Schweiz. Arch. Tierheilk.
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M. Clauss, A. Keller, A. Peemöller, K. Nygrén, J.-M. Hatt, K. Nuss, Band 151, Heft 11, November 2009, 545–549
DOI 10.1024/0036-7281.151.11.545

Postmortal radiographic diagnosis of laminitis in a captive European moose (*Alces alces*)

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Summary

A five year-old bull moose (*Alces alces*) was culled due to chronic hoof overgrowth that required frequent intervention. Radiographic examination revealed changes in phalangeal bone structure usually considered indicative for laminitis in domestic cattle; similar changes were absent in the hooves of a free-ranging moose of similar age. The captive animal had been maintained in exhibits whose flooring were much harder than the soil in natural moose habitat, and on a diet with a high proportion of easily fermentable carbohydrates. These findings indicate that chronic laminitis should be considered as a potential underlying factor for hoof overgrowth, and that measures aimed at reducing the incidence of laminitis in domestic cattle, such as the use of softer flooring and diets with a higher proportion of fibre, might have prophylactic potential in captive wild ruminants.

Keywords: ruminant, laminitis, hoof overgrowth, substrate, nutrition

Postmortal radiographisch diagnostizierte Laminitis bei einem europäischen Elch aus Menschenobhut

Ein fünfjähriger Elchbulle (*Alces alces*) wurde aufgrund chronisch überlanger Klauen, die eine häufige tierärztliche Behandlung notwendig machten, erlegt. Eine Röntgenuntersuchung ergab Veränderungen in der Knochenstruktur, die bei Hausrindern als Anzeichen für Laminitis gewertet werden; bei einem Elch ähnlichen Alters aus freier Wildbahn waren derartige Veränderungen nicht zu finden. Der Elch in Menschenobhut war in Gehegen gehalten worden, deren Böden härter waren als für ein Elchhabitat typisch, und hatte eine Futterration mit einem hohen Anteil an leichtfermentierbaren Kohlenhydraten erhalten. Dieser Fall deutet darauf hin, dass eine chronische Laminitis als potentielle Ursache für scheinbar überschiessendes Klauenwachstum in Betracht gezogen werden sollte. Massnahmen, die bei Hausrindern zur Reduktion der Laminitis-Inzidenz eingesetzt werden, wie ein weicherer Bodenbelag und ein höherer Fasergehalt in der Futterration, könnten auch bei Wildwiederkäuern in Menschenobhut prophylaktisch wirken.

Schlüsselwörter: Wiederkäuer, Laminitis, überschiessendes Klauenwachstum, Bodenbeschaffenheit, Fütterung

Introduction

Treatment of hoof overgrowth is one of the regular, time-consuming veterinary activities in wild hoofstock collections. Overgrown hooves have been sporadically described in the zoo animal literature (Clauss and Kiefer, 2003), but epidemiological investigations addressing the etiology, or the comparative success of different management approaches, are lacking so far. In domestic ruminants, it is accepted that hoof overgrowth can be one of the clinical manifestations of (chronic) laminitis (Momcilovic et al., 2000). Here, we describe the radiological findings in a captive moose (*Alces alces*) with overgrown hooves and compare them to those of a free-ranging individual, outlining the signs typical for laminitis, the differential diagnoses and suggested prophylactic measures.

Case report

A five year-old bull moose (315 kg) kept at a wildlife park was culled due to recurring hoof overgrowth.

The animal had been repeatedly immobilized for hoof trimming. As the condition had also been observed in two male offspring of the bull sired at the same institution, it was decided that no further breeding should be allowed with this male and that the animal should be killed. At the same institution, three female moose were kept as well in which the problem was not evident. The facilities for the moose included a large forest enclosure with a soft forest soil, three smaller "hard stand" enclosures with a surface of compacted clay-gravel, and feeding stations with extensive concrete surfaces. The average space available per moose was 2400 m^2. Moose were kept as pairs of alternating composition, and were shifted between the "hard stand" enclosures and the forest enclosure on a weekly basis.

