

<Case Report>

Sudden death caused by diaphragmatic rupture following rib fracture in a female sika deer (*Cervus nippon*) at a zoo

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Abstract: A one-year-old female sika deer died suddenly with no preliminary signs during exhibition at a zoo. At necropsy, the carcass was emaciated and had dried fur. Examination of the thoracic cavity revealed a diaphragmatic rupture measuring 2 cm in diameter and a fracture in the middle of the right eighth rib. The liver and lungs had irregular circular discolorations caused by diaphragmatic rupture and subsequent herniation. Dark-brown-colored ascitic fluid, hydrothorax, and yellowish hydropericardium were also observed. The cause of death was determined to be diaphragmatic rupture caused by a rib fracture, which led to respiratory imbalance and circulatory disorders.

Keywords: *Cervus nippon*, diaphragmatic rupture, herniation, rib fractures, sika deer

Diaphragmatic injuries are rare in both humans and animals and can be sequelae of penetrating or blunt traumas [2, 14]. These injuries are induced by an increase in abdominal pressure that may cause diaphragmatic tear and visceral herniation [10]. In humans, herniation into the thoracic cavity is often observed, and the delayed presentation of symptoms can lead to complications and increased mortality [4, 14]. Several reports have documented diaphragmatic rupture in animals such as koalas [5] and a cat [13], caused by road traffic accidents, as well as in foals [12] and horses [11] with or without history of injury. A recent study also documented the laparoscopic correction of experimentally induced diaphragmatic rupture in dogs [15]. Here, we report a rare case of diaphragmatic rupture caused by rib fracture in a sika deer during exhibition at a zoo.

A one-year-old female sika deer died suddenly without any preliminary signs. The animal had been housed in an enclosed facility at Daejeon O-World Theme Park located in central Korea (36°17'N, 127°23'E), where it had been fed a diet of commercial pellet, timothy hay, and alfalfa hay. A necropsy was performed according to a standard protocol.

The carcass was emaciated and had dried fur without external wounds. An examination of the thoracic cavity revealed a diaphragmatic rupture measuring 2 cm in diameter (Fig. 1A, B, and D; white arrows) and a fracture in the middle of the right eighth rib (Fig. 1A and B; white circles). Around the rib, congestion of muscles was observed without subcutaneous hemorrhage. The liver and the lung had circular irregular

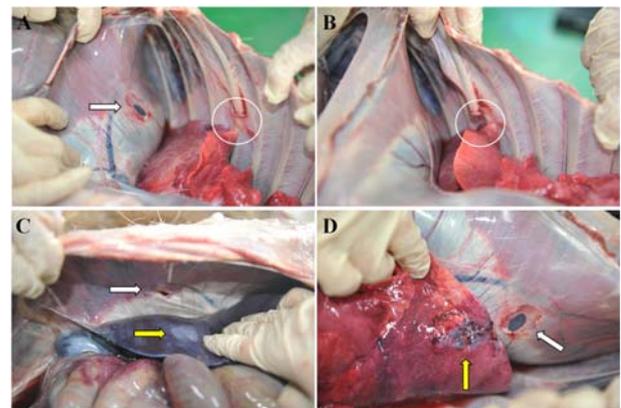


Fig. 1. Gross examination of the diaphragmatic rupture caused by the fracture of the right eighth rib in a one-year-old female sika deer (*Cervus nippon*) on exhibition at a zoo. (A) Examination of the thoracic cavity revealed a diaphragmatic rupture (white arrow) and a fracture in the right eighth rib (white circle). (B) Magnified view of the right eighth rib fracture (white circle). (C) Examination of the abdominal cavity reveals a diaphragmatic rupture (white arrow) and discoloration of the liver due to herniation (yellow arrow). (D) Magnified view of the diaphragmatic rupture (white arrow) and discoloration of the lung due to herniation (yellow arrow).

discoloration (Fig. 1C and D; yellow arrows) caused by diaphragmatic rupture and herniation. Dark-brown-colored ascitic fluid, hydrothorax, and yellowish hydropericardium (data not

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shown) were also observed. Other abdominal organs did not show any specific signs of disorders such as herniation.

To identify the causative agents, microbiological tests for bacteria and microscopic tests for parasites were performed. In brief, for the bacterial examination, tissue samples from the liver, lung, heart, kidney, spleen, and intestine were cultivated in MacConkey (Difco, USA) and blood agar (Asan Pharmacy, Korea) at 37°C for 12–18 h. Parasites in lesions and feces were examined with both naked eye and microscopy. From the small and large intestines, *Escherichia (E.) coli* was identified; however, it was verified as non-hemorrhagic *E. coli*. The other laboratory tests did not reveal any pathogenic bacteria or parasites.

In the present study, congestion of muscles around the rib was observed without subcutaneous hemorrhage. Since reabsorption of subcutaneous hemorrhage is a slow process, its absence in the present study would indicate the rib fracture did not occur as a result of an acute disorder. This would therefore suggest that the rib had been previously fractured and was undergoing the natural healing process, but that an external force subsequently forced it to penetrate the diaphragm.

The diaphragm separates the abdomen from the thorax and has an important role in respiration [1]. A diaphragmatic rupture can lead to the alteration of physiological mechanisms, mainly due to the herniation of abdominal viscera into the thorax [1]. The decrease in thoracic volume causes an increase in abdominal pressure, which affects the respiratory system and causes compression of the vena cava and reduced venous return to the heart. These result in respiratory failure and cardiovascular collapse [1, 6, 10].

In humans, the incidence of diaphragmatic injuries ranges from 1% to 7% in cases of blunt trauma and from 10% to 15% in cases of penetrating wounds [10]. Moreover, injuries are more frequent on the left side (66%) than on the right side (32%) because of the higher frequency of right-handedness among humans [10]. Rupture of the diaphragm often occurs in men and in young people who participate in various physical activities [6]. Motor vehicle accidents are the most frequent causes of diaphragmatic injuries [1, 14]. In animals, most cases of diaphragmatic injuries are identified during necropsies for thoracic trauma [5, 11, 12]. This may be attributed to the natural behavior of wild animals that are reared as a colony that would show hardly any clinical symptoms before death [7].

In humans, the most common symptoms of traumatic diaphragmatic ruptures are dyspnea and pain in the upper abdomen. In such instances, surgical repair is recommended through laparotomy incision [16]. In animals, generally, surgical correction of the fractured ribs is not recommended, but natural healing after quarantine is usually suggested [3]. Zoo veterinarians and zookeepers need to be more vigilant of wild animals reared as a colony as they rarely show clinical symptoms until death.

The sika deer, also known as the spotted deer, is found in East Asia but is now uncommon in the wild [8]. The sika

deer is mainly reared on farms for its antlers although a few specimens are also exhibited in zoos [9].

The deer from the current study had been reared in a mountainous area (about 1,500 m²) with 13 other sika deer and 7 fallow deer (*Dama dama*). It is possible that the rib fracture occurred by blunt force trauma while the animal was competing for feed with other enclosed deer, resulting in the diaphragmatic injury. The sudden death may have been caused by the diaphragmatic rupture following rib fracture, which led to respiratory imbalance and circulatory disorders.

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