大韓獸醫學會誌 (2015) 第 55 卷 第 3 號
Korean J Vet Res(2015) 55(3) : 169~173
http://dx.doi.org/10.14405/kjvr.2015.55.3.169

<Original Article>

Retrospective study of the medical status of 34 Formosan sika deer (*Cervus nippon taiouanu*) at the Taipei Zoo from 2003 to 2014

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(Received: May 12, 2015; Revised: August 9, 2015; Accepted: August 13, 2015)

Abstract : The Formosan sika deer (*Cervus nippon taiouanus*) is an endemic subspecies in Taiwan. The original wild deer has been extinct since the late 1960s. The largest captive population is located at the Taipei Zoo. Except for infectious disease outbreaks, no systemic medical research has been reported for this subspecies. This study was conducted to analyze the medical status of the captive Formosan sika deer population, including the hematological and serum chemistry characteristics. To accomplish this, medical records for 34 Formosan sika deer from January 2003 to January 2014 were acquired and analyzed. The most common illness and cause of death was trauma, followed by gastrointestinal and respiratory disease, respectively. The hematologic and serum chemical values of healthy adults were quite different from those of sika deer (*Cervus nippon yesoensis*). This study provides a closer medical understanding of this subspecies and the results will facilitate its management.

Keywords : Formosan sika deer, gastrointestinal disease, respiratory disease, Taiwan, trauma

Introduction

The Formosan sika deer is an endemic subspecies in Taiwan. They were widely distributed on the coastal plain in Taiwan but became extinct in the wild during the late 1960s because of overhunting and the expansion of agricultural activities [9]. The first captive Formosan sika deer group was reintroduced into wild in 1990 at Kentin National Park in southern Taiwan [9].

A number of disease studies have been reported on sika deer. Most of these reports focused on parasitic infections in the wild population [2, 6, 10, 16, 17]. Reports on diseases in Formosan sika deer are few. Only *Mycobacterium* spp. infection [3] and malignant catarrhal fever [8] have been reported. No systemic disease investigation has ever been reported on the captive Formosan sika deer population.

This study analyzed the medical status of the captive Formosan sika deer population, including hematological and serum chemistry evaluation. To our knowledge, this is the first retrospective study on diseases and hematology in Formosan sika deer. This study is expected to provide more information to assist in the management of this precious subspecies.

Materials and Methods

Animals

The medical records of 36 Formosan sika deer kept at the Taipei Zoo from 2003 January to 2014 January were collected. Two neonates, which died immediately after birth, were excluded from this study. Fourteen males and 20 females were analyzed. The deer were housed in two large naturalistic outdoor enclosures (about 60 × 30 m for each). The main diet is comprised of green grass (*Pennisetum purpureum*), dry Bermuda grass (*Cynodon dactylon*), and alfalfa (*Medicago sativa*) pedicles which were fed *ad libitum*. Each individual is supplied with 600 g low-protein ruminant concentrated food (ingredients: moisture 10.00%, crude protein 13.02%, crude fat 3.56%, crude fiber 15.17%, crude ash 7.96%; Fwusow Industry, Taiwan) every day. Mineral salt (Winning, Taiwan) is provided once a week.

Body weight

Only healthy adults (> 14.5 months) [12] without any current disease, treatment or pregnancy were used for bodyweight analysis (n = 31). Weights were obtained at different times, with a total of 48 recordings (21 for males and 27 for females). The mean and SD were calculated and the average weight of males and females was compared using the Mann-

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Whintney U test. P value ≤ 0.05 was considered statistically significant.

Age

The average age of the current population (n = 8) and the average age at death (n = 16) were calculated. Among the whole population, 10 individuals that were transported to other zoos during the study period were excluded in this analysis. The average age at death for males and females was compared using the Mann-Whintney U test. P value ≤ 0.05 was considered statistically significant.

Common illnesses and causes of death

All of the illnesses reported in the medical records were carefully reviewed and categorized. The number of individuals affected with each illness was calculated and analyzed. One individual could be repeatedly afflicted with the same illness. If the same illness was found in the same individual in the following year, it would be noted as an additional case. The correlation between trauma occurrence and gender was evaluated using relative risk and further compared using Fisher's exact test at the 0.05 significant levels. The causes of death of 16 deceased Formosan sika deer were also analyzed.

Hematologic and serum chemistry values

Blood samples were collected during annual checkup. Only animals that showed no signs of disease or treatment were included for this analysis. There are a total of 133 blood samples from 31 adults. The deer were fasted about 18 h and anesthetized with 200 mg of xylazine and 250–300 mg of ketamine by blow-dart. Blood samples were collected from the jugular vein and kept in EDTA blood collection tubes for hematological test (Exigo Veterinary Hematology Analyzer; Boule Medical, Sweden) and in plain tube for serum chemistry test (SpotChem Ez SP-4430; ARKRAY, Japan). Values between different genders were compared. Male and female combined values were compared with those of sika deer reported in the International Species Information System (ISIS). Student's t-test was used and p value ≤ 0.05 was considered significant.

