Congenital joint laxity and dwarfism: A feed-associated congenital anomaly of beef calves in Canada

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Abstract

Five feeding trials were performed on three ranches to determine if a distinctive, recurring, congenital anomaly in beef calves was associated with feeding clover or grass silage without supplementation to pregnant cows overwinter. The anomaly, termed congenital joint laxity and dwarfism, was characterized at birth by generalized joint laxity, disproportionate dwarfism, and occasionally, superior brachygnathia. The anomaly had been documented for several consecutive years on these ranches and affected 2-46% of the calf crop.

Pregnant cows were divided randomly into feeding groups, and the number of abnormal calves in each group was tabulated. Supplementation of the overwinter grass/clover silage diet with hay (2.5-4.5 kg/head/day) and rolled barley (0.75-1.5 kg/head/day) eliminated the problem. Supplementation of grain, without hay, was not as effective. Varying the proportions of grass and clover in the silage, and the age of the silage, did not alter the teratogenic potency of silage. Vitamin D_3 supplementation did not reduce the risk of the condition. The definitive cause of congenital joint laxity and dwarfism was not determined.

Résumé

Laxité articulaire congénitale et nanisme : Une anomalie associée à la composition de la diète chez le veau de boucherie au Canada

Cinq études nutritionnelles furent effectuées dans trois élevages de bovins afin de déterminer s'il existe une relation entre l'alimentation de vaches gestantes avec de l'ensilage de trèfle ou d'herbe sans supplémentation et le développement d'une anomalie congénitale récurrente et distincte chez des veaux de boucherie. L'anomalie, décrite sous le nom de laxité articulaire congénitale et nanisme, était caractérisée dès la naissance par une laxité articulaire généralisée, du nanisme disproportionné et occasionnellement de brachygnatisme supérieur. L'anomalie fut documentée pendant plusieurs années consécutives dans ces élevages et affectait 2% à 46% des sujets.

Les vaches gestantes furent divisées au hazard en deux groupes et le nombre de veaux anormaux dans chaque groupe fut identifié. La supplémentation de l'ensilage de trèfle et d'herbe durant la période hivernale avec du foin (2,5-4,5 kg/animal/jour) et d'orge roulé (0,75-1,5 kg/animal/jour) a éliminé le problème. La supplémentation avec des grains seulement ne fut pas aussi efficace. Les effets tératogènes de l'ensilage de trèfle et d'herbe ne furent pas altérés en changeant les proportions d'herbe et de trèfle ou par la maturité de l'ensilage. L'addition de vitamine D_3 n'a pas réduit le risque de développement de cette anomalie. La cause définitive de la laxité articulaire congénitale et du nanisme n'a pu être déterminée.

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Introduction

During the last decade, beef calves with a distinctive congenital skeletal anomaly have appeared in significant numbers on six ranches located in north central British Columbia and Alberta, and northwestern Ontario (1). For several consecutive years, anomalous calves, involving 2-46% of the calf crop in any one year, have been documented on four of the ranches. Our early epidemiological work in three of the affected herds in north central British Columbia suggested that the anomalies were associated with overwinter feed (1,2). Abnormal calves were born to cows that were fed exclusively grass or clover silage overwinter. In the same area, cows that had been supplemented with grain or hay did not produce calves with the anomaly.

Abnormal calves were characterized at birth by generalized joint laxity, disproportionate dwarfism, and, occasionally, superior brachygnathia. Because of the predominance of the first two signs, we used the phrase "congenital joint laxity and dwarfism" (CJLD) to describe affected calves. Affected calves also had an increased peripartum mortality rate, and many of those that lived did not reach normal stature as yearlings. A similar condition affecting calves born to cows grazing the native foothill pastures of California was described in 1932 (3) and 1947 (4). Although called "acorn calves", the condition could not be reproduced by feeding acorns to pregnant cows (4). Similar "acorn calves" were documented in Australia in 1964 (5). The problem was hypothesized to be feed-associated in both California (4) and Australia (5); however, no definitive cause was determined. Other congenital syndromes wherein calves exhibit joint laxity without dwarfism (6-10), and dwarfism without joint laxity (11-14), have been documented; however, none of these syndromes appears to be related to CJLD.

