Skeletal malformation in growing milk sheep

A. Gimmel[1], R. Hochstrasser[2], M. Hilbe[3], K. Nuss[4], A. Liesegang[1]

[1]Institute of Animal Nutrition and Dietetics, Vetsuisse Faculty, University of Zurich, Switzerland
[2]dermaVet GmbH, Beratungs- und Gesundheitsdienst für Kleinwiederkäuer, Switzerland
[3]Institute of Veterinary Pathology, Vetsuisse Faculty, University of Zurich, Switzerland
[4]Department of Farm Animals, Vetsuisse Faculty, University of Zurich, Switzerland

Skelettfehlbildung bei wachsenden Milchschafen

Zwei sechs Monate alte weibliche Lacaune-Lämmer mit schweren Skelettfehlbildungen beider Vordergliedmassen wurden der Abteilung für Nutztiere der Universität Zürich vorgestellt. Die klinische Untersuchung zeigte aufmerksame Tiere mit hohen Körpergewichts- und Body-Score-Werten sowie einer schmerzfreie Valgusdeformation ohne Schwellung. Bei beiden Lämmern wurden radiologisch schwere Unregelmässigkeiten in den Epiphysen der Metacarpalknochen festgestellt. Es war ein verzögertes Wachstum in den seitlichen Bereichen der Epiphyse zu erkennen, das zu einer Valgusdeformation führte. Es wurden ernährungsbedingte Ursachen vermutet und eine Ernährungsberatung durch das Institut für Tierernährung und Diätetik der Universität Zürich durchgeführt. Die geschätzte Energieaufnahme dieser Lämmer lag 65 % über dem empfohlenen Höchstwert für wachsende Schafe und der geschätzte Vitamin-D-Gehalt der Nahrung lag 71 % unter der empfohlenen Menge. Beide Tiere wurden euthanasiert und postmortal wurde eine periphere quantitative Computertomographie (pQCT) durchgeführt, um die gesamte (BMD), die trabekuläre (tBMD) und die kortikale Knochenmineraldichte (cBMD) des linken und rechten Metatarsalknochens beider Tiere zu messen. Der BMD und der tBMD bei 10 % der Knochenlänge lagen unter den Referenzwerten und der BMD bei 50 % lag über den Referenzwerten. In der pathologischen Untersuchung konnte eine Salter-Harris-Typ-1-Fraktur im rechten Caput Humeri eines Lammes festgestellt werden. Die histologische Untersuchung des Metacarpalknochens ergab Defekte im Gelenkknorpel mit darunterliegender Eburnisation und einem zerstörten Bereich des Säulenknorpels. Dieser Fallbericht zeigt, dass eine hohe Energieaufnahme über die Nahrung bei Schafen zu Schäden am Knorpel und der Epiphysenzone führt. Darüber hinaus trug eine unzureichende Vitamin-D-Zufuhr zur unvollständigen Knochenmineralisierung sowie zu verzögertem Wachstum und Skelettfehlbildungen bei.

Schlüsselwörter: Energie, Wachstum, Lacaune, Milchschafe, Ernährung, Skelettfehlbildungen

Summary

Two six-month old female Lacaune lambs with severe skeletal malformations 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 epiphysial 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 facture in the right caput humeri of one lamb. Histological evaluation 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

https://doi.org/10.17236/sat00426

Eingereicht: 05.12.2023
Angenommen: 15.03.2024

Skeletal malformation in growing milk sheep

A. Gimmel, R. Hochstrasser, M. Hilbe, K. Nuss, A. Liesegang

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.[2, 3, 5, 6, 8, 9, 10, 11, 12] 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.[2, 8, 10, 11, 14] 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.[2, 8, 10, 11, 14] The second cause is a diet with excess or insufficient vitamin D and/or calcium and/or phosphorus.[2, 8, 10, 11, 14] These nutrients are essential for the mineralization of the growth plate.[2, 8, 10, 11, 14] Insufficiency leads to a delayed mineralization of the chondrocyte columns in the physis, resulting in a widening of the growth plate and in an unstable physeal-metaphyseal region of the bones.[2, 8, 10, 11, 14] Excess supply of these nutrients leads to disturbed endochondral ossification, delayed skeletal maturation and growth of bone length.[2, 8, 10, 11, 14] 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.[3] 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.

Figure 1: Picture of lamb No. 1 showing valgus deformation of both front legs including the axis deviation (a).

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.[13] 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 physes. 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

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.

