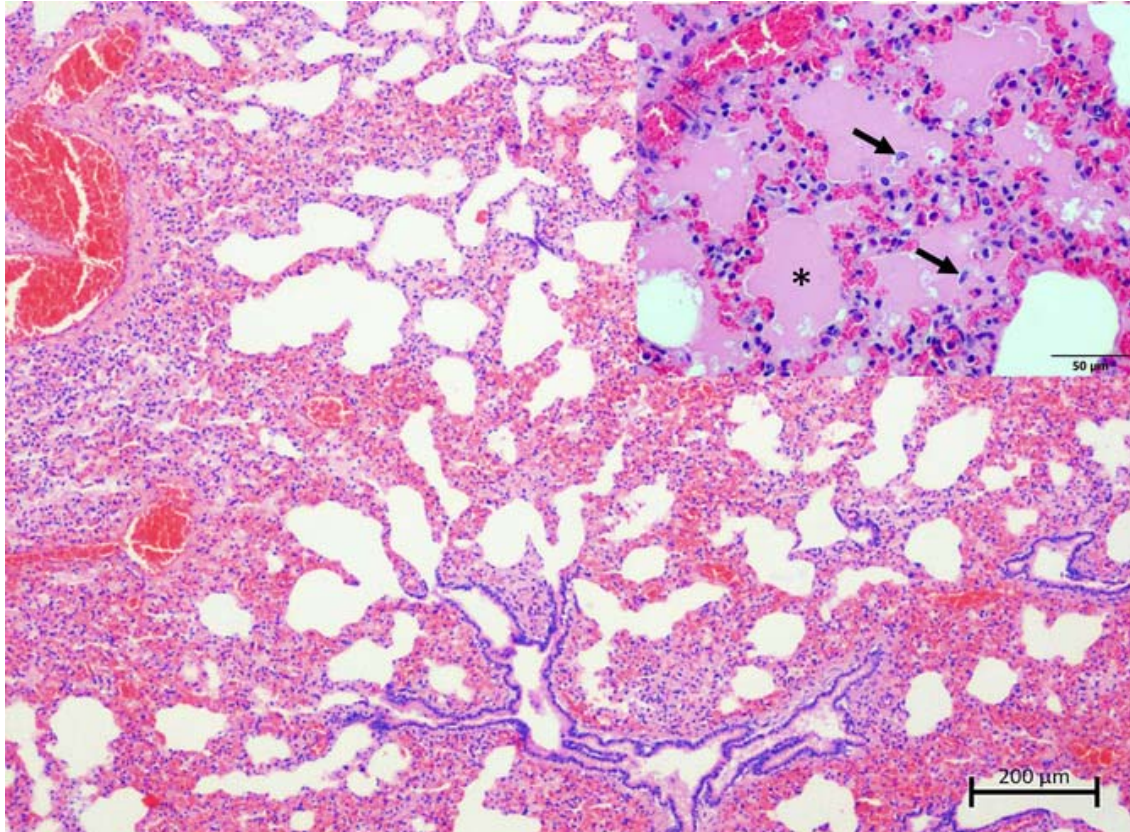
- Congenital peritoneopericardial diaphragmatic hernias can occur in wild antelope.
- Although this condition may go undetected for many years, this case demonstrates that it can result in acute heart failure and death.

- Pressure on the coronary blood vessels by the herniated organs may result in a cardiac tamponade-like effect, resulting in myocardial ischaemia, cardiac myocyte necrosis and acute heart failure leading to death.