Results

Body weight

The average body weights of adult male and female Formosan sika deer at the Taipei Zoo were 73.7 ± 19.1 kg and 51.3 ± 11.8 kg, respectively. Male sika deer presented significantly higher body weight than females ($p < 0.001$).

Age

The average age of the current Formosan sika deer population (n = 8) at the Taipei Zoo ranged from 8.3 ± 6.6 yr. The average age of males (n = 4) and females (n = 4) were 6.3 ± 3.7 yr and 10.3 ± 8.7 yr, respectively. The average age at death was 10.9 ± 7.0 yr (n = 16), and that of males and females was 5.7 ± 4.7 yr (n = 6) and 14.0 ± 6.4 yr (n = 10), respectively. The average age at death showed statistical significance between males and females ($p = 0.015$).

Common illness

The most common illness found in Formosan sika deer at the Taipei Zoo are summarized in Table 1. Some of the individuals suffered from more than one illness during their life. Trauma was the most common illness found in this retrospective study and 67.7% of the individuals (55.7% of the cases) suffered from trauma. The relative risk for trauma for males to females was 0.625. However, this was not statistically significant (p = 0.135).

The second most common illness was gastrointestinal disease, with 29.4% of the individuals (15.2% of the cases) afflicted with it. Twelve cases were recorded with gastrointestinal problems, including tooth root abscess (2 cases), blood in stool (2 cases), tympany (2 cases) and diarrhea (3 cases). Three individuals which did not have medical records showing gastrointestinal disease were found to present gastrointestinal lesions during necropsy, including two with gastric ulceration and one with intussusception.

Table 1. Illness of Formosan sika deer at the Taipei Zoo

Illness	Number of individuals	Number of cases	Percentage	
			of individuals	of cases
Trauma	23	44	67.7	55.7
Gastrointestinal disease	11	12	29.4	15.2
Joint and hoof problem	5	5	14.7	6.3
Cardiovascular disease	5	5	11.8	6.3
Respiratory disease	4	4	11.8	5.1
Reproductive disease	2	3	5.9	3.8
Others	6	6	17.7	7.6
Total	34*	79	100	100

*Total 34 Formosan silk deer were included in disease analysis. One individual could be repeatedly afflicted with the same disease. If the same disease was found in the same individual in the following year, it would be noted as an additional case.

In addition, Formosan sika deer at the Taipei Zoo were also afflicted with joint and hoof problem (n = 5), cardiovascular disease (n = 5), respiratory disease (n = 4) and reproductive disease (n = 2). Other diseases included tick infection (n = 1), cachexia of neonate (n = 1), systemic bacterial infection (n = 2), cataract (n = 1) and adrenalitis (n = 1).

Causes of death

The causes of death for 16 Formosan sika deer are summarized in Table 2. The most common cause was trauma (n = 5), followed by respiratory disease (n = 4) and gastrointestinal disease (n = 3). Two individuals died of cardiovascular diseases, and two individuals died of systemic bacterial infection. There were two male fawns among the 16 deceased deer; one died at one week old because of pneumonia and the other died at 1.5 months old due to systemic bacterial infection.

Table 2. Cause of death in 16 Formosan sika deer at the Taipei Zoo

Illness	Number	Percentage
Trauma	5	31.3
Respiratory disease	4	25.0
Gastrointestinal disease	3	18.8
Cardiovascular disease	2	12.5
Systemic bacterial infection	2	12.5
Total	16	100

Hematologic and serum biochemistry values

The average hematologic and serum biochemical values from 31 healthy adults are shown in Table 3. Compared to females, males had higher white blood cell (WBC; $p < 0.001$), red blood cell (RBC; $p = 0.018$), total protein ($p = 0.002$), albumin ($p < 0.001$) and alkaline phosphatase (ALKP) values ($p < 0.001$), and lower mean cell volume (MCV; $p = 0.005$), mean cell hemoglobin (MCH; $p = 0.001$), blood urea nitrogen (BUN; $p < 0.001$), cholesterol ($p < 0.001$) and triglyceride values ($p = 0.001$).

Compared to the ISIS reference for sika deer, Formosan sika deer at the Taipei Zoo had higher MCV ($p = 0.032$), MCH ($p = 0.002$), total protein ($p < 0.001$), alanine aminotransferase (ALT; $p < 0.001$) and glucose values ($p < 0.001$), and lower RBC ($p < 0.001$), hemoglobin (Hb) ($p < 0.001$), packed cell volume (PCV; $p < 0.001$), albumin ($p = 0.017$), aspartate aminotransferase (AST; $p < 0.001$), ALKP ($p = 0.001$) and triglyceride values ($p = 0.010$).