Repeated appearance of CJLD calves in successive years on several ranches allowed for the planning of feeding trials to test several hypotheses concerning the cause of this anomaly (15). The primary objectives of the trials were to describe clearly the clinical signs and postmortem lesions of CJLD, to determine if the anomaly was associated with feeding clover and grass

TABLE 1
Feeding groups, number of calves and cows, and trial starting dates for each of the five feeding trials

Trial	Ranch[a]	Feeding group	Feed	No. calves/ No. cows	Date trial started
A86	GF	S	Silage	50/56	Nov. 2/85
		SHG	Silage, hay, grain	52/56	
B86	BK	S	Silage	46/52	Dec. 18/85[b]
		SG	Silage, grain	50/52	
A87	GF	SHG	Silage, hay, grain	114/116	Oct. 31/86
B87	BK	RS	Red clover silage	74/78	Nov. 26/86[c]
		GS	Grass silage	70/74	
		RSG	Red clover silage, grain	82/86	
C87	RH	RS	Red clover silage	23/26	Nov. 15/86
		GS	Grass silage	54/57	
		H	Grass hay	24/26	

[a]GF and BK ranches are near Prince George, British Columbia; RH ranch is in Oxdrift, Ontario
[b]All B86 groups were fed silage only from Nov. 1 to Dec. 18 (48 d)
[c]All B87 groups were fed silage only from Oct. 21 to Nov. 26 (37 d)

silage exclusively to pregnant beef cows overwinter, and to rule-out vitamin D deficiency as a cause of CJLD.

Materials and methods

During a period of two years, five feeding trials were performed on three of the affected ranches. The trial identification numbers, ranches, feeding groups, numbers of cows and calves, and starting dates are given in Table 1. Animals excluded from analyses of the trials, with reasons for those exclusions, are listed in Table 2. The methodology was similar in all five trials, but the specific objectives differed for each. No additives, silage preservatives, or acidifiers were added to the silos in any of the five feeding trials. Random assignment of pregnant cows to feeding groups in the fall in all trials was performed using random numbers and a database sort procedure (Reflex, the Analytical Database System, Borland/analytica Inc., 4585 Scotts Valley Drive, Scotts Valley, California)

Trial A86

Trial A86 was one of two feeding trials (A86 and B86) conducted during the winter of 1985/86 to try to clearly demonstrate an association between overwinter feed and CJLD. The entire herd of 112 pregnant Hereford and Hereford-cross heifers and cows on the GF Ranch in north central British Columbia was divided into two feeding groups at the start of overwinter feeding on November 2, 1985. The first group ("S") was fed only silage, whereas the second group ("SHG") was fed the same silage plus about 4.5 kg/head/day hay and some barley. The silage was stored in two dirt-based trench silos sealed with polyethylene film, and consisted of about 50% grass, 35% red clover, and 15% oats. The oats and timothy hay was purchased. Barley was fed to the "SHG" group initially at 0.5 kg/head/day on November 2, increased to 2 kg/head/day by January 15, and decreased gradually thereafter with no barley fed after February 15, 1986. The "SHG" group consumed just over one-half the silage dry matter offered to the "S" group.

We also tested the hypothesis that CJLD was a form of prenatal rickets. Twenty-eight cows in each feeding group (one-half the number of animals in each group, chosen randomly) were each given an intramuscular injection of 3×10^6 IU vitamin D_3 in oil (Poten-D, rogar/STB Inc., London, Ontario) on November 18 and March 1.

Trial B86

For the B86 trial, 104 crossbred heifers were chosen randomly from 235 on the BK Ranch, also in north central British Columbia. All of the heifers received only silage from November 1 to December 18. From December 18 until calving, the silage-only ("S") group was fed red clover-based silage. The silage and grain ("SG") group was fed approximately 1 kg/head/day rolled barley from December 18 to February 15, in addition to red clover-based silage. The quantity of silage consumed daily was the same for the two groups. As in the A86 trial, 26 cows in each feeding group were each given an intramuscular injection of 3×10^6 IU vitamin D_3 in oil (Poten-D) on December 18 and February 26.

