Why Do Cows Become Lame?

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Introduction to Biomechanics

The structures of the bovine digit that support her body weight and work in normal locomotion can and do become diseased in predictable fashion. The bones, tendons, ligaments, corium, and hooves are all potentially involved when things go wrong. A better understanding of the biomechanical relationships in the digits of cattle can help with more rational therapeutics and appropriate preventive maintenance. The things that go wrong with the digits from a mechanical perspective are related to the environmental influences of moisture, infection pressure, and standing surfaces. The distance walked and the characteristics of the substrate walked on also result in predictable problems.

What we see as the current condition of the claws on any cow is a result of continuous growth, continuous wear, and intermittent trimming. The growth rate of hooves is relatively constant but subject to minor modifications. Nutrition can influence hoof growth rate. Hooves do not grow as fast during starvation as during adequate feeding. Since dairy cattle are never intentionally starved this effect is unimportant. A small variation occurs during the lactation/gestation cycle and with season.

Why do we see more disease in rear feet than fore? Why is there more disease in lateral rear claws than medial? The fore versus rear argument in dairy cattle has 3 components. The rear limbs of dairy cattle are forced to carry weight in excess of the original design criteria. The wild-type cow which gave us our modern dairy cows never had a large udder, even at calving. As we have selected for more milk production, I do not think we have been able to simultaneously modify the musculoskeletal system to accommodate this extra weight at the rear of the cow. Secondly, the forelimbs are attached to the body by elastic components versus the direct bony connections in the rear limbs. Concussive forces created during locomotion must be absorbed by the digital cushion and the flexion of the hock and stifle. Thirdly, rear feet are always more exposed to the bacteria and moisture of manure and urine. The skin near the hooves is more likely infected with bacteria due to maceration by this moisture and the hoof capsule is softer due to greater hydration. The medial versus lateral argument is potentially more confusing. Lateral claws grow about 10% faster than medial claws and wear about 8% more in freestall housed Holsteins. Thus lateral claws can progressively outgrow medial claws. They are larger even in fetal calves. Larger lateral claws are more heavily loaded than medial claws. Larger loads result in more potential for mechanical insults. Cows may adopt a toed-out posture to help equilibrate the weight between the rear claws when overgrowth and some discomfort occur. This toed-out posture or being “cow hocked” can be used as an indicator of the need to trim an individual cow or by population evaluation to determine when a group or herd needs trimming.

Body weight is supported by the column of digital bones resulting in the load being approximately evenly divided between the eight digits with normal claws and conformation. The third phalanx or P3 is the end of these columns. The load on P3 is supported by several structures of importance in our concern for lameness. There are laminae in the mural corium, that are tightly attached to lateral and cranial portions of P3, and that interdigitate with laminae in the
hoof wall. These have less surface area of mutual contact per unit of supported weight than in
the horse. Therefore the laminar region of the bovine digit while very important is not as
significant as in the horse for support. There is also support of P3 by ligaments that suspend the
caudal portion of the bone and blend with the interdigital cruciate ligaments axially and with the
laminar corium abaxially. The tension of the deep flexor tendon on P3, in addition to fixing the
bony column in a nearly vertical formation, pulls the distal tip of P3 ventrally and transfers some
weight forward in the claw. Between P3 and the solar corium is a complex arrangement of fat
deposits that cushion and distribute weight transferred to the sole. The fat pad is thickest at the
heel and plays a dynamic role in cushioning during walking. There will be more about the
importance of the digital cushion later.

