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Abstract

An increased incidence of cataract and fatty liver in plains viscachas (Lagostomus maximus) was noted for many years at the Zurich Zoo. Based on elevated serum fructosamine and glucose, diabetes mellitus was diagnosed, and these parameters normalized when the diet of the animals was changed from a low-fiber to a high-fiber diet. Here, we evaluate 177 necropsy reports from before and after the diet change for the incidence of cataracts and fatty liver. Sixteen of 56 animals (29%) that were born before the diet change developed cataract. In contrast, only two of 121 animals (1.65%) that were born after the diet change developed cataracts. The prevalence of cataract and fatty liver in animals born after the diet change (1% and 0%, respectively) was significantly lower than in animals born before (9% and 6%, respectively) the diet change. The results suggest that the plains viscachas at Zurich Zoo were affected by an alimentary induced diabetes mellitus (type 2) before the diet was changed.
OCCURRENCE OF CATARACT AND FATTY LIVER IN CAPTIVE PLAINS VISCACHAS (*LAGOSTOMUS MAXIMUS*) IN RELATION TO DIET

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Abstract: An increased incidence of cataract and fatty liver in plains viscachas (*Lagostomus maximus*) was noted for many years at the Zurich Zoo (Switzerland). Based on elevated serum fructosamine and glucose, diabetes mellitus was diagnosed; and these parameters normalized when the diet of the animals was changed from a low-fiber to a high-fiber diet. In this present study, 177 necropsy reports from before and after the diet changes were evaluated for the incidence of cataracts and fatty liver. Sixteen of 56 animals (29%) that were born before the diet change developed cataract. In contrast, only two of 121 animals (1.65%) that were born after the diet change developed cataract. The prevalence of cataract and fatty liver in animals born after the diet change (1% and 0%, respectively) was significantly lower than in animals born before (9% and 6%, respectively) the diet change. The results suggest that the plains viscachas at the Zurich Zoo were affected by an alimentary-induced diabetes mellitus (type 2) before the diet was changed.

Key words: Plains viscacha, *Lagostomus maximus*, rodent, pathology, diabetes mellitus, cataract, diet.

INTRODUCTION

Plains viscachas (*Lagostomus maximus*; Rodentia, Chinchillidae) are crepuscular rodents that inhabit the pampas grasslands of Paraguay, Bolivia, and Argentina. In the wild, the diet of plains viscachas consists mainly of a wide variety of grasses, forb, and shrubs.2 Viscachas are hindgut fermenters with a voluminous cecum14 that use coprophagy as a digestive strategy.6 These animals are rare in captivity, but have been kept at Zurich Zoo, Switzerland, since 1964. A survey of pathology reports of plains viscachas at this institution by Rubel et al.28 revealed an increased incidence of bilateral cataracts and fatty livers. These findings raised the suspicion that viscachas might be susceptible to diet-induced diabetes mellitus. Diabetes with cataracts has been described previously in other rodents. For example, nutritionally induced type 2 diabetes with possible cataract formation was described in the fat sand rat (*Psammomys obesus*).31 Moreover, a genetic component seems to be involved because different genetic lines of *P. obesus* can be generated that differ in their proneness to diet-induced diabetes.16,18 A diet-induced diabetes mellitus with cataract formation is described also in degus (*Octodon degus*), whereas a genetic etiology is suspected in Chinese hamsters (*Cricetulus griseus*)12 and chinchillas (*Chinchilla lanigera*).10 Additionally, viruses associated with type 1 diabetes-like syndrome have been described in several rodent species including the mouse (*Mus musculus*), rat (*Rattus norvegicus*), degu, and hamster.16 Throughout these reports it is acknowledged that a high-energy diet increases the likelihood of developing diabetes mellitus in predisposed animals.

