Disorders of the Claw and Their Association with Laminitis in Smallholder Zero-grazed Dairy Cows

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ABSTRACT

A cross-sectional study was carried out in which 300 zero-grazed dairy cows from 32 smallholder dairy units were examined for claw lesions in the peri-urban areas of Nairobi, Kenya. The objective of the study was to determine the characteristics of claw disorders and their association with laminitis. Lameness for each cow was determined by assessing the locomotion score through a prescribed locomotion scoring system. Each cow was restrained in a crush and the claws thoroughly washed and examined for any external claw lesions or disorders including signs of laminitis. About 1-2 mm thickness of the horn of the sole for each claw was trimmed to confirm laminitis by presence of sole haemorrhages. Data was analyzed using Genstat statistic software. Prevalence of laminitis was 70.3% out of which 49.3% was subclinical laminitis and 21.0% was chronic laminitis. Claw deformities found to be strongly associated with chronic laminitis were claw overgrowth (χ² = 96.69, r = 0.6, P<0.0001), horizontal grooves (χ² = 61.27, r = 0.5, P<0.0001), concave claws (χ² = 59.39, r = 0.4, P<0.0001), flat claws (χ² = 57.87, r = 0.5, P<0.0001), presence of sole haemorrhages (χ² = 50.16, r = 0.4, P<0.0001), double soles (χ² = 42.57, r = 0.4, P<0.0001) and white line separation (χ² = 37.78, r = 0.4, P<0.0001), while sole bruising was moderately associated with chronic laminitis (χ² = 41.02, r = 0.2, P = 0.0009). Sole haemorrhages were the only lesions strongly associated (χ² = 89.45, r = 0.6, P<0.0001) associated with subclinical laminitis. It was therefore concluded that chronic laminitis was strongly associated with deformity types of claw disorders coupled with diffuse sole haemorrhages, while subclinical laminitis was strongly associated with sole haemorrhages only.

Key words: Lameness, Sole haemorrhages, Claw deformities, Subclinical laminitis, Chronic laminitis

INTRODUCTION

The physiological function of the bovine claw and the pathogenesis of non-infectious claw disorders depend on the state of pododermal microvasculature (Hirschberg and Plendl, 2005). Biologically, laminitis is a systemic disease syndrome that primarily manifests in the claws, hence rightly being referred to as “claw horn disruption” (CHD), which is a term that more appropriately describes its main effects on the claws (Hoblet and Weiss, 2001). Impairment of the corium microvasculature resulting from altered systemic pH, as well as the action of circulating endotoxins and vasoactive substances trigger processes that lead to laminitis (Nocek, 1997; Cook et al., 2004). Laminitis initially develops as insidious subclinical form with delayed manifestation of the clinical symptoms. By the time it gets to the phase of clinical manifestation, the disruptive changes within the claw may already be irreversible (Greenough, 1987; Nocek, 1997; Belge and Bakir, 2005; Nguhiu-Mwangi, 2007; Nguhiu-Mwangi et al., 2008). Apart from causing lameness directly in cattle, laminitis through claw-horn disruption (Hoblet and Weiss, 2001) is also incriminated as a significant contributor to the occurrence of other non-infectious claw disorders such as white line separation, sole ulcers, heel erosion, sole bruising, double soles and sole haemorrhages (Smilie et al., 1991; Nocek, 1997; Belge and Bakir, 2005).

Laminitis may not drastically reduce productivity in dairy cows. However, due to its effects on the quality of the horn of the claws that predispose to the occurrence of other claw disorders and the irreversible damage within the claws, it may eventually have long-term effects on the...
performance of the dairy cow that may subsequently result in the culling of the animal (Nocek, 1997; Belge and Bakir, 2005).

Chronic laminitis in cattle causes gross misshaping of the claw that can easily be mistaken as mere hoof deformity (Rhebun and Pearson, 1982; Greenough, 1987). The claw horn becomes more elongated, flattened, widened and the dorsal wall concave (Greenough, 1987; Nocek, 1997), while horizontal ridges on the dorsal surface of the claw become deeper and more prominent, giving it a rippled appearance (Weaver, 1993; Nocek, 1997). Some of the lesions associated with laminitis can be evident externally, but others are more discernible only after trimming the horn over the sole and the white line (Nocek, 1997; Belge and Bakir, 2005).

It has been stated that laminitis could be the cause or result of some of the non-infectious claw disorders affecting dairy cows (Smilie et al., 1999; Nocek, 1997; Belge and Bakir, 2005), but its association with these claw disorders has not been presented in any literature. The purpose of this paper is therefore to show how subclinical and chronic phases of laminitis are associated with other non-infectious claw disorders in dairy cows.

MATERIALS AND METHODS

The study Area

The study was carried out in the urban and peri-urban areas of Nairobi County, Kenya. Nairobi is the capital city of Kenya with an area estimated at 696 square kilometers and a population of over 3.1 million people. It lies between 01º18´S and 36º45´E. It is 1798 meters above the sea level and has an annual rainfall estimated at maximum of 765 mm and minimum of 36 mm with two distinct seasons of March to June and October to December. Nairobi and its surroundings has a high concentration of smallholder zero-grazed dairy units due to its ready market for milk and related milk products.