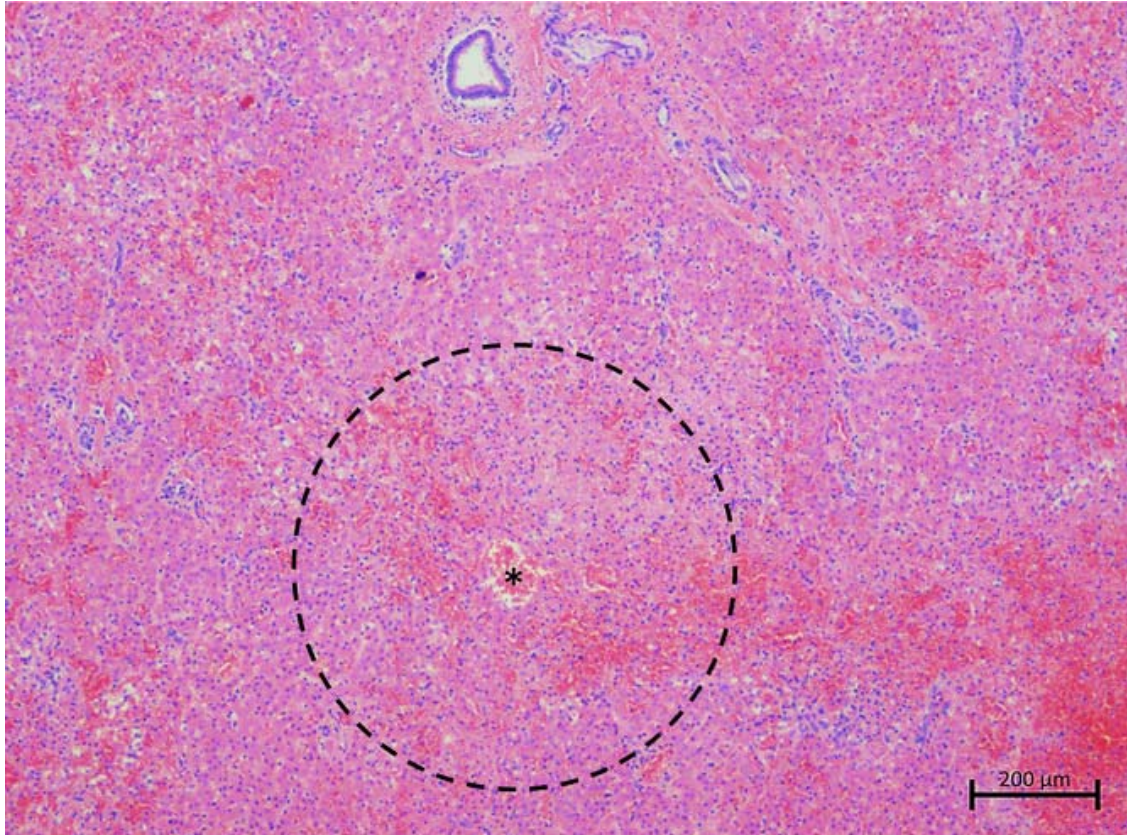


**FIGURE 2.** Histopathology of the heart of the sable antelope (*Hippotragus niger*) calf with a peritoneopericardial diaphragmatic hernia revealed multifocal areas of moderate, acute, myocardial degeneration and necrosis. There are clear areas where the cardiac myocytes are necrotic with shrunken hyper-eosinophilic cytoplasm and the presence of vacuoles around the nucleus (*arrows*). Normal cardiac myocyte for comparison (*arrowheads*) (Hematoxylin and eosin stain, 200x magnification)





**FIGURE 3.** Histopathology of the lungs of the sable antelope (*Hippotragus niger*) calf with a peritoneopericardial diaphragmatic hernia with multifocal to coalescing areas of atelectasis characterised by collapsed alveolar walls and absence of air-filled alveoli. (Hematoxylin and eosin stain, 40x magnification) Inset: In areas the alveolar spaces were filled with protein-rich oedema (*asterisk*) and occasional alveolar macrophages (*arrows*). (Hematoxylin and eosin stain, 200x magnification)



**FIGURE 4.** Histopathology of the liver of the sable antelope (*Hippotragus niger*) calf with a peritoneopericardial diaphragmatic hernia revealed mild to moderate, acute, multifocal areas of periacinar (*dashed circle*) hepatocellular necrosis, congestion and mild haemorrhage surrounding the central veins (*asterisk*) in areas. (Hematoxylin and eosin stain, 40x magnification)

A diagnosis of congenital peritoneopericardial diaphragmatic hernia was based on the gross examination of the carcass during post-mortem examination in conjunction with the clinical history and signalment. The terminal cause of death, acute heart failure, was confirmed on histopathology. The external pressure on the coronary arteries by the liver and abomasum, most likely resulted in ischemic injury of the cardiomyocyte and the resultant acute heart failure.