Components of TMR	Feed intake of entire herd [kg/day]	Metabolic weight ($BW^{0,75}$) of entire herd [kg][5]	Feed intake per kg $BW^{0,75}$ [kg/day]	Feed intake of lamb with 15 kg BW (7,6 kg $BW^{0,75}$) [g/day]
Water	150	1261,15	0,12	900
Hay 1. Cut[2]	60		0,05	360
Hay 2. cut[2]	120		0,10	720
Gras pellets[1]	50		0,04	300
Concentrate[3]	20		0,02	120
Mineral feed[4]	0,825		0,0007	5
Salt[1]	0,275		0,0002	1,6

TMR = Total mixed ratio, as fed basis
[1]Agroscope, 2015; [2]Hay analysis of the farm from 2015 or 2014; [3]88,922 Biogetreidewürfel, Mill Jakob Wicki, [4]KM 4223 Biokonform Mineral Feed
[5]Calculated 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)

of a moderate degenerative joint disease of the antebrachio-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.[7] The BMD and the tBMD at 10 % of bone were below the

Figure 2: Radiograph of both front limbs of lamb No. 1 showing a severe valgus deformity in both front limbs (right > than left front limb). Both metacarpal growth plates show severe irregularities and signs of delayed growth.

reference values, the cBMD was within the reference range at both measuring sites and the BMD at 50 % were above the reference values (Table 3).[6]

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 physeal 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 physes, 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.

	Amount [g]	DM [g]	NEV [MJ]	APD [g]	Ca [g]	P [g]	Mg [g]	Na [g]	Vit D [I.U.]
Hay 1. Cut[2]	360	314	1,7	25,8	1,7	0,8	0,7	0,1	
Hay 2. Cut[2]	720	639	3,8	60,6	3,6	1,7	1,3	0,1	
Gras pellets[1]	300	264	1,6	27,6	1,5	1,1	0,5	0,1	
Bio concentrate[3]	120	105	0,9	11,4	0,0	0,0	0,0		
Mineral feed[4]	5,0	5,0	0,0	0,0	0,8	0,5	0,3	0,1	64
Salt[1]	1,6	1,6	0,0	0,0	0,0	0,0	0,0	0,6	
Total per day	**1506**	**1328**	**5,5**	**125,4**	**7,5**	**4,2**	**2,8**	**1,0**	**64**
Recommendation (Agroscope) 15 kg (daily weight gain of 200 g)		*600*	*4,8*	*75*	*5,5*	*2,5*	*0,5*	*0,5*	*90*
Percentage of total ratio / recommendation (Agroscope)[1]		221	165	167	136	167	550	195	71

DM, dry matter, NEV, net energy fattening, APD, intestinal absorbable protein, Ca, calcium, P, phosphorus, Mg, magnesium, Na, sodium, Vit D, vitamin D
[1]Agroscope, 2015; [2]Hay analysis of the farm from 2015 or 2014; [3]88,922 Biogetreidewürfel, Mill Jakob Wicki; [4]KM 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.

			Lamb Nr. 1	Lamb Nr. 2	Reference values[7]
Left metatarsal bone	10 %	BMD	461	444	607 ± 18
		tBMD	286	348	516 ± 32
	50 %	BMD	834	770	607 ± 18
		cBMD	1049	1025	966 ± 31
Right metatarsal bone	10 %	BMD	403	370	607 ± 18
		tBMD	310	152	516 ± 32
	50 %	BMD	**807**	**784**	607 ± 18
		cBMD	1048	*1008*	966 ± 31

BMD, bone mineral density, tBMD, trabecular bone mineral density, cBMD, cortical bone mineral density, mg/cm^3