After the problem in plains viscachas was recognized, four measures were initiated. First, free-ranging plains viscachas were captured in Argentina in order to generate blood and urine reference values that could be used for monitoring.35 Second, mineral concentrations in serum and whole blood of free-ranging and captive viscachas were compared, and the results did not suggest a mineral implication in the formation of cataracts.11 Third, the diet was changed to contain a higher proportion of roughage and a lower proportion of easily digestible carbohydrates such as fruits, grains, and bread.34 Fourth, a group of animals was bled 3, 6, and 9 mo before and after the initial diet change. Elevated blood parameters indicative of diabetes dropped within the reference values after the diet change in the adult animals.34 It was suggested that these
findings were consistent with a non-insulin-dependent (type 2) diabetes mellitus. However, if this diet change was to be considered effective, a decrease in pathologic findings associated with diabetes, such as cataract and fatty liver, should be expected. In the 8 yr following the diet change, a total of 121 animals born after the change had died, allowing a comparison of necropsy findings from animals with a low-fiber diet with findings from those examined prior to the change.

MATERIALS AND METHODS

Between 5 May 1992–4 May 2008, the Zurich Zoo housed 234 plains viscachas. During this period, 177 individuals died and all available medical records, necropsy reports, and stock lists were evaluated. The animals had been housed at three different locations: two indoor enclosures, and one outdoor enclosure where the viscachas were kept together with vicunas (Vicugna vicugna) and lesser rheas (Pterocnemia pennata). The diet offered to the animals was identical for all locations, with the exception that animals kept with the vicunas and rheas could have had incidental access to the food intended for these other species.

The low-fiber diet (diet 1) consisted of a formerly common zoo diet for herbivores: apples, carrots, lettuce, bread, a commercial mineral-vitamin supplement (Multiforsa M21, Multiforsa AG, 6312 Steinhausen, Switzerland), ryegrass hay, and local browse branches offered ad libitum. However, the apples, carrots, and bread were fed in such amounts that no additional hay intake would have been necessary to meet the theoretical energy requirements. On average, each animal received 0.3 kg carrots, 0.3 kg apples, 0.1 kg bread, and mineral-vitamin supplement per day. Based on published data it was estimated that this diet contained (in dry matter [DM]) 9.0% crude protein, 5.2% crude fiber, 1.0% ether extracts, 3.9% crude ash, and 80.8% nitrogen-free extracts, estimated without intake of additional hay or branches. On 5 May 2000, the diet was changed to a high-fiber diet, based on reports mentioned above on the occurrence of diabetes in other rodent species. The diet contained a 1:1 ryegrass hay and straw mixture, a vitamin-mineral supplement (Multiforsa M21, Multiforsa AG), and a pelleted feed, based on alfalfa meadow hay (PRE ALPIN Lepo, Agrobs GmbH, 82541 Degerndorf, Germany). The actual intake of this diet was measured during 3 days. It contained, on a DM basis, 7.5% crude protein, 39.2% crude fiber, 1.7% ether extracts, 5.6% crude ash, and 46.1% nitrogen-free extracts. The digestible energy (DE) content of the original ration was estimated at 12.5 MJ/kg DM and that of the new ration at 10.3 MJ/kg DM by using data on nutrient content, data on nutrient digestibility measured in viscachas on a mixed diet, and the factorial estimation of DE for rabbits.

Necropsy reports from 5 May 1992–4 May 2008 were used, allowing a comparison of animals born before and after the diet change of 5 May 2000. The reports were analyzed for the occurrence of cataracts and fatty degeneration of the liver. All pathologic examinations were conducted at the Institute of Veterinary Pathology of the Vetsuisse Faculty of the University of Zurich. The first mention of cataract in the medical record was used to determine the onset of cataract development. It was not possible to allocate animals from postmortem records reliably to one of the three locations, which meant that potential correlations with pathologic findings due to location could not be determined. The objective of the analyses presented in this report was to determine whether there were significant differences in cataract occurrence and nutrition-related diseases between the different time periods.

All statistical analyses were performed using a statistics program (Statistica® 7.1, StatSoft® Inc., Tulsa, Oklahoma 74104, USA). Statistical significance was set at $P < 0.05$. Animals born before and after the diet change were regarded as two independent groups. The categorical outcome of cataracts in the two diet groups was examined using contingency tables. The comparison of average age of death between the groups was tested by two-sample t-test. Because of the small number of cataracts in the new diet group, the Mann-Whitney U-test was applied to see whether cataract development was age-related. A P-value of $<0.05$ was accepted as level of significance.