Trial A87

This trial was designed to determine if CJLD could be eliminated from the GF Ranch, for the first time in ten years, by feeding according to the findings of the A86 trial. The A87 trial comprised 116 crossbred Herefords. Thirty-three first-calf heifers were housed and fed separately from the 83 mature cows. All were fed silage, grass hay, and grain (rolled barley), supplemented with a complete mineral mix (Van Waters & Rogers Ltd., 3266 McCallum Road, PO Box 172, Abbotsford, British Columbia). The silage consisted of about 50% grass, 35% red clover, and 15% oats. The first-calf heifers were fed 2–3 kg/head/day grass

TABLE 2
Animals initially entered in feeding trials but later excluded from the analysis of results

Reason for exclusion	Trial / Feeding group	A86 S	A86 SHG	B86 S	B86 SG	B87	C87 RS	C87 GS	C87 H
Not pregnant in fall		2	2	3	—	—	1	3	—
Not pregnant in spring		3	2	3	1	—	—	—	—
Culled in fall (feet, breed type, and not pregnant)		—	—	—	—	23	—	—	—
Abortion		1	—	—	—	—	—	—	—
Stillbirth eaten by scavengers		—	—	—	1	—	—	—	—
Cow died on pasture		—	—	—	—	—	1	—	—
Lost eartags—unable to determine which group cow belonged to at calving		—	—	—	—	12[a]	—	—	—
	Totals	6	4	6	2	35	2	3	0

[a]All twelve of these heifers had a normal calf

hay, whereas the mature cows received 2–2.5 kg/head/day. Slightly more than one-half the quantity of hay was fed in this trial compared to the A86 trial. Both groups received 1.5 kg/head/day rolled barley. Two heifers were not pregnant in the spring.

Trial B87
The B87 trial was designed to replicate the findings of the B86 trial, and to determine if varying the proportions of grass and red clover in the silage altered the risk of CJLD. Two hundred and sixty-one crossbred heifers at the BK Ranch were assigned randomly to one of three treatment groups which were not assembled until November 26. Twenty-three heifers were culled after pregnancy examinations on September 21. Pasture was supplemented with grass silage until October 21; from October 21 to November 26 all the heifers were fed only grass silage. On November 26, the heifers were separated into three treatment groups. The "RS" group was fed red clover silage (80% red clover, 20% grass) free choice, supplemented with a complete mineral mix (Love Feeds Ltd., 2808 58th Ave SE, Calgary, Alberta), whereas the "GS" group was fed grass silage (80% grass, 20% red clover) free choice, supplemented with the same complete mineral mix. The "RSG" group was fed the same diet as the red clover silage group, but was also supplemented with 1.5 kg/head/day rolled barley. At the end of February, the three groups were mixed and all received 1.5 kg/head/day rolled barley for a short time prior to calving. The silage for both the B86 and B87 trials came from a series of large, sealed, dirt- or concrete-based, trench silos.

Trial C87
The C87 trial was designed to determine if cows fed grass hay had the same risk of producing CJLD calves as cows fed grass silage made from the same fields that provided the hay. At the RH Ranch in northwestern Ontario, 105 Hereford crossbred cows exposed to a bull on pasture were assigned randomly to one of three groups. The "H" group was fed grass hay (about 11 kg/head/day), the "RS" group red clover silage (about 32 kg/head/day divided into two feedings), and the "GS" group grass silage (about 36 kg/head/day divided into two feedings) from November 15 to calving. None of the groups received any grain supplementation but all cows had access to a complete mineral mix. The red clover silage, consisting of 50% red clover and 50% grass, had been harvested in 1984 and stored in a sealed dirt-based trench silo. The grass silage, consisting of 95% timothy, was harvested in 1986 and stored in a sealed concrete-based trench silo. The grass hay, consisting of 95% timothy, was harvested in 1986 from the same fields that were used to make silage. The square bales were stored indoors.

