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NOTE

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Severe hydrocephalus in a raccoon dog (*Nyctereutes procyonoides*)

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ABSTRACT. Hydrocephalus is one of the most common central nervous system malformations in domestic dogs, yet they are poorly documented and studied in wild carnivoran mammals. A pup of raccoon dog (Nyctereutes procyonoides) was rescued and brought to Wildlife Center. The pup showed generalized ataxia, a domed skull, and an open bregmatic fontanelle. Ultrasound and MRI showed severe enlargement of the lateral ventricle with the loss of septum pellucidum resulting in a single large ventricle and cervical syringohydromyelia. Although treatment was attempted, the animal was euthanized due to poor prognosis. At necropsy, macroscopic findings were identical to the diagnostic imaging, where marked enlargement of the calvarium, and attenuated gyri and sulci were observed. Finally, hydrocephalus was confirmed. Here, we describe a case of hydrocephalus in a raccoon dog (Nyctereutes procyonoides).

KEY WORDS: hydrocephalus, raccoon dog, syringohydromyelia

Hydrocephalus refers to the condition where excessive cerebrospinal fluid (CSF) accumulates in the cranial cavity, caused by either an increase in CSF formation or a decrease in CSF absorption due to an underlying multifactorial disorder [12]. The increase in pressure causes compression atrophy in the surrounding cerebral parenchyma, eventually leading to an active distention in the ventricular system. It is associated with a wide variety of diseases and syndromes and may be congenital or acquired. Acquired hydrocephalus has been reported with numerous conditions, including obstruction, infection-caused loss of brain parenchyma with subsequent ventricular enlargement, or, in rare instances, increased CSF production from a tumor of the choroid plexus [1]. Causes of congenital hydrocephalus are harder to identify, with research on the genetic deposition of congenital hydrocephalus limited even in domestic animals.

In this study, a raccoon dog (*Nyctereutes procyonoides*) pup approximated to be 3-weeks-old was rescued and brought to the Seoul Wildlife Center located in Seoul, Republic of Korea. The age was estimated based on the coat and weight, by experts of the wildlife rescue center, who had reared raccoon pups for years. Physical examination showed generalized ataxia, dehydration, a domed skull, and opened bregmatic fontanelle. Brain ultrasonography through the bregmatic fontanelles showed enlarged ventricles and temporal horn, confirming a diagnosis of hydrocephalus (Fig. 1). After 3 days of intensive care, the pup was bright and alert but showed no improvement in ataxia. The animal had mild peripheral alopecia in the legs, and localized balding was noted in the cranial area (Fig. 2). The pup was relatively well-nourished, with a body condition score of 2 out of 5. In the rescue center, it was fed with a mixture of puppy milk replacer and canned puppy food, and was given regular vitamin and nutritional supplements through oral and intravenous routes. It showed consistent appropriate weight gain and no signs of malnutrition were observed.

Magnetic resonance imaging (MRI) using 0.3T system (AIRIS Vento, Hitachi Medical Systems, Singapore) in T1W and T2W sagittal and transverse imaging in 3.0 mm slice thickness of the brain area was performed to further study the condition of the patient. Severe enlargement of the lateral ventricle with the loss of septum pellucidum resulting in a single large ventricle was observed, and only a thin rim of the cerebral tissue was left as the cerebral gyri flattened from the inside (Fig. 3A). Sparing of the butterfly-shaped diencephalon ventral to the ventricle with asymmetric and irregular contour was shown (Fig. 3B). Enlargement of all the ventricles and subarachnoid space was observed, indicating a possible obstruction at or near the arachnoid villi [12]. Additionally, multiple hyperintensities and irregular margin at the cervical spinal cord on the T2W sequence could be seen, indicating cervical syringohydromyelia. No specific anatomical relationship between the hydrocephalus and syringohydromyelia was observed through the MRI. Unfortunately, no histopathological study was performed on the specimen that could further evaluate the mentioned lesions.

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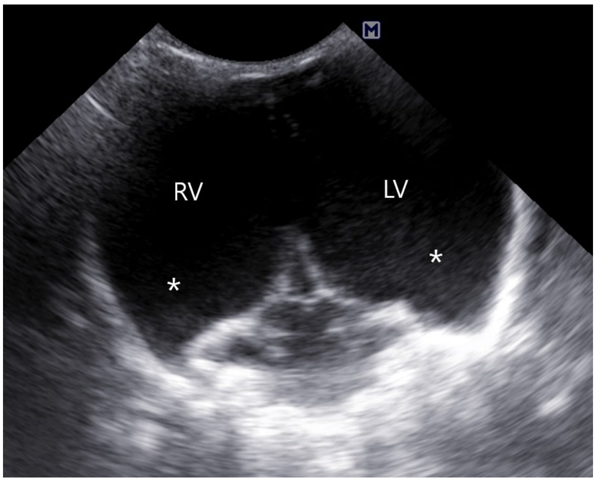

Fig. 1. Ultrasonography through the bregmatic fontanelle, showing the brain with an enlarged left (LV) and right ventricle (RV).