Discussion

The average age at death of the Formosan sika deer population was 10.9 ± 7.0 yr (n = 16), and that of males was lower

Table 3. The average hematologic and serum biochemical values (mean ± SD) of adult Formosan sika deer (> 14.5 months) at the Taipei Zoo

Measurement	Male (reference interval)	Female (reference interval)	Male and female combined (reference interval)	Reference‡
WBC ($10^3/\mu L$)*	4.8 ± 1.6 (2.2–7.5)	3.7 ± 1.3 (1.7–6.8)	4.0 ± 1.5 (1.8–7.4)	4.2 ± 1.5
RBC ($10^6/\mu L$)*,†	8.6 ± 1.8 (5.3–11.9)	7.7 ± 2.3 (2.8–11.5)	7.9 ± 2.2 (3.0–11.8)	10.0 ± 2.4
Hb (g/dL)†	12.3 ± 1.8 (9.5–15.0)	12.7 ± 2.5 (8.6–17.6)	12.5 ± 2.1 (9.0–17.6)	15.4 ± 2.9
PCV (%)†	34.7 ± 7.5 (24.6–50.7)	35.4 ± 8.6 (16.2–52.3)	35.2 ± 8.3 (16.2–52.3)	42.7 ± 7.9
MCV (fL)*,†	41.4 ± 10.1 (31.0–50.3)	50.1 ± 25.4 (32.7–132.1)	47.5 ± 22.3 (32.0–122.7)	43.3 ± 7.4
MCH (pg/cell)*,†	14.9 ± 3.5 (10.5–18.1)	17.9 ± 6.6 (11.9–37.1)	17.0 ± 6.0 (11.6–35.7)	15.4 ± 2.7
MCHC (g/dL)	36.8 ± 9.0 (18.8–42.8)	37.0 ± 7.7 (23.5–58.6)	37.0 ± 8.0 (21.4–58.6)	35.7 ± 2.6
PLT ($10^3/\mu L$)	312.4 ± 214.8 (50.8–867.4)	239.3 ± 130.3 (30.1–473.7)	262.8 ± 165.1 (34.0–677.0)	276.0 ± 165.0
Total protein (g/dL)*,†	7.7 ± 0.7 (5.9–8.7)	7.3 ± 0.8 (6.4–8.5)	7.4 ± 0.8 (6.2–8.7)	7.0 ± 0.8
Albumin (g/dL)*,†	3.7 ± 0.3 (3.1–4.3)	3.4 ± 0.4 (2.6–4.2)	3.5 ± 0.4 (2.7–4.2)	3.6 ± 0.7
AST (IU/L)†	58.3 ± 33.2 (32.9–102.1)	56.9 ± 17.8 (31.0–91.5)	57.3 ± 23.4 (30.7–94.8)	71.0 ± 30.0
ALT (IU/L)†	42.7 ± 13.2 (24.8–75.1)	44.8 ± 17.0 (19.0–77.4)	44.2 ± 16.0 (19.0–76.7)	39.0 ± 18.0
BUN (mg/dL)*,†	19.7 ± 5.9 (8.8–29.0)	25.2 ± 10.6 (11.4–51.8)	23.6 ± 9.8 (10.3–48.4)	27.0 ± 7.0
Creatinine (mg/dL)	1.7 ± 0.47 (1.1–2.8)	1.7 ± 0.5 (1.0–2.8)	1.7 ± 0.5 (1.0–2.8)	1.7 ± 0.6
UA (mg/dL)	0.3 ± 0.2 (0.0–0.5)	0.8 ± 4.1 (0.0–0.9)	0.7 ± 3.6 (0.0–0.8)	0.1 ± 0.1
GLU (mg/dL)†	184.6 ± 51.6 (91.8–262.8)	178.3 ± 59.7 (84.4–282.0)	180.1 ± 57.4 (83.1–280.0)	151.0 ± 62.0
ALKP (IU/L)*,†	319.4 ± 206.0 (100.7–887.2)	113.4 ± 134.8 (29.2–545.7)	177.4 ± 186.0 (34.7–683.3)	235.0 ± 244.0
CHOL (mg/dL)*	48.7 ± 22.4 (12.1–95.8)	76.7 ± 31.5 (32.3–176.5)	68.7 ± 31.8 (22.0–150.9)	74.0 ± 32.0
TG (mg/dL)*,†	12.8 ± 7.9 (2.0–24.4)	21.5 ± 15.9 (3.5–59.0)	18.9 ± 14.5 (2.2–51.4)	23.0 ± 15.0

*Statistically significant between males and females ($p < 0.05$). †Statistically significant between the combined values and those of sika deer in ISIS database ($p < 0.05$). ‡Reference reported for sika deer in ISIS.

