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Abstract

Since 1956, when the Basle Zoo (Switzerland) initiated the breeding of lesser kudu (Tragelaphus imberbis), 43% of the lesser kudu juveniles died before reaching an age of 6 mo. In this study, the objective was to obtain the pathological findings, nutritional history, and family tree information in order to evaluate the influence of husbandry on juvenile mortality in these animals. The main cause of death was white muscle disease (WMD), diagnosed in 14 cases (26%) of the deceased juveniles. Although enclosure size had remained constant and animal accessibility to the public was constantly high, both herd size and juvenile mortality had increased from 1956-2004. The diet consumed by the whole group in 2004 had deficient levels of vitamin E and selenium. The increasing linear trend of the mortality rate since the 1960s was significant, and there was a significant correlation between herd size and overall juvenile mortality. In contrast, there was no correlation between herd size and the occurrence of juvenile mortality associated specifically with WMD. Other investigated factors (sex, inbreeding, and season) had no significant effect on overall mortality up to 6 mo of age or on mortality associated with WMD. These results characterize both a dietary and a husbandry problem, and are supported by a lack of similar juvenile mortality in another facility where the diet was supplemented with vitamin E, animal numbers were kept low, and the enclosure structure offered more retreat options for the animals.
JUVENILE MORTALITY IN CAPTIVE LESSER KUDU
(Tragelaphus imberbis) AT BASLE ZOO AND ITS RELATION
to nutrition and husbandry

Dorothea Besselmann, Dr. med. vet., Daniela Schaub, Dr. med. vet., Christian Wenker, Dr. med. vet.,
Jürg Völlm, Dr. med. vet., Nadia Robert, Dr. med. vet., Claude Schelling, P.D., Dr. med. vet.,
Hanspeter Steinmetz, M.Sc., Dr. med. vet., and Marcus Clauss, M.Sc., Dr. med. vet., Dipl. E.C.V.C.N.

Abstract: Since 1956, when the Basle Zoo (Switzerland) initiated the breeding of lesser kudu (Tragelaphus imberbis), 43% of the lesser kudu juveniles died before reaching an age of 6 mo. In this study, the objective was to obtain the pathological findings, nutritional history, and family tree information in order to evaluate the influence of husbandry on juvenile mortality in these animals. The main cause of death was white muscle disease (WMD), diagnosed in 14 cases (26%) of the deceased juveniles. Although enclosure size had remained constant and animal accessibility to the public was constantly high, both herd size and juvenile mortality had increased from 1956–2004. The diet consumed by the whole group in 2004 had deficient levels of vitamin E and selenium. The increasing linear trend of the mortality rate since the 1960s was significant, and there was a significant correlation between herd size and overall juvenile mortality. In contrast, there was no correlation between herd size and the occurrence of juvenile mortality associated specifically with WMD. Other investigated factors (sex, inbreeding, and season) had no significant effect on overall mortality up to 6 mo of age or on mortality associated with WMD. These results characterize both a dietary and a husbandry problem, and are supported by a lack of similar juvenile mortality in another facility where the diet was supplemented with vitamin E, animal numbers were kept low, and the enclosure structure offered more retreat options for the animals.

Key words: Lesser kudu, Tragelaphus imberbis, white muscle disease, vitamin E, diet, herd size, inbreeding.

CASE REPORT

Lesser kudu are found browsing in dry forests and brush in northeastern Africa.1,12 They are considered to be difficult animals in captive situations and therefore are rarely kept in zoos. The problem of successfully raising lesser kudu at Basle Zoo (Switzerland) was discussed in two previous reports.11,14 Lang11 observed that juvenile mortality decreased after installation of a heatable nest box; low environmental temperature was identified as one of the main factors influencing juvenile mortality. Rüedi et al.14 previously reported that low vitamin E levels in three juvenile animals resulted in their deaths, which were associated with white muscle disease (WMD). Rüedi et al.14 examined the vitamin E content of plasma and liver samples of healthy and diseased animals as well as the diet offered to the kudu and recommended the inclusion of wheat germ to increase dietary vitamin E levels.

Nevertheless, a generally high loss of juveniles as well as cases of WMD seem to have persisted over the years. The aim of this study was to assess juvenile mortality, the incidence of WMD, and potential contributing causes to this scenario by evaluating the necropsy reports since 1956, the family trees of the animals affected, and the diets consumed by lesser kudu at the Basle Zoo.