Fig. 2. A domed head with thinning of the hair causing cranial alopecia.

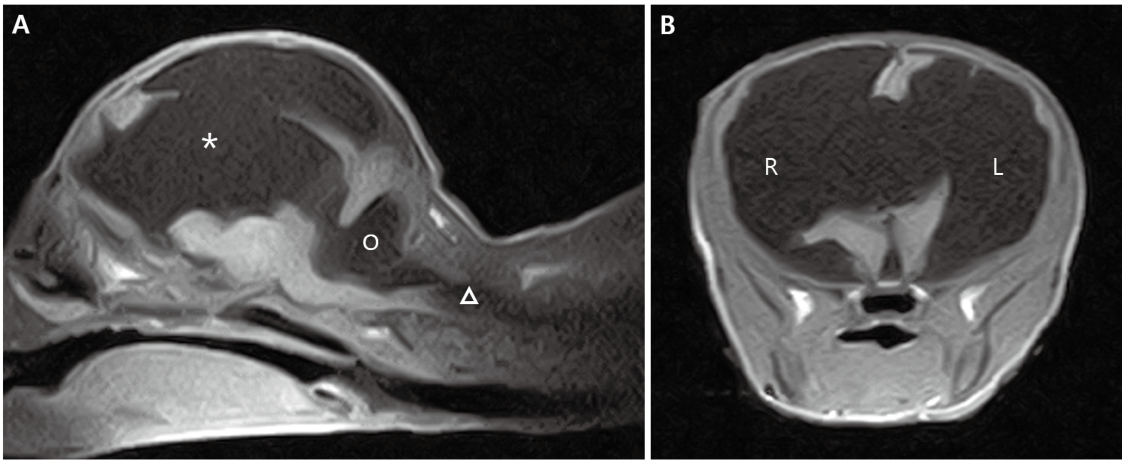

Fig. 3. (A) Sagittal T1 weighted MRI showing extreme enlargement of the lateral ventricle (asterisk), the fourth ventricle (circle) and the cerebral aqueduct connecting the two. (B) Axial T1 weighted MRI showing sparing of the butterfly-shaped diencephalon with irregular contour ventral to the bilateral enlargement of the lateral ventricle.

Antibiotic therapy of amoxicillin clavulanate intravenous (IV) once (SID), followed by Cefazolin IV CRI for the next days, was administered in consideration of encephalitis; however, there was no improvement. Additionally, Furosemide IV SID and Mannitol IV SID was used to help lower the intracranial pressure, while Omeprazole IV was administered to lower CSF production. Methylprednisolone sodium succinate (MPSS) IV was given for 3 days in tapering dosage for its neuroprotective effects. The animal was hospitalized but did not show any major improvement for over a month. Euthanasia was performed due to poor prognosis. Gross examination revealed a dome-shaped marked enlargement of the calvarium (Fig. 4A). The brain was swollen with attenuated gyri and sulci and collapsed when taken out from the skull. The central canal of the spinal cord was dilated. Serial cross-sections of the brain revealed marked dilation of the ventricles, including the lateral ventricles, creating a large 22 mm radius cavity (Fig. 4B). Brain parenchyma was severely atrophied while all other major parenchymal organs were grossly normal. No remarkable findings were made in the thyroid glands, and no signs of trauma, such as fracture, bruising and internal hemorrhage, were seen.

Furosemide, a loop diuretic, is prescribed to halt further progression of hydrocephalus through the reduction of CSF production [3]. However, impairment of CSF flow due to blockage, such as in non-communicating hydrocephalus, will render the treatment unresponsive due to the unavailability of an effective drainage. In this raccoon pup, deteriorating condition and extreme hydrocephalus upon MRI and gross necropsy suggests that the continuous treatment of furosemide was ineffective. This goes in line with the diagnosis of syringohydromyelia, confirming the possible blockage leading to the dilation of the spinal canal.