Each animal received a daily ration of apples (0.6 kg), three different compound feeds (horse pellets 1.4 kg, pellets from whole maize plants 1.0 kg, a "cervid mash" 0.5 kg), horse cobs (0.6 kg) and mineral supplements (250 g), resulting in a total dry matter (DM) of 3.4 kg, as well as a daily ration of browse, which varied according to season and availability, and was recorded to amount to 0.9 kg DM. The calculated nutrient content of the total non-browse diet (calculated during a survey on feeding practices in European moose facilities; Clauss et al., 2002) was (in % DM) crude protein 10.3, neutral detergent fibre (NDF) 33.6, acid detergent fibre 21.2, and contained 18.9 mg copper (Cu) per kg DM. Moose were fed in pairs, and neither a selection of certain feeds by one animal and consumption of a proportion of feeds intended for the other animal could be excluded. The NDF from browse in the total measured diet represented 9.7 % DM.

After death, the animal's legs were dissected and transported to the Clinic for Ruminants of the Vetsuisse Faculty for further investigations. Gross post-mortem investigations revealed an abnormal appearance of the hoof horn, with horizontal grooves and ripples, a concave dorsal wall and the change of the normal direction of horn growth – all of which are considered indicative of chronic laminitis in domestic ruminants (Ossent and Lischer, 1998). For comparison, the hooves of a Finnish, free-ranging moose (396 kg, estimated at 5 years by judging the dentition; closed growth plates of the Ossa metacarpalia and metatarsalia at radiography confirmed adult status) were investigated. A visual inspection of the hooves did not reveal any indications of disease.

The phalanges of the front- and hindlimbs were x-rayed using a palmaro- or plantarodorsal approach. Additionally, the claws of the right hind limb were investigated using an abaxio-axial view. Phalanges I and II did not show any abnormalities. At the third phalanges (Fig 1, left), however, an enlargement of the medulla-like cavity of the bone and the vascular channels was evident, as well as an indentation of the osseous margin in the apical area, and irregular solear margins. The corresponding pictures (Fig. 1, right) of the free-ranging moose showed a bone of a more homogenous radiographic density and even solear margins. The abaxioaxial radiograph of the lateral claw of the right hind limb (Fig. 2, left) showed a peculiar angulation of the coronary hoof border. Additionally, the apex of the third phalangeal bone had a large distance from the coronary hoof border. The solear margin of the bone was, again, very irregular, and its apex of a low radiographic density. These observations were particularly striking when compared to the corresponding structures in the free-ranging moose (Fig. 2, right), who had an even coronary hoof border, good radiographic density and clear, regular margins.

Figure 1: Plantaro-dorsal radiographic view of the distal right hind limb of a captive bull moose (left) as compared to that of a free-ranging animal (right). Note the enlargement of the vascular channels, indentation of the osseous margin in the apical area, and characteristic irregular solear margins of the pedal bones in the captive animal.