Assessment of calves
Calving crews at each of the ranches examined all calves within 24 h of birth. The date and time of birth, tattoo and eartag number of the dam, calf number, calf sex, birthweight, and calving ease were recorded on calving-event record sheets. The presence or absence of a cleft palate was noted. Scores of 0 (not present) to 3 (severe) were given for the degree of: dwarfism, metacarpophalangeal hyperextension, lateromedial carpal flexibility, and mandibular extension beyond the maxilla (superior brachygnathia) present in the calf. Dwarfism was assessed clinically in two ways: first, by observing the length of the limbs relative to the body of the calf; second, by palpating the length of the shaft of the humerus. The joints, head, neck, back and navel were examined and the presence of any other defects noted.

Necropsy examinations were performed on all dead calves born to cows or heifers in the A86 and B86 feeding trials. Recorded information included calf sex, birthweight, and crown-rump length. Lateromedial flexibility of the carpus, and maximum hyperextension of the metacarpophalangeal and metatarsophalangeal joints were measured with a goniometer. The right humerus, radius, metacarpus, and femur were cut sagittally with a bandsaw to examine the growth plates. The skull was cut sagittally to examine the cranio-occipital synchondrosis. Measurements were made of total bone length, and epiphyseal and diaphyseal lengths for the humerus, radius, metacarpus and femur.

Analysis of data

Data were entered into a database management program (Reflex) at the Western College of Veterinary Medicine. Analyses by crosstabs, interactive graphing, stratification and contingency tables were performed using the program and a Casio Fx-250 pocket scientific calculator.

The scores for degree of dwarfism, metacarpophalangeal hyperextension, lateromedial carpal flexibility, and superior brachygnathia were added to obtain an overall clinical score (maximum 12). Calves with an overall clinical score of 2 or less were declared normal; calves with a clinical score of 3 or more were declared to have CJLD. This categorization allowed for contingency table analysis and ensured that calves declared abnormal were obviously abnormal. Risk (R) and relative risk (RR) were used as measures of the degree of association between CJLD and overwinter feed, and between CJLD and vitamin D_3 injection status (16). A chi-square test of association, with a correction for continuity, was used on the contingency tables to determine the significance of the association between CJLD and the other variable (17). To test for interaction between vitamin D_3 and type of feed, the data were entered into a statistical program (PC-SAS, SAS Institute Inc., Box 8000, Cary, North Carolina) at the Ontario Veterinary College, and Breslow-Day tests for homogeneity of odds ratios between strata were performed (18).

To estimate the day of gestation on which overwinter feeding was started for each cow, a gestation length of 283 days was assumed (19). From this figure was subtracted the number of days between the calving date for each cow and the date of commencement of overwinter feeding.

Results

At the conclusion of the A86 feeding trial, 102 heifers and cows had given birth to term calves. Seventeen calves had a clinical score of 3 or more and were categorized as having CJLD. All CJLD calves were born to "S" cows; "S" calves had a 35 times greater risk ($p < 0.005$) of having CJLD compared to "SHG" calves.

Of the 114 calves (one set of twins) born after the A87 feeding trial, 113 were normal. One calf had severe CJLD and died within 12 h of birth. This calf was born to the only first-calf heifer which was not supplemented with hay until after the 180th day of gestation. She was fed only silage for approximately 73 days (from day 107 to 180 of gestation).

At the conclusion of the B86 feeding trial, 96 of the 104 heifers had given birth to term calves. CJLD-affected calves (12.5%) were observed in both the "S" (10 of 46) and "SG" (2 of 50) groups, but calves in the "S" group had a five times greater risk ($p < 0.025$) of having CJLD, compared with the "SG" group. One of the two CJLD-affected calves born to an "SG" heifer was assessed a clinical score of 7.

The vitamin D_3 status of the dam had no discernible effect on the occurrence of CJLD in either the A86 or B86 trial. Breslow-Day tests for homogeneity showed no evidence of interaction between vitamin D_3 status and feeding group.

Overall in the B87 trial, 25/238 calves (10.5%) had CJLD. Although the "RSG" group had a lower prevalence of CJLD (6 of 82, 7%) than did either the "RS" group (11 of 74, 15%) or the "GS" group (8 of 70, 11%), the difference between groups was not statistically significant ($0.05 < p < 0.10$).