RESULTS

One hundred and seventy-seven plains viscachas died at the Zurich Zoo between 5 May 1992–4 May 2008. The major findings were bite lesions ($n = 64, 36\%$). Forty (62.5\%) of the 64 animals with bite lesions died perinatally. Cataracts were found in 10\% ($n = 18$) of the cases (Table 1). Cataract was bilateral in 16 cases, one case was unilateral, and in one case it could not be reconstructed from the report whether the noted state was uni- or bilateral. The one viscacha with
unilateral cataract showed cystic degeneration of the left lens, and focal ablation of the retina was suspected. It was born before the diet change. In three animals, the cataract was described as cortical, and in three cases, calcification of the lens was diagnosed (Table 2). Two animals with cataract were originally free-ranging plains viscachas from Argentina. Sixteen of 56 animals (29%) that were born before the diet change and only two of 121 animals (1.65%) born after the diet change developed cataracts (Table 3), a significant difference ($\chi^2 = 30.37, P < 0.001$). Postmortem examination revealed fatty liver in 6% ($n = 11$), 6 (55%) of which also had cataract; all were born before the diet change. Here too, there was a significant reduction of fatty liver occurrence in the high-fiber diet group ($\chi^2 = 25.34, P < 0.001$). The age distribution was different between the two groups that were compared. While diet 1 (low-fiber diet) was fed, 44% of plains viscachas that died were younger than 1 yr, while during the time of diet 2, 81% of plains viscachas were younger than 1 yr. However, medical record analysis documented that cataract development was independent of age (Mann-Whitney U-test: $U = 12, P = 0.57$). The onset of cataract was recorded in 11 viscachas that were born in the zoo. Five animals developed cataract under 1 yr, and in four animals, the cataract was noticed between the ages of 2–4 yr. One animal was older than 6 yr, and the two wild-caught viscachas developed cataract after more than 7 yr in captivity.

**DISCUSSION**

The findings support the conclusion that the change of the dietary regime from a ration with a high proportion of fruits, grains, and bread to a diet with a high proportion of roughage led to a reduction of cataract and fatty liver in the captive plains viscachas at the Zurich Zoo. Cataract formation in plains viscachas appears to indicate a diabetic status. This interpretation is supported by elevated fructosamine, glucose, and cholesterol values recorded in animals before the diet change, and implies that cataract is caused by diabetes. This is in accord with literature reports on other rodents, including degus, sand rats, and rats with streptozotocin-induced diabetes. Other etiologies are possible for cataract formation, such as inheritance; toxins or medication; injury of the lens; or inflammation of the eye. In dogs and humans, an age-related cataract is known, and additionally, dietary deficiencies can cause cataract. To the authors’ knowledge, nothing but the diet was changed in the husbandry of the viscachas at Zurich Zoo, making other causes unlikely.

In diabetic animals, fatty degeneration of the liver occurs as the result of lipid accumulation in the liver because of increased lipid mobilization. Fatty infiltration of the liver is also reported in sand rats that are fed a normal laboratory chow that induces diabetes mellitus type 2 in this species. Reasons for the finding that fatty livers and cataract appeared to rather occur alternatively, and less often together, in animals before the diet change cannot be elucidated. It is speculated that susceptibility to fatty liver and cataract formation could differ between individuals, or between different stages during diabetes.

Cataract formation in diabetic animals is caused by abnormally elevated glucose concentration in the lens. The enzyme aldose reductase converts glucose to sorbitol, which increases the osmotic pressure in the lens; this causes water to...
flow in, and results in clouding. Cataract formation in plains viscachas might be accelerated by increased aldose reductase activity in the lens similar to that of degus with type 2 diabetes mellitus. Diabetic cataract is always bilateral. In the animal with unilateral cataract, a trauma-related etiology was suspected. In three cases, cataract was described as cortical, and in three cases, calcification of the lens was diagnosed. However, in the other viscachas, the localization of cataracts was not specified. Dystrophic calcification is associated with hypermature cataracts. Dogs fed a 30% galactose diet develop cataract that approaches from initial accentuations of the sutures to cortical opacities.