In the domestic dog, congenital hydrocephalus is reported to be more common than acquired hydrocephalus and typically recognizable in patients as young as 2 to 3 months [1]. In wild animals, however, the low probability of survival after the onset of hydrocephalus makes the condition a rare case. Internal hydrocephalus has been previously reported in bears [4] and red fox [8],

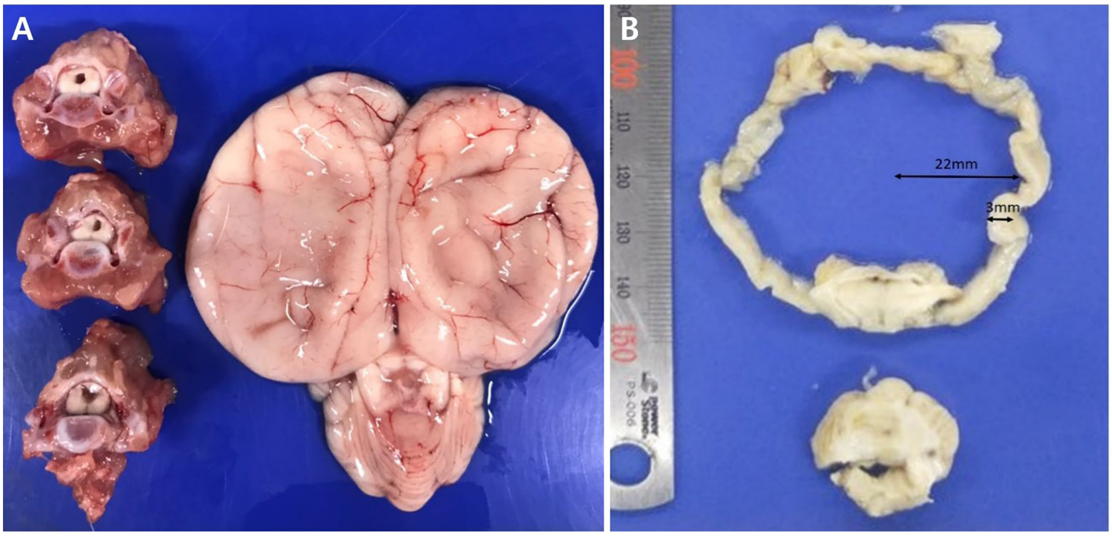

Fig. 4. Gross findings of the brain and spinal cord. (A) Marked swelling of the brain with attenuated gyri and sulci. Central cavitation in the cervical spinal cord. (B) Cross section of the brain shows marked dilation of the lateral ventricles and parenchymal atrophy. The fourth ventricle is also dilated.

but in these cases, alopecia and syringohydromyelia were not described. Common findings include ataxia, compression of the gyri, and blindness.

A previous report of hydrocephalus associated with periventricular encephalitis in a young red fox [8] proposed infectious agents as a possible cause of hydrocephalus in wild animals. Though cases of hydrocephalus caused by rabies may be rare, experimental models in chicks [2], as well as clinical case reports in humans [5], have been made. Hydrocephalus from rabies is caused by the viral inflammation around the cerebral aqueduct [6], causing blockage, and subsequent hydrocephalus. As rabies remains a common zoonotic disease with wildlife involvement, rabies should be in the list of differential diagnoses when symptoms of acute, progressive encephalitis of unknown origin are observed in wild animals [7]. Rabies is of greater concern in raccoon dogs, as they are identified as important vectors of rabies in several European countries [11], and in South Korea [9]. Unfortunately, no tests for viral infection were run in this animal; hence, viral causes cannot be ruled out in this study. However, the increase in CSF volume, young age, extreme deformation of the calvarium, lack of improvement on antibiotic treatment, and doming of the head all coincide with congenital hydrocephalus. The animal showed no other symptoms of infection, including fever and leukocytosis, during its hospitalization.

Hydrocephalus is one of the most common central nervous system malformations and is extensively studied in domestic dogs, yet it is poorly documented, explored, and treated in wild carnivoran mammals. Furthermore, no treatment attempts and diagnostic imaging using ultrasonography and *MRI* have been reported in hydrocephalic wild canids in the past. Detailed diagnostic procedures, including testing for common infectious agents such as rabies, are recommended in patients showing signs of acute encephalitis in the management of wildlife health. Though the prognosis of this patient was poor, successful treatment options in the domestic dog show that recovery is possible [10]. Treatment may be impractical for most wildlife species, but studies may enable treatment to be an option in rarer and critically endangered individuals.

POTENTIAL CONFLICTS OF INTEREST. The authors have nothing to disclose.

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