In the C87 trial, 101 calves were born to 99 cows. Twenty-four of the calves had CJLD, and all were born to cows in the two groups fed silage. Calves in the "RS" (9 of 23, 39%) and "GS" (15 of 54, 28%) groups were greater than 15 times more likely than calves in the "H" group (0 of 24, 0%) to be affected with CJLD (RR = 15; $p < 0.005$).

Overwinter feeding of cows began at an average gestational age of 107, 137, 117, and 145 days in the A86, B86, B87, and C87 trials respectively. In the A86, B86 and B87 trials, cows which began overwinter feeding as late as day 152 had CJLD-affected calves. During the C87 trial, the cow that began overwinter feeding at the latest gestational age, 197 days, had a CJLD-affected calf with mild dwarfism, whereas a cow that began overwinter feeding at day 162 of gestation had a severe CJLD-affected calf.

Description of the syndrome

During the two-year study, 98 calves had some degree of malformation. Joint laxity was the predominant clinical sign, being present in more than 90% of the cases (Table 3). The laxity usually was present in all joints of the limbs, being especially obvious in the distal joints. Laxity of the metacarpophalangeal joint caused metacarpophalangeal hyperextension in the weight-bearing calf (Figure 1). Similarly, the weight-bearing distal hindlimb assumed a sickle-shape due to laxity of intertarsal, tarsometatarsal, and metatarsophalangeal joints. Ranch owners referred to these calves as "banana-leg" calves. Severely affected calves walked

TABLE 3
Relative frequency of the major clinical signs of congenital joint laxity and dwarfism (CJLD)[a]

Clinical signs	Frequency of cases (%)
Joint laxity	91
Disproportionate dwarfism	71
Superior brachygnathia	24
Joint laxity and dwarfism	57
All 3 clinical signs	20

[a]Based upon a total of 98 CJLD-affected calves identified during the five trials

Figure 1. A newborn calf severely affected by congenital joint laxity and dwarfism. Note the crouched appearance, short legs, metacarpophalangeal hyperextension, and "sickle-shaped" rear legs.

on the palmar and plantar surfaces of their phalanges so that dewclaws of both fore and hindlimbs contacted the ground (Figure 1). Because of the carpal laxity, lateromedial flexibility of the fully extended carpus was often demonstrable. Many calves assumed varus or valgus leg postures when standing. These postural deformities were due to joint laxity and instability, and not to any deformation of the long bones of the limbs. Scoliosis, kyphoscoliosis, diaphyseal curvature of the long bones, or cleft palate were not documented in any of the calves. Three calves had lateral rotation of the metacarpal bones, and two others had some degree of kyphosis.

Seventy-one percent of the affected calves were disproportionate dwarfs. There was great variability in shortening of long bones. Clinically, the humerus appeared most obviously affected, and had marked diaphyseal shortening with little or no lessening of diaphyseal width.

Joint laxity at birth interfered with the ability of CJLD calves to stand and walk. Upon rising they moved slowly, with the front limbs held apart, the hindlimbs narrow-based, and the pelvis sloping downward. Severely affected calves spent more time in recumbency during the first week than did normal calves. Within two weeks of birth, the joints became stable and the calves walked normally. Calves born with shortened limbs often attained reasonable weaning weights, but remained smaller than herdmates (Figure 2). As yearlings, many had a characteristic short, concave maxilla (Figure 2).

Histology

Histological findings suggested that the problem was one of impeded endochondral ossification. Appositional ossification responsible for diaphyseal and cortical widening and growth of flat bones proceeded normally. The epiphyses were abnormal, and had various degrees of overgrowth of chondrocytes with occasional malalignment, and delayed mineralization. Secondary ossification centers were slow to develop. There was no evidence of increased bone fragility, nor was there evidence of abnormalities of any other organ system.

Figure 2. Illustration of the size variability of yearlings affected with CJLD. Note the relatively shorter limbs and maxillas of the two CJLD-affected animals compared with a normal herdmate.