(5.7 ± 4.7 yr, n = 6) than that of females (14.0 ± 6.4 yr, n = 10) with statistical significance ($p = 0.015$). Among the 16 deceased deer, two male fawns died below 2 months of age. If these two border values were excluded, the average age at death of the Formosan sika deer population increased to 12.4 ± 6.0 yr (n = 14). The average age at death of males and females would become 8.5 ± 2.3 yr (n = 4) and 14.0 ± 6.4 yr (n = 10), respectively, and show no statistical significance ($p = 0.089$).

The common illness and causes of death in the Formosan sika deer population were compared with other studies. A report indicated that trauma was the most common illness and cause of death in captive cervid herds in Michigan, USA [2], which was similar to our results. Trauma was the most common illness and cause of death, and fighting was the major cause. Interestingly, trauma occurrence in males and females did not show statistical difference in our study. Farmed dominant male sika deer were reported to tolerate the presence of other males and only fought other males while the females were in estrus or just after copulation [4]. The male tolerance behavior may be a reason that the trauma incidence in males was not higher than that in females.

Gastrointestinal disease was the second most common illness and the third most common cause of death in Formosan sika deer in this study. It was the second most common cause of death in captive white-tailed deer [7] and the third most common cause of death in wild roe deer [1], in which gastritis and enteritis due to infection were the major causes. In contrast, the three deaths attributed to gastrointestinal disease in our study were due to gastric ulceration (n = 2) and intussusception (n = 1).

Respiratory disease was the second most common cause of death (25.0%) in our study. Similarly, respiratory disease was the second most common cause of disease in captive cervid herds in Michigan, USA [2], and bronchopneumonia was the most common cause of death in captive white-tailed deer (*Odocoileus virginianus*) [7]. Most respiratory disease in Formosan sika deer was identified during necropsy, but not from ante mortem diagnosis. This indicated that a more effective way to monitor and diagnose respiratory disease in Formosan sika deer is imperative.

We compared hematology values between males and females. Males had higher WBC, RBC, total protein, albumin and ALKP than females, while the MCV, MCH, BUN, cholesterol, and triglyceride values were lower than females. A report indicated that RBC and PCV were significantly higher and MCH was lower in excited male than in excited female sika deer [13], which was consistent with our data. Male Formosan sika deer had higher total protein and albumin than females, which was also observed in fallow deer (*Dama dama L.*) [15]. Moreover, a study showed that ALKP activity was higher during antler growth period in male sika deer [11], which may account for the higher average ALKP value seen in male Formosan sika deer.

Compared to the ISIS reference on sika deer, the RBC, Hb, PCV and albumin values in Formosan sika deer were lower, which may be related to the anesthesia agent (xylazine) used at the Taipei Zoo. Xylazine belongs to alpha 2 agonist family of tranquilizers, which alters capillary permeability and causes a certain degree of haemodilution in deer [18]. Loss of protein, particularly albumin, and lower Hb and PCV may occur [14, 18]. With the exception of the higher total protein in our study, these were consistent with ISIS reference ranges. We assumed that higher total protein concentration in our study was primarily due to mild dehydration because Formosan sika deer were withheld water prior to anesthetization. The Alpha 2 agonist also regulates pancreatic beta cell receptors that inhibit insulin release and increase hepatic glucose production [5]. This may be the reason why the glucose value in our study is higher than the ISIS value. In addition, the stress caused by chasing and darting the deer may also play a role in the hyperglycemia.

Formosan sika deer is an endemic subspecies native to Taiwan. No data are available for this subspecies in ISIS. Referring the nearest species to sika deer was therefore used for comparison. However, it is highly possible that different subspecies have variable hematologic and serum biochemical reference values. This may account for certain values in Formosan sika deer were significantly different from those of sika deer in ISIS.

In this study, hematological tests were performed using the Exigo Veterinary Hematology Analyzer (Boule Medical), which is not indicated for use on deer. The nearest species analysis profile for the instrument, the cow profile, was used for the Formosan sika deer instead. A substitute manual complete blood count would be suggested to attain more precise data, although this will be very laborious and time-consuming.

This report is the first retrospective study on diseases and hematology analysis of captive Formosan sika deer, which could provide clearer understanding of this subspecies from the medical view. Although the study span was 11-years long, the sample size was still small (n = 34). Further and longer investigation, both on captive groups and wild populations, should be continued to offer more information to assist in the management of this precious subspecies.

Acknowledgments

We thank the staff at the Medical Center of Taipei Zoo (Taiwan) for their assistance in data collection.

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