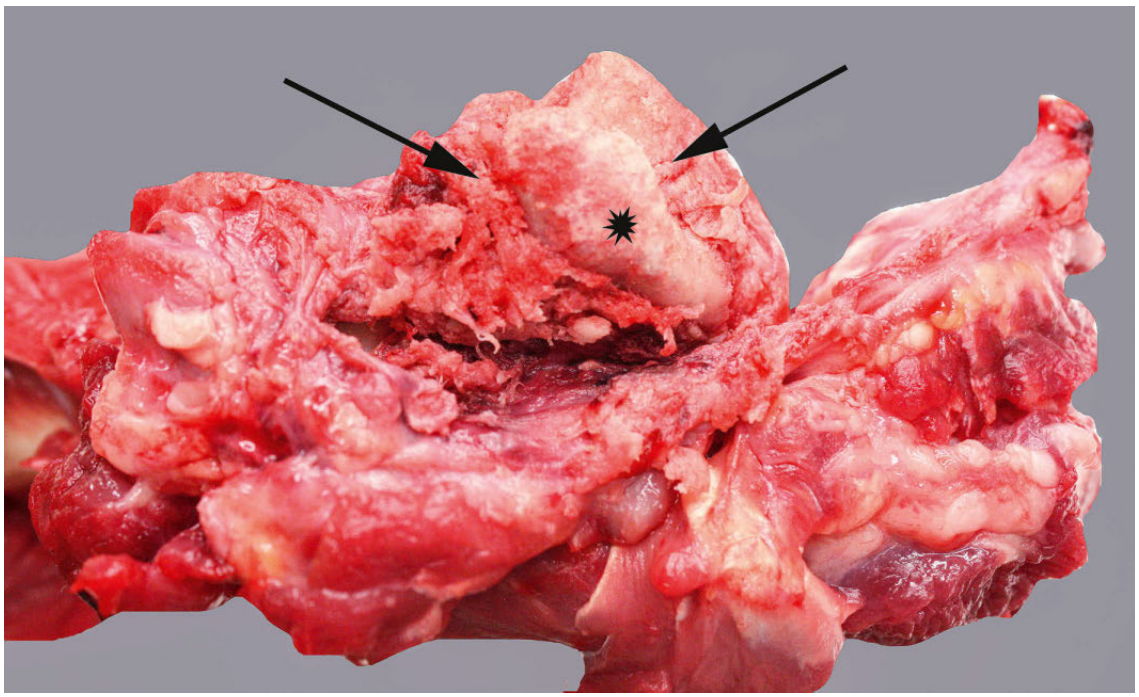

Figure 3: Right humerus of lamb **No 1:** The caput humeri around the epiphyseal growth plate (star) is teared off (arrows).

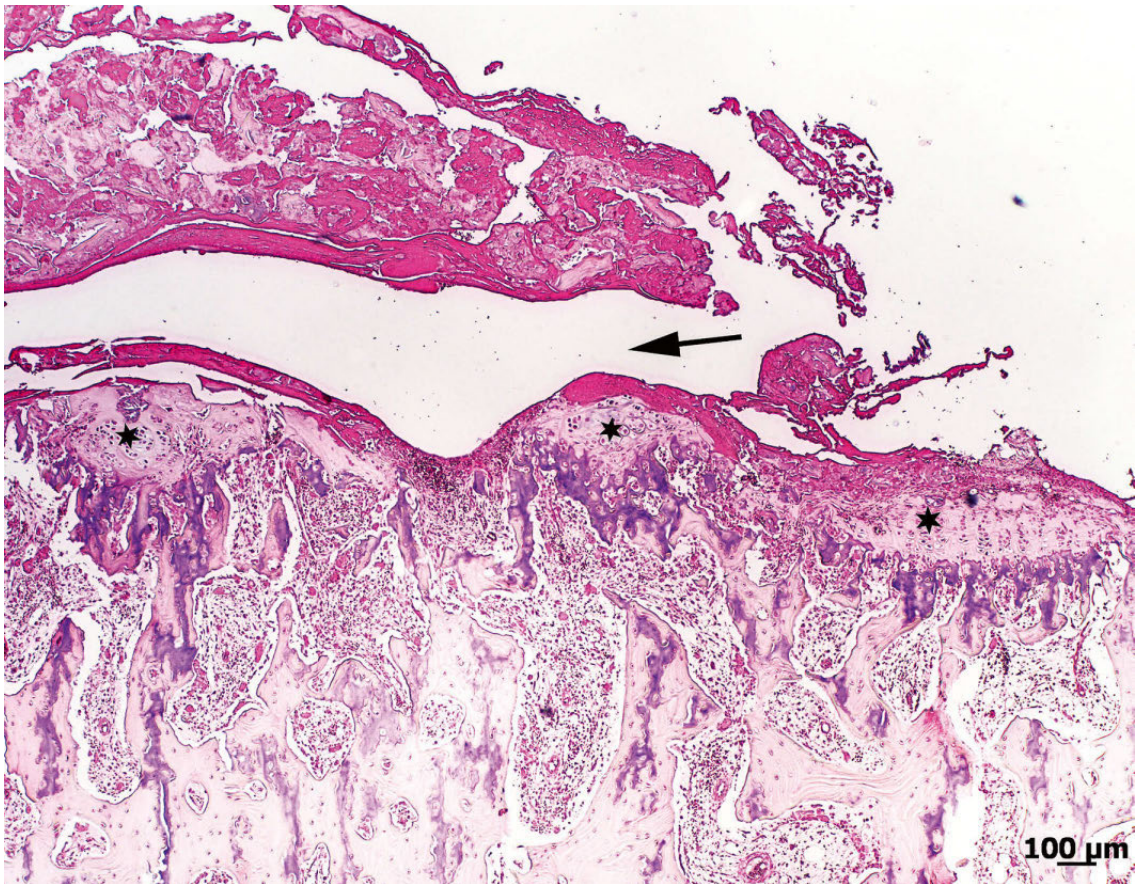

Figure 4: Right metacarpus of lamb **No. 1:** Normal articular cartilage (stars) and loss of articular cartilage (arrow) with pannus formation. Stain: Haematoxylin and eosin, magnification: 4×