Discussion

The findings strongly supported our hypothesis that CJLD was associated with using grass and clover silage as the sole overwinter feed for pregnant beef cows. Supplementation of the grass and clover silage diet with hay (2.5–4.5 kg/head/day) and rolled barley (0.75–1.5 kg/head/day) eliminated the problem. Supplementation with grain (but no hay) reduced the risk of CJLD to a lesser extent. However, in both of the grain-supplement trials (B86 and B87), all of the heifers were fed silage exclusively for 37–48 days before the SG group was separated and supplemented with grain (Table 1). If grain had been supplemented from the start of overwinter feeding, fewer CJLD-affected calves might have been observed in the grain groups. Variations in the proportions of grass and clover in the silage, and the age of the silage, did not alter teratogenic potency.

The period of gestation during which the fetus is susceptible to CJLD may be very long; evidence from these trials suggests that the susceptible period includes day 107 to at least day 230. One heifer that produced a CJLD-affected calf was fed silage exclusively from day 107 of gestation to day 180. This finding suggested that irreversible damage to the fetus had occurred by day 180 of gestation. Yet, other cows fed silage exclusively as late as day 197 had CJLD-affected calves. Assuming that a period of several weeks of fetal exposure is necessary to cause the skeletal changes of CJLD observed, the susceptible period for these cows would span day 197 to day 230 or longer. Therefore, we recommend that silage be supplemented with hay and grain from the start of overwinter feeding, and that this supplementation be continued until calving.

In the C87 trial, timothy grass fed as hay to 24 pregnant cows produced no CJLD-affected calves, whereas timothy grass harvested from the same fields and fed as silage to 54 cows produced 15 CJLD-affected calves.

This finding suggests that a process taking place during silage storage may transform the grass to a feed that is teratogenic when fed to pregnant cows as the exclusive overwinter diet. The transformation process could occur in one of three (or more) ways. First, effluent often leaves the silage pit during the first days of ensiling, carrying with it a variety of leached materials (20). The volume and precise nature of the effluent depends on the moisture content and type of ensiled forage (20). A substance necessary for the prevention of CJLD may be lost in the effluent. Second, wet conditions in the silage pit may allow fungal growth and production of a mycotoxin, which could cause CJLD. Growth of fungi and subsequent mycotoxin production—even under the anaerobic conditions of the silo—have been documented (21). Moreover, aerobic production of mycotoxins after the silo has been opened is possible as anaerobiosis cannot be maintained during the feed-out of silage. Certain mycotoxins have been shown to be teratogenic when fed to pregnant mice, the nature of the response depending upon the stage of embryonic development at the time of maternal exposure (22). Furthermore, feeding rice contaminated with the fungus *Fusarium rosarium* to broiler chicks rapidly and consistently induces osteochondrosis or tibial dyschondroplasia (23), a condition that is thought to be caused by T-2 or some other mycotoxin (24). Third, the process of fermentation itself may either produce a substance which is responsible for CJLD, or bind or alter a substance which in the unbound or unaltered state prevents CJLD. The most likely of these alternatives—deficiencies from leaching or fermentation, or toxicosis from fungal or fermentation toxin production —cannot be determined from the findings of this research, and will require further investigation.

There are striking clinical similarities between the CJLD-affected calves described in this study and "acorn calves." As feed is strongly implicated as causal for both the acorn calves and CJLD, the two conditions may share a common causal pathway. The conclusions of Barry and Murphy (5) that certain unspecified seasonal and environmental conditions or "stresses" convert forage into a teratogenic substance are very similar to our conclusions concerning CJLD. Strong similarities also exist with the situation in California where the investigators concluded that the acorn calf condition was nonhereditary, and was due to a maternal deficiency probably occurring between day 90 and day 180 of gestation (4). Supplemental feeding of pregnant cows on pasture practically eliminated the occurrence of acorn calves (4). Wagnon (25) attributed the decreased prevalence of acorn calves in California by the 1960's to the increased use of supplemental range feeding, along with improved management of the breeding herds.