## **DISCUSSION**

Congenital peritoneopericardial diaphragmatic hernia, an uncommon condition in humans and animals has been reported in a limited number of animal species; dogs and cats, calves, alpacas and horses.<sup>1-9</sup> To the authors' knowledge, this is the first report in a wild antelope species.

Congenital peritoneopericardial diaphragmatic hernias are defects in the diaphragm resulting in communication between the peritoneal cavity and the pericardial sac, present at birth. The diaphragmatic defect is relatively large with round edges, easy movement of abdominal organs between the peritoneal cavity and the pericardial sac is possible, and it may occur in conjunction with other developmental anomalies within the same animal.<sup>14</sup> Common concurrent developmental anomalies include umbilical hernias, hypoplastic lungs, pulmonary

stenosis, ventricular-septal defects, patent ductus arteriosus, hydranencephaly, extra ribs and vertebral anomalies.<sup>5</sup> Due to the lack of direct association between the diaphragm and pericardial sac in normal dogs, cats and ruminants, the majority, if not all, of the diagnosed peritoneopericardial diaphragmatic hernias in these species are congenital in nature.

Acquired peritoneopericardial diaphragmatic hernias are defects in the diaphragm that developed after birth and is most commonly trauma-associated. The defect does not occur in conjunction with other developmental anomalies, can vary in size, but the edges are often ragged with the formation of attachments associated with the inflammatory response that often accompanies the traumatic injury.

Although the age of an animal may be suggestive of the presence of a congenital peritoneopericardial diaphragmatic hernia, the clinical signs in some animals can take years to manifest in some animals or not at all in others. In a retrospective study of 66 cats, 40% of the study group was found to have a congenital peritoneopericardial diaphragmatic hernia but showed no clinical signs. They were found as incidental findings on regular physical exam.<sup>15</sup> Therefore, it is important that not only age is considered when differentiating between congenital versus acquired hernias.<sup>14</sup> Diaphragmatic herniation in young animals can either be the result of defective embryonal development, to be more specific the incomplete fusion of pleuroperitoneal folds or trauma. Parturition is an important contributing factor to the incidence of trauma-related hernias due the uterine compression forces. Normally various other co-existing congenital defects like skeletal or thoracic developmental defects or umbilical hernias accompany congenital peritoneopericardial diaphragmatic hernias, as was seen in this case.<sup>14</sup> The most common clinical signs observed in affected animals are respiratory and gastrointestinal signs. Cats seem to have a predisposition for respiratory signs, especially coughing and muffled heart sounds, whereas dogs show a predisposition for gastrointestinal signs, in particular vomiting.<sup>1</sup> The latter is because the gastrointestinal tract may be involved in the herniation in dogs whereas the liver is more commonly associated in many other species.<sup>1</sup>

The size of these defects can vary from as small as two centimeters or as large as a complete absence of the diaphragm. Most peritoneopericardial diaphragmatic hernias are detected in young animals, and most of them are large enough to allow for the herniation of multiple organs.<sup>14</sup> Defect size is not well correlated when determining whether a peritoneopericardial diaphragmatic hernia is trauma-related or congenital. Larger defects in neonates may be fatal and are therefore recorded whereas small defects may be overlooked and only manifest later in an animal's life.

The sable antelope calf in this report died at 2 weeks of age. The observation of any clinical signs was precluded by the overall challenge in clinical monitoring and management of wild animals (even in captive environments) and in this case even more so considering the extensive management system on the farm in conjunction with the fact that, like other antelope, sable antelope hide their young for the first few weeks of life. Previous reports indicated that the Holstein calf was described as a poor doer and the alpaca as a runt when compared to other crias of similar age.<sup>4, 6</sup> Similar non-specific signs were seen in dogs and cats; poor growth, reduced weight gain, weight loss and recurrent anorexia.<sup>3</sup> The size of the hernia and the specific organs involved will determine the presence, specificity and course of the clinical signs if and when present.<sup>5</sup>



The diaphragmatic defect in the reported sable antelope calf was large enough to allow herniation of at least the abomasum and left liver lobe into the pericardial space. The displacement of the organs into the pericardial sac most likely caused a cardiac tamponade-like effect that would have been perpetuated post-feeding. Prolonged cardiac tamponade will cause compression of, among others, the coronary blood vessels with subsequent ischaemia. In the face of prolonged ischaemia, cardiac myocyte necrosis will ensue and be a sole or important contributor to acute heart failure, its sequela and death. This was confirmed on the histopathological examination of the sampled organs. The pressure on the blood vessels in the trapped portion of the liver most likely resulted in an increase in hydrostatic pressure in the hepatic and abdominal circulation leading to mild ascites.