Basle Zoo

At the Basle Zoo, lesser kudu were kept on a 400-m² outdoor enclosure. In addition, they had access to the outdoor giraffe enclosure, which was situated next to the kudu enclosure and separated from it by a semipermeable gate. The indoor enclosure consisted of four single boxes (4 m × 9 m), which usually were combined but could be separated. The whole group was kept together at all times. There was one single box that was not visible to visitors where, after birth, mother and offspring were separated from the group for 2 days. In winter, the lesser kudu were kept indoors and the

From the Division of Zoo Animals and Exotic Pets, Vetsuisse Faculty, University of Zurich, Winterthurerstrasse 260, CH-8057, Zurich, Switzerland (Besselmann, Schaub, Steinmetz, Clauss); the Zoological Garden Basle, Binningerstrasse 40, CH-4054, Basle, Switzerland (Wenker, Völlm); the Centre for Fish and Wild Animal Health, Institute for Animal Pathology, Vetsuisse Faculty, University of Berne, Länggass-Strasse 122, CH-3012, Berne, Switzerland (Robert); and Clinical Laboratory, Vetsuisse-Faculty, University of Zurich, ETH Zurich, Tannenstrasse 1, 8092 Zurich, Switzerland (Schelling). Correspondence should be directed to Dr. Clauss (mclauss@vetclinics.uzh.ch).

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Figure 1. Number of juvenile deaths in lesser kudu (*Tragelaphus imberbis*) attributed to white muscle disease between 1975 and 2004.

visitors could approach the animals at close distances (<1 m).

Necropsy reports for 54 juvenile (younger than 6 mo of age) lesser kudus that died between 1956 and 2005 at the Basle Zoo were evaluated for the cause of death and the occurrence of specific diseases. The 54 juveniles that died had an average lifespan of 45 days. The most frequent diagnoses at necropsy were WMD (14); enteritis (8); renal alterations (7); and starvation (7). Other causes of death were pneumonia (4) and necrobacillosis (2). The occurrence of WMD did not change notably over the years (Fig. 1). In particular, there was no notable change after the 1980 report of Rüedi et al. It is interesting to note that in the few years after that study, no mortality associated with WMD was reported. This observation may be the result of a short-lived awareness of the problem after it was investigated.

WMD in 14 juveniles had been classified as severe in eight and medium-grade in six cases. Histopathological investigation revealed typical lesions limited to skeletal muscle fibers in five cases, heart muscle fibers in one case, and combined alterations in eight cases. Histologically, lesions were characterized by multifocal hypercontraction and hyaline degeneration and mineralization of disseminated or grouped myofibers, associated with varying macrophage infiltration and proliferation of satellite cells. The lesions were compatible with the changes usually described in nutritional myopathies in domestic livestock.

There were four additional animals that showed only mild signs of WMD at necropsy and therefore were assigned to a main "cause of death" group other than WMD. In animals affected with enteritis, bacteriologic culture revealed *Escherichia coli* in three cases and *Clostridium perfringens* in three cases. There was also a severe infestation of *C. perfringens* in animals with primary diagnoses other than enteritis. Overall, 11 animals (20%) were diagnosed with *C. perfringens* at necropsy. All parasitologic examinations (*n* = 8) were negative.

In the spring of 2004, all diet items offered to the whole group of lesser kudus, as well as the remaining uneaten food, were weighed for 3 consecutive days in order to assess the diet. Intake recording on an individual level was not deemed feasible for this survey, because it would have caused undue stress for the respective animals. The diet ingested daily by nine animals (one adult male, six adult females [including two that were lactating], and two juveniles) in the spring of 2004 consisted of 8.53 kg lucerne hay (*Medicago sativa*); 1.96 kg of a pelleted compound feed (crude protein 15.3%, crude fiber 18.0%, vitamin E 400 mg/kg, selenium
0.5 mg/kg); 2.29 kg carrots; 1.63 kg beet roots; 0.58 kg fennel; 0.49 kg sugar beets; and 0.13 kg chicory. The proportion of roughage to nonroughage food components, on an as-fed basis, was 55:45. The results were entered into Zootrition software V2.5 (St. Louis Zoo, St. Louis, Missouri 63110 USA), which contained customized information on the composition of the diet items used at the Basle Zoo, and compared this information with the recommendations for another browsing ruminant, the okapi (Okapia johnstoni). Calculated crude protein levels of this diet were 95% of the recommendations for okapi maintenance, whereas vitamin E levels were 52% and selenium levels were 60% of the recommendations. During the growing season, the animals also received freshly cut grass.