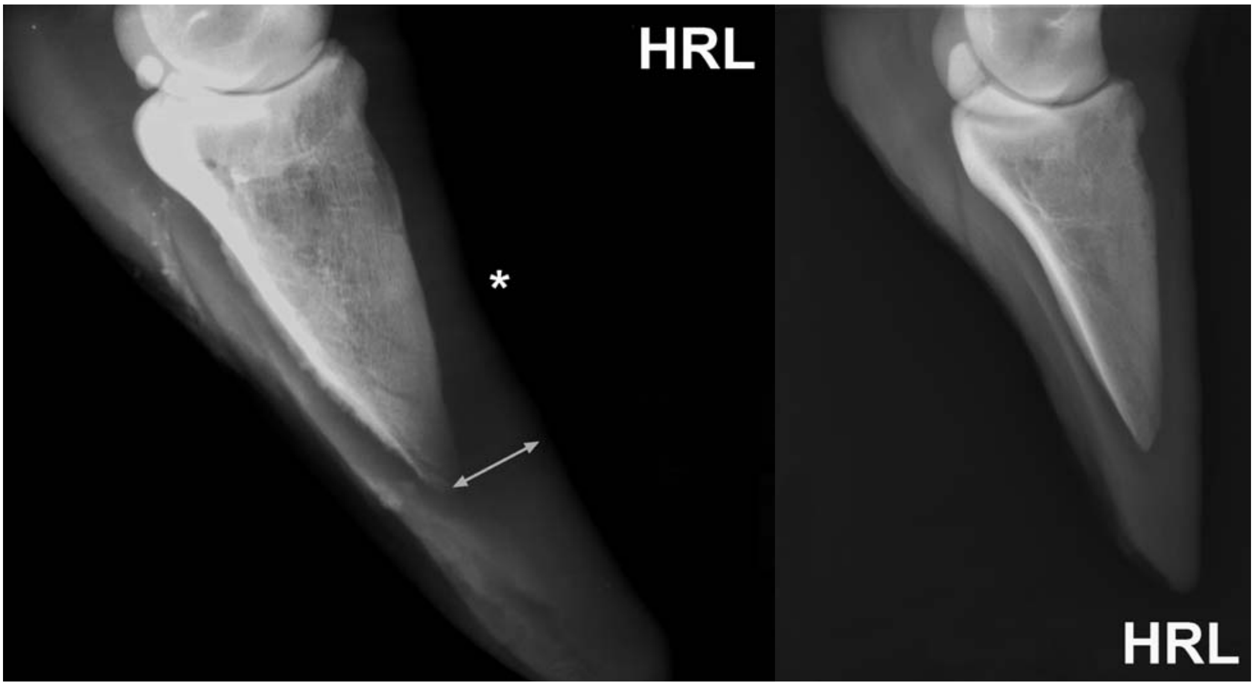

Figure 2: Axio-abaxial radiographic view of the lateral claw of the right hind limb of a captive bull moose (left) as compared to that of a free-ranging animal (right). Note the concave shape of the dorsal hoof wall (asterix) and the increased distance between the phalangeal bone and the coronary hoof border (arrow), the flat solear horn surface and the irregular solear margin of the pedal bone in the captive animal.

Discussion

In the absence of systematic studies into the causes of and the preventive measures against hoof overgrowth in captive wild ruminants, a case like this one can serve to encourage similar diagnostic procedures and experimental changes in husbandry and feeding practices. The comparison with a free-ranging animal of similar age emphasizes that the findings in the captive moose should not be considered as normal consequences of age, but interpreted as consequences of captivity and the particular husbandry conditions. Due to differences in the length of the digits in ruminants, the lateral claw of the hindlimb is a predilection site for abnormalities (Keller et al., 2009), as in our case. Ideally, the diagnostic workup in such a case should have included a histological investigation of the claws. However, histology is unlikely to yield results in chronic laminitis (Boosman et al., 1989; Lischer et al., 2002), and therefore the macroscopic appearance of the claws as well as well as radiography are usually considered sufficient for a diagnosis (Gantke et al., 1998).
Hoof overgrowth must be considered a multifactorial process. Studies in cattle provided evidence of a genetic component, although it is not a case of simple autosomal recessive heredity (Glicken and Kendrick, 1977; Andersson and Lundstrom, 1981). According studies in captive wildlife are missing. The soil substrate of the enclosure has traditionally been considered important in the etiology and the prevention of hoof overgrowth, although systematic surveys are, to our knowledge, lacking so far in captive wild hoofstock. Concrete surfaces, often considered to have a prophylactic effect due to their abrasiveness, have been associated with laminitis in domestic cattle (Rowlands et al., 1983), and suspected to be a contributory factor to hoof overgrowth in moose (Lindau, 1968; Schwartz, 1992). This could mainly be due to a lack of locomotor activity on a surface that offers too much resistance to the foot: In cattle, less activity and a reduced hoof health was measured on a concrete as compared to a rubber mat surface (Jungbluth et al., 2003). In general, there is a trend away from concrete towards softer surfaces in cattle (Somers et al., 2003). For moose, it could be shown by comparative behavioral and morphological observations that animals with low mobility had less hoof abrasion (Bubenik et al., 1978). Therefore, hard surfaces that can be assumed to result in less movement could significantly contribute to the problem of hoof overgrowth. Overgrown hooves and hard flooring most likely resulted in a mechanical overloading of the suspensory apparatus of the phalangeal bone in our moose, with a subsequent rotation of the bone and an increased distance between its apex and the coronary hoof border. The absence of such changes in the free-ranging animal is particularly striking.
In a free-ranging moose population with a low copper status, Franzmann et al. (1974) and Flynn et al. (1977) reported an increased incidence of hoof overgrowth. In captive moose (Clauss and Kiefer, 2003), giraffe (*Giraffa camelopardalis*) (Kovacs et al., 1975) and gazelle (*Gazella soemmeringii*) (Clauss et al., 2007), lower copper levels in

