Skeletal malformation in growing milk sheep

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Skeletal malformation of both front limbs were presented to the Department of Farm Animals, University of Zurich. The clinical examination showed alert animals with a high body weight and body condition score as well as a valgus deformation without pain or swelling. Radiographic examination showed severe irregularities in the epiphysis plate of the metacarpal bones in both lambs. Delayed growth in the lateral aspects of the physis was evident and resulted in valgus deformation. Nutritional causes were considered as the main reason for this presentation and a nutritional consultation was performed by the Institute of Animal Nutrition and Dietetics, University of Zurich. The estimated energy intake of these lambs was 65% higher than the recommended maximum for growing sheep and the estimated vitamin D content of the diet was 71% below the recommended allowance. Both animals were euthanized and peripheral quantitative computed tomography (pQCT) was performed postmortem to measure total bone mineral density (BMD), trabecular bone mineral density (tBMD) and cortical bone mineral density (cBMD) of the left and right metatarsal bone of both animals. The BMD and the tBMD at 10% of bone length were below the reference values and the BMD at 50% was above the reference values. In addition, postmortem examination revealed a Salter-Harris-Typ-1 fracture in the right caput humeri of one lamb. Histological examination showed defects in the articular cartilage with an eburnation in the metacarpal region and a disrupted area of columnar cartilage. This case report supports the fact that a high dietary energy intake leads to damage to the cartilage and the epiphyseal zone in sheep. In addition, insufficient dietary vitamin D intake contributed to the incomplete bone mineralization, as well as delayed growth and skeletal malformation.

Keywords: Energy, growth, Lacaune, milk sheep, nutrition, skeletal malformation
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Introduction

Skeletal malformation in growing animals is a known problem and has been described in multiple species, most commonly in those bred to grow rapidly. Two main causes for orthopedic diseases in growing animals are currently discussed. Firstly, a high energy intake, which directly affects growth rate and weight gain via nutrient supply and indirectly through changes in concentrations of growth hormones. The results are increased static forces through weight gain and an enlarged zone of chondrocyte growth in the physis of the bones, which results in damage to the cartilage and the epiphyseal zone. The second cause is a diet with excess or insufficient vitamin D and/or calcium and/or phosphorus. Insufficiency leads to a delayed mineralization of the growth plate. Excess supply of these nutrients leads to disturbed endochondral ossification, delayed skeletal maturation and growth of bone length. The net effect of both pathogenic mechanisms is skeletal malformation, a deviation from the normally straight bone axis. This disease complex is hardly known in sheep in Switzerland, since they are mostly used in extensive farming systems. However, when sheep are farmed to produce milk or meat, and the growth of the animal is promoted, the same skeletal problems can occur, as described in this case report.

Case Report

This report includes two lambs, but all 15 lambs of that breeding cycle on this farm showed similar clinical signs as described below. Both lambs presented to the Department of Farm Animals at the Vetsuisse Faculty of the University of Zurich in Switzerland were female Lacaune lambs, which were intended for future milk production. At presentation, they were both six months old. The owner presented these animals because they showed severe signs of a progressive skeletal malformation of the forelimbs, with the first signs appearing at around three months of age. The lambs of that breeding cycle had not been separated from the lactating sheep after weaning and as a result, the 60 head strong herd received the same feed, not discriminating between adult and growing animals. According to the owner, the lambs grew extremely fast compared to lambs in the previous years and were highly active despite their deformed limbs. It was the first time the owner had seen this kind of problem in his sheep. In the previous breeding cycle, he had separated the lambs from the lactating sheep after weaning and fed the lambs with the same ration as the sheep in the dry period.

In the clinical examination, both animals showed attentive behavior with a body condition score (BCS) of 4/5. Both front limbs in both lambs were deformed with an axis deviation (a) of 14 to 40 degrees (Figure 1). The joints were neither swollen nor painful on palpation. Due to the valgus deformity, anomalies in the front claws were noted in both animals. The weight of lamb No. 1 was 34 kg, the weight of lamb No. 2 was 33 kg. The remainder of the clinical examination was within normal limits.