Historically, inbreeding, as judged from the family trees compiled from the lesser kudu register of the Basle Zoo, often occurred in the herd. Daughters bred with their fathers in 32 cases, mothers with sons in 11 cases, and a sister with a brother in one case. Thus, 44 of 133 animals are a product of direct inbreeding. The breeding male who sired offspring from 1985–1994 was diagnosed at autopsy with severe WMD.

The number of animals per year, based on births and losses, were compiled from the lesser kudu register of the Basle Zoo. During the initial decade, the herd of lesser kudu consisted of two to six animals but increased steadily up to 11 animals in 2004. Statistical analyses of birth and mortality data were performed using Statistika® 5.0 (Stat-Soft®, Tulsa, Oklahoma 74115 USA). Logistic regressions were used (PROC LOGISTIC from SAS, Release 8.01, SAS Institute Inc., Cary, North Carolina 2002 USA) to investigate if the overall mortality up to 6 mo of age and mortality due to WMD were affected by sex, inbreeding, season of birth, and decade of birth. Additionally, correlations between herd size (measured as number of births per year) and mortalities were evaluated. The results of the logistic regression analyses revealed a significant effect of the decade of birth on the mortality rate up to 6 mo of age. The linear trend of the mortality rate since the 1960s is as follows: 1959–1969, 13% (n = 31); 1970–1979, 21% (n = 19); 1980–1989, 28% (n = 18); 1990–1999, 55% (n = 47); 2000–2005, 75% (n = 20) and was determined to be significant (P < 0.001). All other investigated factors such as sex, inbreeding, and season had no significant effect on either mortality up to 6 mo of age or mortality associated with WMD. As for WMD, the decade of birth did not have a significant effect. There was a significant correlation between the herd size, as characterized by the number of births per year, and the occurrence of juvenile mortality (r² = 0.48, P < 0.001; Fig. 2); however, there was no correlation.
between the number of births per year and the occurrence of juvenile mortality associated with WMD ($r^2 = 0.03, P = 0.39$).

**Stuttgart Zoo**

For comparison, husbandry, nutrition, and juvenile mortality data in lesser kudu at a comparable zoo (Zoological and Botanical Garden Wilhelma, Stuttgart, Germany) also were obtained for this study. In contrast to the Basle Zoo, the Stuttgart Zoo keeps lesser kudu with a juvenile mortality average of 20%. The outside and inside enclosures are not accessible to the visitors at the Stuttgart Zoo. Similar to the Basle Zoo, there is a semipermeable fence to the giraffe enclosure, well visible to visitors. In contrast, the lesser kudu at the Stuttgart Zoo are able to withdraw from display at all times and can return to their hidden outdoor enclosure. There are 10 boxes for the lesser kudu group, whose size is comparable to that of Basle Zoo. At the Stuttgart Zoo, the buck is separated at night; once young males become sexually mature, they are removed from the group to prevent inbreeding. Moreover, a breeding male is removed if there are attempts to breed with his female offspring. After birth, mother and offspring are separated from the group for 3 or 4 wk and in the winter, up to 4 mo. Juveniles obtain a single preventive vitamin E/selenium injection on their first day. In addition, the food of the whole herd is supplemented with an oral vitamin E/selenium formulation (Vitamin E/Selen Liquid RS, Chevita AG, 85276 Pfaffenhofen, Germany) that is sprayed over the food three times a week. In pregnant females, the formulation is applied daily 1 wk before and after birthing. Kudus have access to branches with leaves ad libitum throughout the vegetation period. The regular diet consists of lucerne, grass, pellets, oat flakes, soft food, potatoes, a variety of breads, and corn cobs.