However, Hart *et al* (4) also noted that the birth of acorn calves tended to follow dry years when animals were confined for a long period in the same area on poor dry feed. This differs remarkably from the feed conditions producing CJLD, where the (wet) silage was good quality, palatable, and well-consumed overwinter on an essentially *ad lib* basis. By the time of calving, the dams in Canada continued to be in excellent condition, unlike the dams in California. Perhaps the leaching process hypothesized for CJLD led to the same deficiency thought to occur in the poor dry feed of California. Fungal mycotoxicosis and fermentation irregularities are unlikely to have occurred under the dry pasture conditions in California. However, the California researchers may have focussed their attention too early in the year. Guilbert and Rochford (26) observed that heavy weight losses in cattle in the California foothills would often occur at the time of first autumn rains when the feed value of the old (dry) forage was reduced by its being leached and beaten into the ground; the new forage was too scant and watery to supply sufficient feed. These conditions, appearing after the dry season, could well support any of the three processes hypothesized for CJLD: a deficiency from leaching, a fungal mycotoxicosis, or even a fermentation problem. Despite the similarities demonstrated by comparison of the conditions of CJLD and acorn calves, no light is shed on a definitive cause for either condition.

No other documented congenital skeletal defect of calves matches the description of CJLD reported herein. "Limber legs" of Jersey calves is progressive and there is muscle atrophy (6,7). Photographs of calves with osteogenesis imperfecta look very similar to CJLD calves; however, osteogenesis imperfecta involves progressive deterioration and is marked by bone fragility, fractures, fragile pink teeth, tendon and ligament ruptures, and chronic tenosynovitis (8–10). Descriptions of brachycephalic "snorter" dwarfs do not mention any degree of joint laxity (11,13,14). Calves born to dams on manganese-deficient diets have enlarged joints, stiffness, twisted forelimbs, "knuckled-over" pasterns, and general physical weakness (27,28).

Ingestion of certain toxic plants by pregnant cows can cause congenital skeletal defects in calves, but none describes the collection of defects seen in CJLD. Arthrogryposis, torticollis, scoliosis, rotation of distal limbs, and occasional cleft palate characterize "crooked calf disease" (29), a condition associated with ingestion of *Lupinus* spp. containing the quinolizidine alkaloid anagyrine (30,31,32). Ingestion of locoweed leads to lateral rotation of the forelimbs, contracted tendons, "anterior flexure" (presumably meaning hyperextension) and hypermobility or looseness of the hock joints, and flexure of the carpus of lambs and calves (33). Ingestion of locoweed is also accompanied in the dam by neurological disorders, abortions, and death (33). The ingestion of certain species of *Lathyrus* may lead to many of the signs described for locoweed, as well as increased bone fragility, exostoses, curvature of the long bones, kyphosis, and scoliosis (34,35). Ingestion of poison hemlock (*Conium maculatum*) can lead to permanent flexure of the carpal or elbow joints, lateral rotation of the front limbs, and occasional scoliosis or cleft palate (36,37).

Our early hypothesis that CJLD may be a manifestation of prenatal rickets was based on three observations. First, overgrowth of chondrocytes and delayed mineralization of the growth plates of calves affected in previous years were similar to findings described for neonatal rickets (38). Second, the vitamin D content of silage is reported to be very low (39) and the rumen of adult cattle does not produce vitamin D (40). Third, the wavelengths of ultraviolet light necessary for transformation of the provitamin 7-hydroxycalciferol to vitamin D_3 are almost entirely filtered out by the atmosphere during the winter months because of the acute angle of the winter sun in northern latitudes (41). In Canada therefore, pregnant beef cows fed an exclusive overwinter diet of grass or clover silage may have very low levels of vitamin D (42). However, our hypothesis was not supported; vitamin D_3 supplementation of the pregnant cows in the 1985/86 trials did not reduce the risk of CJLD.

To researchers in western Canada in the early 1980's, CJLD appeared to be a potentially devastating but isolated condition, confined to the Prince George area of British Columbia. We now have documented CJLD calves in several other locations across Canada, including Dawson Creek, British Columbia, Barrhead and High Prairie, Alberta, and Oxdrift and Cochrane, Ontario (1). Canadian ranchers who contemplate feeding grass or clover silage to their pregnant beef cows overwinter should be aware of how to reduce the risk of CJLD. Although the definitive etiology of CJLD is unknown, cow-calf producers now have a management technique to prevent the condition.

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