In lamb No. 1, the radiographs showed a severe valgus deformation of the digits stemming from the delayed growth of the metacarpal physis. A moderate focal widening of the medial aspect of the distal radial physis and focal sclerosis of the associated metaphysis was also seen. In addition, signs...
of a moderate degenerative joint disease of the antebra-chio-carpal joint were visible. A circumferential soft tissue swelling at the level of the carpus was evident radiographically. There was also a desmopathy at the insertion of the medial collateral ligament (Figure 2). The radiographic findings in lamb No. 2 were similar. A list of differential diagnoses was created. Degenerative and (para)neoplastic diseases were highly unlikely considering the signs began at three months of age. Anomalous, traumatic, and vascular problems seemed improbable because a high number of animals were affected. A hereditary malformation was considered, but the owner used the same ram and ewe as in the previous breeding season and no problems had been observed. No indications for inflammatory and infectious disease processes were observed in the clinical examination. Toxic causes were considered, but no evidence could be found. Therefore, nutritional causes were the most likely reason for these changes and the Institute of Animal Nutrition and Dietetics at the Vetsuisse Faculty of the University Zürich conducted a nutritional consultation. Both lambs were euthanized due to a guarded prognosis.

As the lambs were kept in a large herd, the feed intake was estimated according to their metabolic body weight (Table 1). With the estimated feed intake, the nutrient composition of that diet could be approximated (Table 2). In addition to the diet the animals received drinking water ad libitum. The calculations showed that the estimated energy intake of these lambs was 65% higher than the recommended maximum for a lamb of 15 kg. In addition, the estimated vitamin D content of the diet was 71% below the recommended allowance. In addition to diet calculations, peripheral quantitative computed tomography (pQCT) was used to measure total bone mineral density (BMD), trabecular bone mineral density (tBMD) and cortical bone mineral density (cBMD) of the left and right metatarsal bone of both animals (Table 3). The measurements were taken at 50% of bone length and at 10% of bone length, measuring from the distal end of the bone. The BMD and the tBMD at 10% of bone were below the

*Table 1: Estimated daily feed intake of the total mixed ratio (TMR) of a lamb with 15 kg body weight based on metabolic body weight.*

<table>
<thead>
<tr>
<th>Components of TMR</th>
<th>Feed intake of entire herd [kg/day]</th>
<th>Metabolic weight (BW0,75) of entire herd [kg]</th>
<th>Feed intake per kg BW0,75 [kg/day]</th>
<th>Feed intake of lamb with 15 kg BW (7,6 kg BW0,75) [g/day]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>150</td>
<td></td>
<td>1261,15</td>
<td>0,12</td>
</tr>
<tr>
<td>Hay 1. Cut²</td>
<td>60</td>
<td></td>
<td></td>
<td>0,05</td>
</tr>
<tr>
<td>Hay 2. cut³</td>
<td>120</td>
<td></td>
<td></td>
<td>0,10</td>
</tr>
<tr>
<td>Gras pellets¹</td>
<td>50</td>
<td></td>
<td></td>
<td>0,04</td>
</tr>
<tr>
<td>Concentrate³</td>
<td>20</td>
<td></td>
<td></td>
<td>0,02</td>
</tr>
<tr>
<td>Mineral feed⁴</td>
<td>0,825</td>
<td></td>
<td></td>
<td>0,0007</td>
</tr>
<tr>
<td>Salt¹</td>
<td>0,275</td>
<td></td>
<td></td>
<td>0,002</td>
</tr>
</tbody>
</table>

TMR = Total mixed ratio, as fed basis

¹Agroscope, 2015; ²Hay analysis of the farm from 2015 or 2014; ³88,922 Biogetreidewürfel, Mill Jakob Wicki, ⁴KM 4223 Biokonform Mineral Feed