Further nutritional etiologies for cataract are described in a review of Bunce et al., including a riboflavin-deficient diet for carnivores such as young cats (Felis catus), chinook salmon (Oncorhynchus tshawytscha), and rainbow trout (Oncorhynchus mykiss) and for omnivores like young rats (R. norvegicus) and young pigs (Sus scrofa domestica). Prenatal deprivation of vitamin E can also lead to cataract formation in the omnivorous turkey (Meleagris gallopavo) and the rat. Cataract is not described in conjunction

Table 2. Pathologic findings of the eyes of all viscachas with cataract. In 16 cases cataract was bilateral, one case was unilateral, and in one case it was unknown whether cataract was uni- or bilateral.

<table>
<thead>
<tr>
<th>Date of death</th>
<th>Cataract type</th>
</tr>
</thead>
<tbody>
<tr>
<td>07.11.92</td>
<td>Pronounced, bilateral cataract</td>
</tr>
<tr>
<td>24.11.92</td>
<td>Cataract bilateral, rupture of the lens capsule, in one eye synechia of the iris and the lens; irregular orientation and swelling of lens fibers; Morgagni bodies</td>
</tr>
<tr>
<td>24.11.92</td>
<td>Bilateral cataract; irregular orientation and swelling of lens fibers; Morgagni bodies</td>
</tr>
<tr>
<td>07.12.92</td>
<td>Cortical cataract, bilateral; cortical lens fibers degenerated; focal proliferation and fibrous metaplasia of the epithelium of the lens</td>
</tr>
<tr>
<td>13.04.95</td>
<td>Bilateral cataract</td>
</tr>
<tr>
<td>22.12.97</td>
<td>Bilateral cataract</td>
</tr>
<tr>
<td>13.07.98</td>
<td>Cataracta calcarea totalis, bilateral</td>
</tr>
<tr>
<td>27.01.99</td>
<td>Bilateral cataract</td>
</tr>
<tr>
<td>27.01.99</td>
<td>Bilateral cataract</td>
</tr>
<tr>
<td>16.03.99</td>
<td>End stage cataract, bilateral; multiple foci of calcification in the sclera</td>
</tr>
<tr>
<td>19.02.00</td>
<td>Cystic degeneration of the left lens stroma, focal intravital retina ablation suspected</td>
</tr>
<tr>
<td>15.05.00</td>
<td>Cortical cataract, bilateral</td>
</tr>
<tr>
<td>26.05.00</td>
<td>Pronounced bilateral cataract with partial calcification of the lens</td>
</tr>
<tr>
<td>13.11.01</td>
<td>Cataract, bilateral</td>
</tr>
<tr>
<td>30.08.01</td>
<td>Cataract (unknown if uni- or bilateral)</td>
</tr>
<tr>
<td>29.10.02</td>
<td>Bilateral cataract</td>
</tr>
<tr>
<td>13.07.98</td>
<td>Cataracta calcarea totalis, bilateral</td>
</tr>
<tr>
<td>16.03.99</td>
<td>End stage cataract, bilateral; multiple foci of calcification in the sclera</td>
</tr>
<tr>
<td>19.02.00</td>
<td>Cystic degeneration of the left lens stroma, focal intravital retina ablation suspected</td>
</tr>
</tbody>
</table>

Table 3. Occurrence of cataract and fatty liver in plains viscachas (Lagostomus maximus) born before and after the diet change from 5 May 2000 as well as occurrence of cataract and fatty liver in the entire analyzed period from 5 May 1992–4 May 2008.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of animals</td>
<td>56 (100%)</td>
<td>121 (100%)</td>
<td>177 (100%)</td>
</tr>
<tr>
<td>Cataract*</td>
<td>16 (29%)</td>
<td>2 (1.65%)</td>
<td>18 (10%)</td>
</tr>
<tr>
<td>Fatty liver</td>
<td>11 (20%)</td>
<td>0 (0%)</td>
<td>11 (6%)</td>
</tr>
</tbody>
</table>