**Pathophysiology of Claw Horn Disease**

When the events commonly known as laminitis occur, a vascular disturbance affects
both the laminar and the non-laminar corium as well. The edema and resulting swelling reduces
the ability of normal circulatory dynamics to oxygenate the corium. Some anoxic damage may
occur. Additional, not yet characterized triggers may activate metalloproteinases resident within
the soft tissues. The mechanical properties of the corium and the collagenous supports of P3 that
have thus been insulted can be altered with the result of lower tensile strength. As a
consequence, P3 may move within the horny capsule beyond the limits occurring in healthy
claws. With the exaggerated movement of P3 2 specific lesions may develop. If P3 moves closer
to the sole, abnormal pressure may cause further anoxic damage to the solar corium. If mild, this
may appear as hemorrhage in the sole at a later trimming. If severe, the solar corium may die
and result in a sole ulcer. In housed cattle the ulcer is most common at the caudal portion of P3
in proximity to the flexor tuberosity where the subcorial fat pad is thin and in extensively
managed cattle it more often occurs under the distal portion of P3. The abnormal movement of
P3 relative to the laminar corium may result in ruptured blood vessels that lead to hemorrhage. If
the hemorrhage is very mild it is later seen as a red line in the sole at the sole-wall junction or
white line. If the hemorrhage is more extensive, it can result in a hematoma that later becomes
either a sterile abscess or a septic abscess if the white line is separated and permits entry of
environmental bacteria. Cattle that must make sharp turns on rough flooring may experience
more white line lesions due to the lateral forces placed on the wall. During a turn there may be
claw deformation that can pull the wall from the corium or shear the corium if the structural
integrity of the tissue is already compromised by edema. Anecdotal evidence supports the
consequences of rubber flooring as a reduction in white line lesions without changing the
incidence of sole ulcers.

It is important to note that the lesions of the corium that we recognize as and call
laminitis require weight bearing during the period of primary damage to the corium. No one
knows how long episodes of altered permeability and edema last following the chemical
messengers from ruminal acidosis. However, if the cow did not stand during that period, there
would be no mechanical damage to the corium. In the vast majority of cases, the lesions within
the claw that we call laminitis are the consequence of standing or walking on damaged corium.
Standing is perhaps a worse insult to the corium than walking. With each step there is normal
movement of P3 within the horny capsule of the claw. This movement results in periodic
perfusion of parts of the corium. When a cow stands without shifting her weight these periodic
changes in blood flow within the corium are probably interrupted. Thus standing motionless is
potentially more damaging to an already insulted corium than walking. Only in the rarest cases
do the lesions of laminitis actually develop while cows are lying. Thus the great stress in recent years on cow comfort and maximizing opportunities through time management and providing attractive lying surfaces are actually anti-laminitis efforts.

Claws with abnormal shape, particularly of the ground contact surfaces are more prone to mechanical insult to the corium. This is most commonly seen when excess horn production occurs at the axial border of the claws near the heel. The horn is probably being produced at an accelerated rate by this portion of the sole in response to stimulation by chronic dermatitis caused by *Dichelobacter nodosus* which is recognized to cause skin hypertrophy of the heels and interdigitally. Unfortunately, this site on the sole where an excess rate of horn production is observed is also that of the common sole ulcer. During weight bearing the corium deep to the horn buildup will be compressed in a fashion similar to when P3 movement within the claw is excessive.

**Risk Factors for Lameness**

**Environmental risk factors for claw horn diseases**

Most concern for the prevention of laminitis has been focused on the nutritional management of cattle to minimize the occurrence ruminal acidosis. Ruminal acidosis is probably a necessary but not sufficient condition for the development of the most commonly observed lesions of subacute ruminal acidosis, sole and white line hemorrhages, white line abscesses, and sole ulceration. Environmental conditions, cow behavior and the support of the digital cushion appear to modify the final expression of the insult caused to the laminae and corium of the claws caused by ruminal acidosis. Subacute ruminal acidosis likely occurs in most dairy cattle in North America at some time during lactation. Despite this likely common occurrence, lameness is more variable and even quite severe in some herds. The reports of Manson & Leaver, Livesey & Fleming, and Peterse et al. describe the incidence of laminitis lesions in small groups of cattle in experimental herds with diet treatments that were either high or low concentrate feeding levels relative to forage. In each study there were more cases of lameness in the higher concentrate feeding groups. The consequences of standing on concrete are considered by many to be very important in the development of lesions of laminitis. Pressure exerted on specific portions of the claw may contribute to the observed lesions of either hemorrhage or necrosis. Cattle claws are commonly shaped in less than desirable forms. When these misshapen claws are supporting a cow on an unforgiving surface, the localized pressure can contribute greatly to damage of underlying structures. It is these consequences that have lead to my suggesting that barn floors be surfaced with something other than concrete and that routine trimming can prevent many of the more severe cases of lameness. It is of interest that the installation of rubber by feed alleys, in parlor holding areas, along alleys connecting pens to the milking parlor, and most recently complete alley covering with rubber mats has been increasing. Thus far there is no data on the effects of these changes on lameness but unquantified observations of cow behavior by the author suggest that we are moving in the right direction.