³Calculated as follows: Herd with 15 lambs of 15 kg (7,6 kg BW0,75) and 45 adults of 75 kg (25,5 kg BW0,75)
After euthanasia, the front legs were brought to the Institute of Veterinary Pathology, Vetsuisse Faculty, University of Zurich for macroscopical evaluation and bone histology to further quantify the lesions. The bones were cut sagitally to better evaluate the different regions (e.g., articular cartilage, physis with growth plate and diaphysis) and small slices were fixed in 4% formalin and subsequently decalcified in RDF mild decalciﬁer (CellPath, Ltd.). After decalcification, the bone slices were embedded in paraffin, trimmed, and stained with hematoxylin and eosin (HE) stain. Macroscopically, the physical alterations of the radius and the metacarpal bones were readily visible. In addition, a Salter-Harris-type-1 separation of the proximal humeral physis was seen in lamb No. 1 (Figure 3; arrows). There were bony particles present in the thickened articular capsule of the shoulder joint and in the surrounding musculature. In the intact columnar and hypertrophic cartilage areas of the physis, regenerative processes were discernible as small chondrone formations (Figure 4). In lamb No. 2, no further abnormalities were seen post-mortem.

The right metacarpal region in lamb No. 1 showed a defect in the articular cartilage of the carpo-metacarpal joint with a reddish-brownish discoloration and better visibility of the subchondral bone (eburnation). Histologically, the macroscopically discerned metacarpal eburnation was a loss of articular cartilage with overlying granulation tissue with few inﬂammatory cells (pannus formation) in this area, which was inﬁltrating the edge of the articular cartilage lesion (Figure 5, arrows, and inlet).

**Discussion**

Nutritional consultation of these lambs showed an excessive dietary energy intake and an insufﬁcient vitamin D intake. This supports the known fact that high body weight and BCS lead to increased static forces as well as delayed mineralization of the cartilaginous columns which in turn lead to disruption, disorganization, and finally primary focal closure of the

**Table 2:** Ration calculation of the total mixed ratio (TMR) for a lamb with 15 kg.

<table>
<thead>
<tr>
<th></th>
<th>Amount [g]</th>
<th>DM [g]</th>
<th>NEV [MJ]</th>
<th>APD [g]</th>
<th>Ca [g]</th>
<th>P [g]</th>
<th>Mg [g]</th>
<th>Na [g]</th>
<th>Vit D [I.U.]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay 1 Cut²</td>
<td>360</td>
<td>314</td>
<td>1.7</td>
<td>25.8</td>
<td>1.7</td>
<td>0.8</td>
<td>0.7</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Hay 2 Cut²</td>
<td>720</td>
<td>639</td>
<td>3.8</td>
<td>60.6</td>
<td>3.6</td>
<td>1.7</td>
<td>1.3</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Gras pellets¹</td>
<td>300</td>
<td>264</td>
<td>1.6</td>
<td>27.6</td>
<td>1.5</td>
<td>1.1</td>
<td>0.5</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Bio concentrate³</td>
<td>120</td>
<td>105</td>
<td>0.9</td>
<td>11.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral feed⁴</td>
<td>5.0</td>
<td>5.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.8</td>
<td>0.5</td>
<td>0.3</td>
<td>0.1</td>
<td>64</td>
</tr>
<tr>
<td>Salt¹</td>
<td>1.6</td>
<td>1.6</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Total per day</td>
<td>1506</td>
<td>1328</td>
<td>5.5</td>
<td>125.4</td>
<td>7.5</td>
<td>4.2</td>
<td>2.8</td>
<td>1.0</td>
<td>64</td>
</tr>
<tr>
<td>Recommendation (Agroscope)</td>
<td>600</td>
<td>4.8</td>
<td>75</td>
<td>5.5</td>
<td>2.5</td>
<td>0.5</td>
<td>0.5</td>
<td>90</td>
<td></td>
</tr>
<tr>
<td>Percentage of total ratio / recommendation (Agroscope)¹</td>
<td>221</td>
<td>165</td>
<td>116</td>
<td>136</td>
<td>167</td>
<td>550</td>
<td>195</td>
<td>71</td>
<td></td>
</tr>
</tbody>
</table>

DM, dry matter, NEV, net energy fattening, APD, intestinal absorbable protein, Ca, calcium, P, phosphorus, Mg, magnesium, Na, sodium, Vit D, vitamin D ¹Agroscope, 2015; ²Hay analysis of the farm from 2015 or 2014; ³88,922 Biogetreidewürfel, Mill Jakob Wicki; ⁴KM 4223 Biokonform Mineral Feed

**Table 3:** Results of the peripheral quantitative computed tomography (pQCT) bone mineral density measurements of the left and right metatarsal bone of the two lambs.