horn from overgrown claws as compared to horn from normal claws was reported, but no such difference was detected in mouflon (*Ovis ammon musimon*) (Vollmer et al., 1985). Given the comparatively high copper levels in the diet fed to moose at the facility under investigation here (18.9 mg Cu/kg DM vs. 8 mg/kg DM usually considered adequate for ruminants, Kamphues et al., 2004), copper deficiency is an unlikely explanation for the hoof overgrowth observed in the moose bull.

Traditionally, a high concentration of dietary protein was believed to trigger hoof overgrowth in moose and other hoofstock (Marma, 1972; Kühme, 1974). This could not be confirmed in an experimental study in white-tailed deer (*Odocoileus virginianus*), in which diets of different protein content were used and hoof growth was measured (Sikarskie et al., 1988). In a survey on captive moose, the daily amount of dietary protein offered to the animals did not differ between facilities that did or did not have problems with hoof overgrowth (Clauss et al., 2002). Instead, an oversupply with easily fermentable carbohydrates and the resulting rumen acidosis are considered a major factor in triggering laminitis in cattle (Nocek, 1997; Ossent et al., 1997), and should be given particular attention in the design of zoo hoofstock diets. Several non-roughage diet items, among them not only plain grains or many low-fibre pelleted feed, but also fruits and vegetables, have very fast fermentation rates (Hummel et al., 2006a) that will lead to high acidotic loads in the rumen. In a questionnaire survey on captive giraffe in Europe, a trend was found that facilities that reported the occurrence of laminitis fed, on average, more fruits and vegetables, bread or grains to their animals than facilities that did not report any cases of laminitis (Hummel et al., 2006b). Similarly, in a survey on the feeding practice in captive moose in Europe (Clauss et al., 2002), all twelve facilities where overgrown hooves had been observed or reported fed fruits and vegetables to their animals, whereas this was only the case in 8 (62 %) of the 13 facilities without overgrown hooves. When the data from the same survey for the amount of non-roughage food items fed per animal during wintertime are compared among those facilities where the natural vegetation of the enclosure did not contribute substantially to the overall food intake of the moose, there was a trend ($p = 0.057$) for facilities with overgrown hooves to feed larger amounts of non-roughage food items to their animals. In a comparison of two captive wild ruminant herds, Zenker et al. (2009) found that the herd that received the higher proportion of concentrates had the lower rumen pH as determined in fluid from rumenocentesis, and also had the higher incidence of clinical signs indicative of laminitis.

If we assume a contribution of dietary factors to laminitis, one evident question is why the problem was not observed in all animals exposed to the same diet. On the one hand, it can be speculated that laminitis is triggered by dietary or environmental factors in only particularly (genetically) susceptible animals. On the other hand, a social component might be relevant with respect to dietary influences. Dominant animals – such as males in cervids – could monopolize attractive feeds, like the highly digestible concentrates, and therefore be particularly susceptible. Similar to the case of our bull moose, Spiecker (1967) describes the case of a male fallow deer (*Dama dama*), kept with a harem of females, that had a very good body condition, indicative of prime access to the concentrate portion of the diet, and that also had hoof overgrowth.

Thus, although robust, large-scale studies on a connection between hoof overgrowth and laminitis, and both exhibit flooring and dietary husbandry are lacking in captive hoofstock, these results suggest that a diet that is unlikely to cause acidosis might be considered prophylactic against hoof problems. In this respect, the low proportion of forage-derived fibre in the diet of the moose of this study would be considered alarming in cattle rations. Neither genetics, flooring, or nutrition can be ruled out or demonstrated to have caused the radiologic signs of laminitis in this bull moose. As a consequence of the findings, the feeding of the remaining animals was changed to a ration of ad libitum lucerne hay, 1.0 kg of pellets from whole maize plants, the mineral supplements and browse. A set of new moose enclosures is in the planning stage anyhow, and a softer flooring has been included in the general design.

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Received: 3. April 2009
Accepted: 19. May 2009