*Cataract was bilateral in 16 cases, one case was unilateral, and in one case it was unknown whether cataract was uni- or bilateral.
with vitamin C deficiency, but scorbatic guinea pigs (*Cavia porcellus*) that were fed a high-galactose diet developed cataract sooner than their ascorbate-supplemented littermates.\(^4\) Deficiencies of some essential amino acids may also have a cataractogenic effect. Deficiency of phenylalanine,\(^21\) tryptophan,\(^4\) and histidine\(^31\) causes cataract in the omnivorous rat. In the kitten\(^26\) and Atlantic salmon\(^3\) (*Salmo salar*) (carnivores), histidine deprivation leads to cataract. Cataract is caused by methionine deficiency in fingerling Atlantic salmon.\(^4\)

Some mineral deficiencies also cause cataract, e.g., in association with hypocalcemia due to renal failure or hypoparathyroidism in dogs.\(^8\) Nutritional hypocalcemia with resultant cataract is described in rabbits\(^6\) and rats.\(^4\) Zinc deficiency is known to cause cataract in rainbow trout\(^20\) and chinook salmon.\(^23\) Cataract also appears in the second and third generation of rats on a selenium-deficient diet,\(^4\) and selenium excess too may cause cataract when administered as selenite in young rats.\(^12\) Although a comparison of the mineral status of serum from free-ranging and the captive Zurich viscachas\(^11\) had revealed a generally higher mineral status in selenium, copper, and zinc, these elevated levels were considered unlikely to be involved in cataract formation, because the elevated levels in the captive animals were still well below reported toxic levels.

The diets were not analyzed for the various nutrients mentioned above. Mineral and vitamin deficiencies are improbable because the viscachas were supplemented with the same mineral-vitamin supplement (Multiforsa M21, Multiforsa AG) before and after the diet change. Plains viscachas use coprophagy as a digestive strategy.\(^6\) Therefore, it is improbable that they suffer from a particular amino acid deficiency on mixed diets. One may assume that they are capable of using microbial protein as an additional source of amino acids, similarly to other coprophagic animals such as rabbits. Rabbits can meet their amino acid needs on quite simple diets based on forage and grain by-products.\(^5\) Additionally, diet 1 had a 1.5% higher crude protein content than diet 2. In spite of the multiple possibilities, it may be concluded that diet induced diabetes is the most probable cause of cataract development in the plains viscachas of Zurich Zoo.

The authors suppose that plains viscachas develop diabetes mellitus type 2 on a formerly common zoo diet for herbivores, because they are adapted to the barren pampas grassland and therefore also adapted to less-energetic food—similar to fat sand rats (*P. obesus*), which are adjusted to desert life and develop diabetes mellitus type 2 on a regular laboratory diet.\(^31\) The new diet for the viscachas, with a high proportion of roughage, was considered to be more similar to their natural diet.

Nevertheless, a genetic predisposition could be present, similar to sand rats, in which a diabetes-prone and a diabetes-resistant line were isolated,\(^16\) or similar to humans, in whom the incidence of diabetes mellitus type 2 is increased in so-called thrifty genotypes in some populations.\(^22\) However, even in the case of a genetic predisposition, the diet change should be considered as an appropriate (though symptomatic) prophylactic measure.

Although both fatty liver and initial stages of sugar cataracts are reversible, diabetic cataracts may become irreversible after a prolonged period without appropriate treatment in humans.\(^29,33,37\) The time of onset and the duration of the diabetic state of the plains viscachas at Zurich Zoo were unknown. Therefore, animals born before and animals born after the diet change were analyzed separately. One of the two animals with cataract that were born after the diet change may have consumed high-energy dietary components (e.g., carrots) of the vicunas that were housed in the same enclosure. The other animal lived in an indoor enclosure without access for visitors. It is unknown why this animal developed cataract, because it should theoretically never have received high-energy feed; this suggests that cataract may have developed for other than dietary reasons.

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**LITERATURE CITED**


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