<table>
<thead>
<tr>
<th></th>
<th>Lamb Nr. 1</th>
<th>Lamb Nr. 2</th>
<th>Reference values⁷</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left metatarsal bone 10%</td>
<td>BMD</td>
<td>461</td>
<td>444</td>
</tr>
<tr>
<td></td>
<td>tBMD</td>
<td>286</td>
<td>348</td>
</tr>
<tr>
<td></td>
<td>cBMD</td>
<td>1049</td>
<td>1025</td>
</tr>
<tr>
<td>Right metatarsal bone 10%</td>
<td>BMD</td>
<td>403</td>
<td>370</td>
</tr>
<tr>
<td></td>
<td>tBMD</td>
<td>310</td>
<td>152</td>
</tr>
<tr>
<td></td>
<td>cBMD</td>
<td>1048</td>
<td>1008</td>
</tr>
</tbody>
</table>

BMD, bone mineral density, tBMD, trabecular bone mineral density, cBMD, cortical bone mineral density, mg/cm³
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Figure 3: Right humerus of lamb No 1: The caput humeri around the epiphyseal growth plate (star) is teared off (arrows).

Figure 4: Right metacarpus of lamb No. 1: Normal articular cartilage (stars) and loss of articular cartilage (arrow) with pannus formation. Stain: Haematoxylin and eosin, magnification: 4x.
growth plate. In one lamb, a Salter-Harris-Type-1 fracture of the humerus had occurred which was only diagnosed post-mortem. Incomplete ossification of the growth plate is seen when diets insufficient in vitamin D and/or calcium and/or phosphorus are fed. In these lambs, the diet was insufficient in vitamin D (< 90 IU, Table 2) and the lambs were kept indoors, so no cutaneous synthesis of vitamin D was possible, so that the sheep were dependent on dietary vitamin D exclusively. A high BMD measured at 50% of bone length indicates that the bones were subject to additional force, leading to compression and thus a higher mineral density at the measuring site. Histologically, this would coincide with the eburnation of the cortical bone visible on the metacarpus. The present case report underlines how the combination of clinical examination of individual animals, further specific history and nutritional examination, and finally post-mortem examination was key to the successful diagnosis and solution of a herd problem. Upon receiving this diagnosis, the owner separated the remaining lambs and proceeded to only feed them hay, mineral feed, and salt to cover their nutritional needs according to the recommendations.

In mildly affected animals, the deformation was corrected with maturation. None of the affected lambs were used for future breeding or for milk production, but instead used for meat consumption. For the next breeding cycle, lambs were fed separately, and no problems re-occurred.

**Conclusion**

The cause of a skeletal malformation in lambs could be diagnosed by combining the results of clinical, nutritional, and pathological examinations. Growing animals should be fed separately from high yielding production animals and be fed a diet that is complete and balanced regarding energy (daily intake NEV 4.8 MJ original matter (OM)), vitamin D (daily intake 90 IU OM) and calcium (daily intake 5.5 g OM) and phosphorus (daily intake 2.5 g OM) according to the recommendations and therefore allows for adequately slow and healthy growth.

**Figure 5:** Epiphysis of the right humerus of lamb No. 1: Fibrin exudation (arrow) and rest of intact columnar epiphysis with small chondrone formations (stars). Inlet: Pannus tissue replacing the articular cartilage (star). Stain: Haematoxylin and eosin, magnification: 4x
Malformation du squelette chez des brebis laitières en croissance