growth plate.[2, 8, 10, 11, 14] In one lamb, a Salter-Harris-Typ-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.[2, 8, 10, 11, 14] In these lambs, the diet was insufficient in vitamin D (< 90 I.U., 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.[7] 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.[1] 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 I.U. OM) and calcium (daily intake 5,5 g OM) and phosphorus (daily intake 2,5 g OM) according to the recommendations[1] and therefore allows for adequately slow and healthy growth.

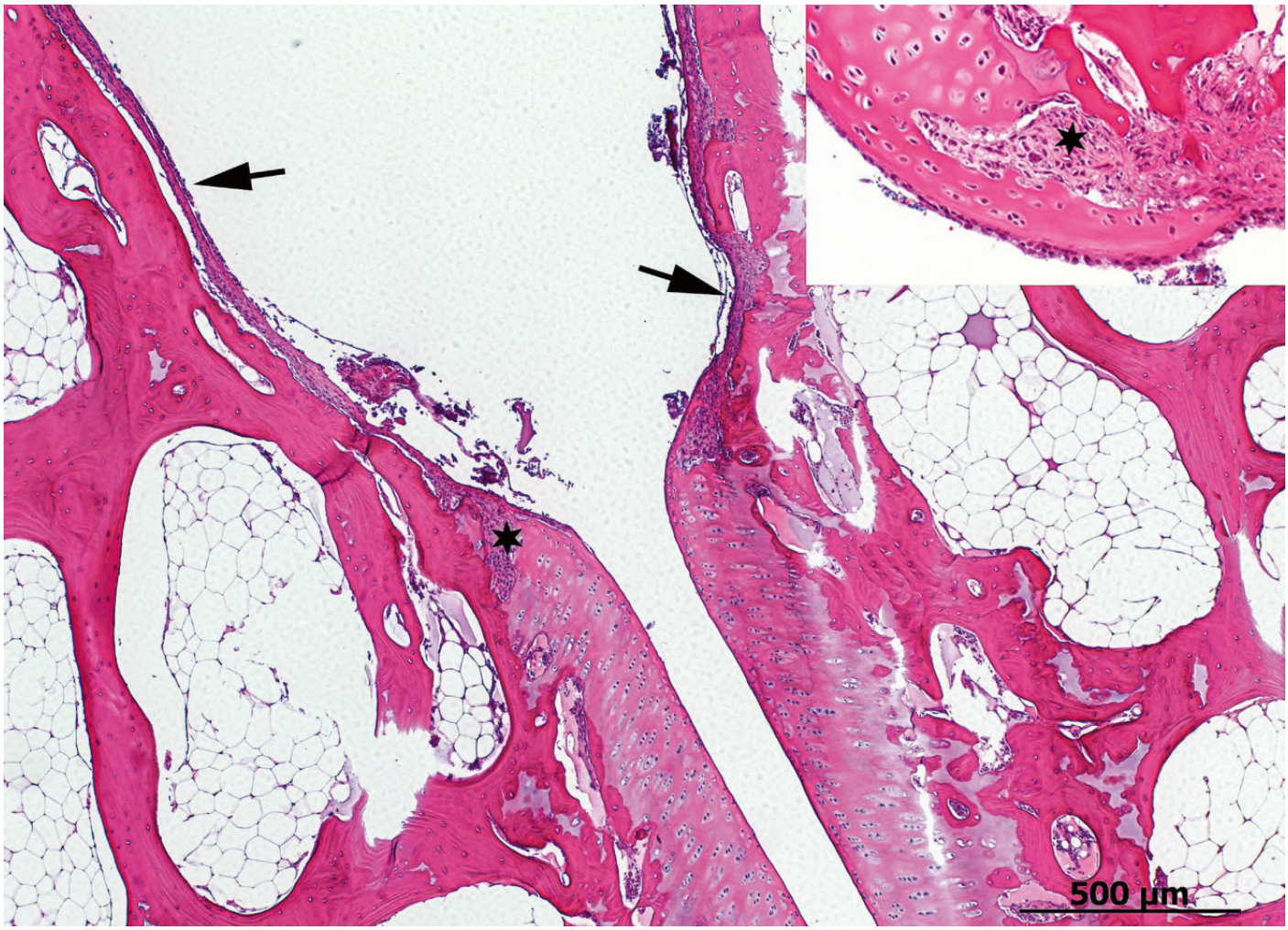

Figure 5: Epiphysis of the right humerus of lamb **No. 1:** Fibrin exudation (arrow) and rest of intact columnar epiphysis with small chondrone formations (stars). Inlet: Pannus tissue replacing the articular cartilage (star). Stain: Haematoxylin and eosin, magnification: 4x