The diaphragm defect of the sable antelope calf had a smooth, thin and round edge connecting it to the pericardial sac. The smooth fibrous edge, the size of the defect and the age of the animal were indicative of a congenital cause.

To the authors' knowledge, congenital peritoneopericardial diaphragmatic hernia has not been reported in any wild African antelope up to date. In addition, this is one of a few congenital peritoneopericardial diaphragmatic hernias that resulted in acute heart failure and the death of the animal.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

## REFERENCES

1. Banz AC, Gottfried SD. Peritoneopericardial diaphragmatic hernia: a retrospective study of 31 cats and eight dogs. *J Am Anim Hosp Assoc.* 2010; 46(6): 398– 404.
2. DeVilbiss B, Ziegler J, Righter D, Allen A, Barrington G, Haldorson G. Diaphragmatic hernia in a two-year-old alpaca (*Vicugna pacos*). *J Zoo Wildl Med.* 2011; 42(3): 513– 7.
3. Evans SM, Biery DN. Congenital peritoneopericardial diaphragmatic hernia in the dog and cat: a literature review and 17 additional case histories. *Vet Radiol.* 1980; 21(3): 108– 16.
4. Foster D, Chinnadurai S, Nutt J, Pandiri A, Linder K, Alley M, et al. Congenital peritoneopericardial diaphragmatic hernia in an alpaca. *Aust Vet J.* 2011; 89(1-2): 51– 4.
5. Hicks KA, Britton AP. A fatal case of complicated congenital peritoneopericardial diaphragmatic hernia in a Holstein calf. *Can Vet J.* 2013; 54(7): 687– 7.
6. Horney F, Cote J. Congenital diaphragmatic hernia in a calf. *Can Vet J.* 1961; 2(11): 422.
7. Margolis C, Zakošek Pipan M, Demchur J, Or M, Henthorn P, Casal ML. Congenital peritoneopericardial diaphragmatic hernia in a family of Persian cats. *JFMS Open Rep.* 2018; 4(2):2055116918804305.
8. Pauwels FF, Hawkins JF, MacHarg MA, Rothenbuhler RD, Baird DK, Moulton JS. Congenital retrosternal (Morgagni) diaphragmatic hernias in three horses. *J Am Vet Med Assoc.* 2007; 231(3): 427– 32.
9. Santschi EM, Juzwiak JS, Moll HD, Slone DE. Diaphragmatic hernia repair in three young horses. *Vet Surg.* 1997; 26(3): 242– 5.



10. Meng RL, Straus A, Milloy F, Kittle CF, Langston H. Intrapericardial diaphragmatic hernia in adults. *Ann Surg.* 1979; 189(3): 359.
11. Michaëlsson M, Ho SY. Congenital heart malformations in mammals: an illustrated text. London: Imperial College Press; 2000.
12. Nikiphorou X, Chioti R, Patsikas M, Papazoglou L. Peritoneopericardial diaphragmatic hernia in the dog and cat. *J Hell Vet Med Soc.* 2016; 67(3): 189– 94.
13. Clinton JM. A case of congenital pericardio-peritoneal communication in a dog. *Vet Radiol.* 1967; 8(1): 57– 60.
14. Kelmer G, Kramer J, Wilson DA. Diaphragmatic hernia: etiology, clinical presentation and diagnosis. *Compend Equine.* 2008; 3: 28– 36.
15. Reimer SB, Kyles AE, Filipowicz DE, Gregory CR. Long-term outcome of cats treated conservatively or surgically for peritoneopericardial diaphragmatic hernia: 66 cases (1987–2002). *J Am Vet Med Assoc.* 2004; 224(5): 728– 32.