Deux agneaux Lacaune femelles de six mois présentant de graves malformations squelettiques des deux membres antérieurs ont été présentés au Département des animaux de rente de l’Université de Zurich. L’examen clinique a montré des animaux alertes avec un poids corporel et une note d’état corporel élevés ainsi qu’une déformation en valgus sans douleur ni gonflement. L’examen radiographique a montré de graves irrégularités dans la plaque épiphysaire des os métacarpiens chez les deux agnelles. Un retard de croissance du côté latéral de la physèse était évident, entraînant une déformation en valgus. Des causes nutritionnelles ont été considérées comme étant la principale raison de cette situation et une consultation nutritionnelle a été effectuée par l’Institut de nutrition animale et de diététique de l’Université de Zurich. L’apport énergétique estimé de ces agneaux était supérieur de 65% au maximum recommandé pour les moutons en croissance et la teneur estimée en vitamine D du régime alimentaire était inférieure de 71% à l’apport recommandé. Les deux agneaux ont été euthanasiés et une tomodensitométrie a été réalisée post mortem pour mesurer la densité minérale osseuse totale (DMO), la densité minérale osseuse trabéculaire (DMOt) et la densité minérale osseuse corticale (DMOc) des métatarses gauche et droite des deux animaux. La DMO et la DMOt à 10% de la longueur de l’os étaient inférieures aux valeurs de référence et la DMOc à 20% était supérieure aux valeurs de référence. En outre, l’examen post-mortem a révélé une facture de Salter-Harris-Typ-1 dans le caput humeri droit d’un agneau. L’évaluation histologique a montré des défauts dans le cartilage articulaire avec une éburnération sousjacente dans la région métacarpienne et une zone de destruction du cartilage colonnaire. Ce rapport de cas confirme le fait qu’un apport énergétique alimentaire élevé entraîne des lésions du cartilage et de la zone épiphysaire chez les ovins. En outre, un apport alimentaire insuffisant en vitamine D a contribué à une minéralisation osseuse incomplète, ainsi qu’à un retard de croissance et à une malformation du squelette.

Mots clés: Énergie, croissance, Lacaune, brebis laitière, nutrition, malformation du squelette

Malformazione scheletrica nelle pecore da latte in crescita

Due agnelli di sei mesi di età, entrambe femmine, della razza Lacaune, con gravi malformazioni scheletriche di entrambi gli arti anteriori sono state presentate al Abteilung für Nutztiere der Universität Zürich (Dipartimento di Animali da reddito dell’Università di Zurigo). L’esame clinico ha mostrato animali vigili con un alto peso corporeo e un punteggio di condizione corporea elevato, nonché una deformità valgica senza dolore o gonfiore. L’esame radiografico ha mostrato gravi irregolarità nella piastra epifisaria delle ossa metacarpali in entrambe gli agnelli. La crescita ritardata negli aspetti laterali del fisi era evidente e ha portato alla deformità valgica. Le cause nutrizionali sono state considerate come la principale ragione di questa presentazione e una consulenza nutrizionale è stata effettuata dall’Institut für Tierernährung und Diätetik der Universität Zürich (Istituto di Nutrizione Animale e Dietetica dell’Università di Zurigo). L’apporto energetico stimato di questi agnelli era del 65% superiore al massimo raccomandato per le pecore in crescita e il contenuto stimato di vitamina D nella dieta era del 71% al di sotto dell’apporto raccomandato. Entrambi gli animali sono stati eutanasiati e una tomografia computerizzata quantitativa periferica (pQCT) è stata eseguita post-mortem per misurare la densità minerale ossea totale (BMD), la densità minerale ossea trabecolare (tBMD) e la densità minerale ossea corticale (cBMD) dell’osso metatarsale sinistro e destro di entrambi gli animali. La BMD e la tBMD al 10% della lunghezza dell’osso erano al di sotto dei valori di riferimento e la BMD al 50% al di sopra dei valori di riferimento. Inoltre, l’esame post-mortem ha rivelato una frattura di Salter-Harris di tipo 1 nel caput humeri destro di un agnello. La valutazione istologica ha mostrato dei difetti nella cartilagine articolare con eburnazione nella regione metacarpale e un’area danneggiata della cartilagine colonnare. Questo caso clinico supporta il fatto che un elevato apporto energetico dietetico porta a danni alla cartilagine e alla zona epifisaria nelle pecore. Inoltre, un insufficiente apporto dietetico di vitamina D ha contribuito alla mineralizzazione ossea incompleta, così come alla crescita ritardata e alla malformazione scheletrica.

Parole chiave: Energia, crescita, Lacaune, pecore da latte, nutrizione, malformazione scheletrica
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