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 physis 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 animaux ont été euthanasiés et une tomographie quantitative périphérique 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 droit des deux animaux. La DMO et la DMOt à 10 % de la longueur de l'os étaient inférieures aux valeurs de référence et la DMO à 50 % 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 éburnation 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 dei 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 eburneazione 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

Skeletal malformation in growing milk sheep

A. Gimmel, R. Hochstrasser, M. Hilbe, K. Nuss, A. Liesegang

Literaturnachweis

[1] Agroscope, 2015. Fütterungsempfehlungen für Wiederkäuer (Grünes Buch), Bern, CH http://www.agroscope.admin.ch/futtermitteldatenbank/04834/index.html?lang=de (accessed 11.08.2023)

[2] Bernath C, Nuss K, Dennler M, Counotte M, Geyer H, Devaux DJ. Prevalence of metatarsal growth plate lesions in Swiss fattening bulls. Schweiz Arch Tierheilkd. : 164.11: 709–720

[3] Carlson CS, Hilley HD, Meuten DJ, Hagan JM, Moser RL. Effect of reduced growth rate on the prevalence and severity of osteochondrosis in gilts. Am. J. Vet. Res. 1988: 49(3): 396–402.

[4] Gimmel A, Hochstrasser R, Hilbe M, Nuss K, Liesegang A. Der Einfluss des Körpergewichtes auf wachsende Knochen - Ein Fallbericht. In: Kreuzer, Michael; Lanzini, T; Liesegang, Annette; Bruckmaier, R; Hess, H D; Ulbrich, S E. Zukunft der Tierernährung zwischen Effizienz und Konsumentenansprüchen: Tagungsbericht, 8. Mai 2018. Zürich: ETH Zürich, 129–132

[5] Henderson, EW. Factors Involved in Malformation of the Bones of Growing Chickens: I. The Value of Egg Yolk and Chicken fat. Poult. Sci. 1933: 12(2): 91–96.

[6] Kealy RD, Lawler DF, Ballam JM, Lust G, Smith GK, Biery DN, Olsson SE. Five-year longitudinal study on limited food consumption and development of osteoarthritis in coxofemoral joints of dogs. J Am Vet Med Assoc. 1997: 210(2): 222–225.

[7] Kovács S, Wilkens MR, Liesegang A. Influence of UVB exposure on the vitamin D status and calcium homoeostasis of growing sheep and goats. J. Anim. Physiol. Anim. Nutr. 2015: 99: 1–12.

[8] Kronfeld DS, Meacham TN, Donoghue S. Dietary aspects of developmental orthopedic disease in young horses. Vet. Clin. N. Am., Equine Pract. 1990: 6(2): 451–465.

[9] Lall SP, Lewis-McCrea LM. Role of nutrients in skeletal metabolism and pathology in fish—an overview. Aquaculture, 2007: 267(1–4): 3–19

[10] Nap RC, Hazewinkel HAW: Growth and skeletal development in the dog in relation to nutrition; a review. Vet. Q. 1994: 16(1): 50–59.

[11] Owens FN, Dubeski P, Hanson PF. Factors that alter the growth and development of ruminants. J Anim Sci. 1993. 71.11: 3138–3150.

[12] Reiland S. The effect of decreased growth rate on frequency and severity of osteochondrosis in pigs. Acta Radiol. Suppl. 1978: 358: 107–122

[13] Thompson JM, Meyer HH. Body condition scoring of sheep. Oregon State University, USA. https://ir.library.oregonstate.edu/downloads/9p290956v (accessed 04.08.2023)

[14] Toll PW, Gillette RL, Hand MS, Thatcher CD, Remillard RL, Roudebusch P, Novotny, TL. Small animal clinical nutrition. Topeka, Kansas: Mark Morris Institute, 2010: 501–542.

Korrespondenzadresse

Annette Liesegang
Institute of Animal Nutrition and Dietetics, Vetsuisse-faculty
University of Zurich
Winterthurerstr. 270
CH-8057 Zürich
Telefon+41 44 635 88 04
E-Mail: aliese@nutrivet.uzh.ch