Lameness incidence in bullocks housed on slatted floors, 4.75% of 12010, in winter in Ireland was twice that of bullocks housed in bedded packs, 2.43% of 2882, in 1984. Similarly, a cross-sectional survey of Dutch dairy calves on 117 farms between 2.5 and 12 months of age observed more sole hemorrhages in heifers housed on slatted floors than in bedded packs. The prevalence of sole hemorrhage in bedded packs was 5% and was 45% on slatted floors. A comparison between 11 herds with chronic laminitis problems and 11 control herds was made
during 2 years by Dr. Christer Bergsten in the vicinity of Skara, Sweden. There was a correlation between the stall surface, either concrete or with a rubber mat, and the occurrence or hemorrhages. Fewer sole hemorrhages occurred in stalls fitted with rubber mats. The cows were in tiestalls and bedding use was not found to influence the prevalence of sole hemorrhages although it was described as minimal in all stall types. The only publication suggesting an effect of environment on laminitis in freestall housing compared the problem in 2 herds with the same owner and stall design but managed differently due to the requirements of the manure removal system. The herd with a higher incidence of lameness used less bedding. Both the proportion of animals standing in the alleys and the proportion of animals standing half in the stalls was higher for the herd with more lameness.

Standing time on concrete is heavily influenced by the environmental design of dairy facilities and modified by overcrowding and management activities. Synchronization of behavioral activities again leads a group of cattle to mostly lie down at the same time. Overcrowding of freestall pens prevents some of the subordinate animals from access to a stall. When a stall becomes available it might signal the pen is ready to collectively eat or be milked thus preventing that timid animal from lying at all. Data from long term observations of groups of cattle with known dominance structure showed that a very subordinate animal, usually a heifer, might stay in a stall during some group eating times. Reasons for this are speculative but, regardless, the result is slug feeding for that animal when she does leave the stall. Subordinate animals are also more likely to stand either in the alley altogether with the head placed in a stall or half in a stall. Interpretation of this behavior is that it provides a reduction in the danger posed by more dominant cattle. Housing first lactation animals separate from older cows has resulted in a reduction of the negative effects of these social interactions on the heifers.

**Individual cow risk factors for claw horn lesions.**

Recent research by Bicalho and others at Cornell has shown that age increases the likelihood of claw lesions. Claw lesions in a large study population (~4500 cows) were 10% in L1, 32% in L2, 41% in L3 and 49% in L4+. In addition the thickness of the digital cushion measured ultrasonographically between the interior surface of the sole horn and the flexor tuberosity of P3 was correlated with the occurrence of claw horn lesions. First parity animals have a thinner digital cushion in general than older cows but weigh less and have fewer lesions. Thus the interaction seems to be between the mechanical load of the cows weight and the distribution of that weight over the sole by the digital cushion. Body condition scores were made at the time of digital cushion measurements and were highly correlated. Thus the thickness of the fat pad in the digit can be approximated by assessing the body condition score of the cow. Thin cows develop more claw lesions than fat cows.

The dynamic aspect of the digital cushion in preventing lameness was demonstrated in a separate study. Cows with claw horn lesions and high locomotion scores were randomized to pens that were milked normally 3 times per day or pens that were milked 2 times per day. Locomotion scores were determined at monthly intervals after the randomization to pens for 4 months. Locomotion scores improved for the cows switched to 2X milking. Less forced standing time resulted in better locomotion, no loss of potential milk production, recovery of body condition and normal reproduction. Not all herds could maintain separate milking frequency pens but is an option in some circumstances.
Conclusions

Providing the environmental circumstances and time management for cows to lie down at least 12 hours per day minimizes the mechanical disruption of the potentially insulted soft tissues within the claw capsule. Nutritional management to minimize ruminal acidosis and maintain good body condition further reduce the risk of lameness. Proper and frequent trimming are a must to maintain normal weight distribution over the sole and wall of the hooves. Lameness will still occur but can be minimized with attention to these 3 important and sometimes difficult management activities.