**DISCUSSION**

Although the problem of low vitamin E and selenium status has been recognized at the Basle Zoo for a long time, cases of WMD have occurred continuously over the years, as documented by pathology reports and serum biochemistry and vitamin E levels in various animals. In general, vitamin E deficiency is a well-recognized problem in zoo animal management. The lack of cases around the time of the first investigation into the problem at Basle Zoo, together with its later reoccurrence, suggests that changes in management must be implemented in a manner that guarantees their persistence over time. Although parental application of vitamin E/selenium achieves increased serum levels and potentially a reduction of serum biochemistry abnormalities, as documented by Rüedi et al., applying medication parenterally to animals with a nervous nature can be stressful and impractical. The addition of vitamin E/selenium to the diet is the preferred method of administration as described by Graffam et al., or as reported in practice at the Stuttgart Zoo. In particular, the supplementation of pregnant and recent lactating females with vitamin E/selenium is extremely important and will help to provide sufficient levels of those nutrients to the offspring via colostrum and milk. In sheep, serum values of vitamin E and selenium from the dam are positively correlated with the content of their colostrum and with the serum values of lambs after intake of colostrum.

Apart from the fact that the diet as measured for this study was deficient in both vitamin E and selenium, the feeding of fresh grass during the summer is also a probable factor that can lead to WMD. It should be noted that grass grown in the Jura region of Switzerland is known to be deficient in selenium. Therefore, such grass should not be fed unsupplemented to susceptible species. It has been suggested that the herd should be provided browse forage by ensiling tree foliage. However, unless nutritional analyses demonstrate a different result, foliage from locally grown trees also should be evaluated for selenium content.

The susceptibility to *C. perfringens*, which also was detected in some animals affected with WMD, indicates an increased prevalence of infection or a weakened immune system. A low level of vitamin E and/or selenium in the juveniles could have resulted in an insufficient immune defense. Stress, as a result of group size, no hiding opportunities, and/or inadequate feeding could have resulted in an increased bacterial infections. During a study between 1991 and 1998 involving different stocks from Niedersachsen (Germany), 125 sheep and 23 goats with a suspicion of vitamin E/selenium deficiency were examined. Twenty percent of these sheep with vitamin E/selenium deficiency did not show any muscle or liver alterations but had unspecific signs such as anemia and hypoproteinemia, partly in combination with endoparasitism, diarrhea, and cachexia. Hence, it appears that a generally poor vitamin E status of the Basle Zoo’s lesser kudus could have made juveniles susceptible to a variety of other diseases, although no measurements on immunological function were performed.

In contrast to our hypothesis that the family tree may have impacted mortalities, it could not be demonstrated that the inbreeding that occurred at the Basle Zoo had a measurable effect on the health
status of neonate animals, as demonstrated in other species. Therefore, even though inbreeding is undesirable and should be prevented, it could not be associated definitively with the high juvenile mortality of lesser kudus at the Basle Zoo. Rather, other management factors seem to be of more importance in impacting mortality. It was noted that both herd size and juvenile mortality increased over the decades and that there was a significant correlation of the number of births with the number of juvenile deaths per year but not with the number of deaths associated with WMD. These findings suggest that social stress should be regarded as another factor that may have some influence on juvenile mortality. Compared with the Stuttgart Zoo, the lesser kudus at the Basle Zoo were exposed to more stressful conditions due to the lack of opportunities to withdraw from visitors, the continuous presence of the adult male in the herd, and the high number of animals stocked. The separation of the male at night, as performed at the Stuttgart Zoo, corresponds to the natural behavior of the species, because free-ranging males rarely stay together with the females. Social stress caused by overcrowding leads to maternal malnutrition, parasitism, disease, and higher juvenile mortality rates in white-tailed deer (Odocoileus virginianus). In another breeding species commonly regarded as nervous, namely the black rhinoceros (Diceros bicornis), the accessibility of the enclosure to visitors has been demonstrated to be correlated directly with increased fecal stress hormone levels and the occurrence of disease. A group size of six adults is recommended for the lesser kudu, but the Basle Zoo group size has increased continuously since 1991. In addition to dietary measures addressing vitamin E/selenium supplementation, a general reduction in herd size seemed warranted and was predicted also to reduce overall juvenile mortality.

CONCLUSIONS

Due to the results of this study, the herd size at the Basle Zoo was reduced to six adult animals and an oral vitamin E/selenium supplement (Vitamin E-Selen Liquid RS, Chevita, Pfaffenhofen, Germany) was added to the daily ration (calculated dose per animal and day: alpha tocopherol acetate 1,800 IU, sodium selenite 0.5 μg). In addition, measures that limit visitor access to all parts of the animals’ enclosures have been installed in the form of wood covers and plant groups. The efficacy of these measures will have to be evaluated over the coming years to determine if these management changes will reduce the juvenile mortality associated with the lesser kudu herd.

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LITERATURE CITED


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