Selection of the Smallholder dairy Units

A purposive selection of 32 smallholder zero-grazing dairy units was done. Each had 5-20 adult dairy cows. The median number of cows to the units was 10. Purposive selection method was used because of the difficulties from farmers being hesitant to allow their animals to be used for the study; hence it was based on their willingness to participate and to allow their cows to be used. The farms were selected with the assistance of local veterinarians and veterinary paraprofessional workers with whom the farmers were acquainted.

Selection of the cows

A total of 300 dairy cows were selected for the study from the 32 smallholder zero-grazing dairy units. A cow qualified to be recruited into the study population if she had calved at least once. Among the cows that were selected, 40% had 1 or 2 parities and 60% had 3 or more parities. Lane and non-lane cows were included in study. They included the four main dairy breeds, which were Friesian, Ayrshire, Guernsey and Jersey or their cross breeds.

The cows were selected using simple systematic sampling method in which the cows that met the selection criteria in each smallholder zero-grazing unit were serially tagged with numbers 1, 2, 3-- n, where n was the serial number of the last cow that met the selection criteria in the unit. The assigning of the serial numbers to the cows was randomly done by a farm-worker who was not aware of the research objectives in order to avoid being biased. The investigator then did the systematic sampling of the serially numbered cows in each unit by selecting every alternate cow within the serial numbers. For example cow numbers 1, 3, 5, 7-- n or 2, 4, 6, 8-- n until the last cow within the smallholder zero-grazing unit. Therefore the cows within a zero-grazing unit that met selection criteria were either all picked from only even numbers or only odd numbers. For any smallholder zero-grazing unit that had a total of 5 eligible cows or less, all of them were included in the study, while systematic sampling was done only for units with more than 5 eligible cows.

Examination of the Selected Cows

Each of the selected cows was assessed for lameness using a locomotion scoring system adapted from Sprecher et al. (1997). This was followed by each cow being restrained in a crush for examination of claw disorders. In most of the smallholder zero-grazing units, the restraint facilities were poor and therefore only the hind limbs were examined because of the difficulties of accessing the forelimbs while the cows were within these facilities. Moreover, it is clearly known that a higher percentage of claw disorders in cattle affect mainly the hind limbs (Tranter et al., 1993), hence examining the hind limb would be a reliable indicator of the claw disorder status.

With the cow well restrained in a crush, each hind limb claw was evaluated on the dorsal surface for signs of laminitis and other disorders. Each limb was raised off the ground by fastening it with a rope tied to an overhead cross-bar, thoroughly washed and the sole examined for any gross lesions. About 1-2 mm thickness of the horn of the sole was trimmed-off using a quitter knife in order to expose any underlying lesions. Trimming was non-invasive because it did not reach the level of the corium, hence no pain was caused to the cows. Foot anaesthesia using 2% lignocaine hydrochloride was applied when examining any cow with painful claw lesions.

Each claw lesion was pre-coded with a specific code number and recorded in designated data entry forms using a simple numerical system. Numerical “1” was used for presence of subclinical laminitis, chronic laminitis or a claw disorder, while numerical “0” for absence of claw disorders (i.e. when the claw was normal). The “1” or “0” entries made it easier and convenient to import the data into computer analysis software. Diagnosis of laminitis was mainly based on presence of haemorrhages occurring on the weight-bearing surfaces of the claws as red or yellow discolourations. The haemorrhages would either be on one or more zones of the weight-bearing surface and would either occur alone or concurrently with other non-infectious claw lesions such as sole bruising, sole ulcer, heel erosion, white line separation and double soles (Nocek, 1997; Belge and Bakir, 2005). Normal-looking claws but with sole haemorrhages were diagnosed as having subclinical laminitis, but those with sole haemorrhages concurrently with other claw disorders/ deformities were diagnosed as having chronic laminitis.
Those with no sole haemorrhages were diagnosed as having only the manifesting disorder.

Location of each lesion on the weight-bearing surface of the claws was classified according to the 6 conventional zones as described by Greenough and Vermunt (1991) as shown in Figure 1.

The distribution of haemorrhages on the weight-bearing surfaces of the claws was categorized according to 5 conventional haemorrhage scores also described by Greenough and Vermunt (1991), which is presented in Table 1.

Data management and analysis

The data were stored in Microsoft Office Excel 2003 (Microsoft Corporation, 2003) spreadsheets. They were cleaned, verified and validated to be correct as per the entries from the record sheets. The data were imported into SAS® 2002-2003 (SAS Institute Inc. Cary, NC, USA). Descriptive statistics were computed for each claw disorder per cow and then for the entire study population. The prevalence rate of each claw disorder was calculated independent of other claw disorders. It was calculated as the number of cows (CL) affected by the specific claw disorder divided by the total number of cows (300) examined multiplied by 100 to give the percentage (%).

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\text{Prevalence} (\%) = \frac{\text{CL} \times 100}{300}
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After descriptive statistics, the test of association between laminitis and the non-infectious claw disorders and the manifesting symptoms was done in three stages. The first stage was Chi-square \((\chi^2)\) statistics to test for unconditional associations as well as strength of those associations between laminitis and the other claw disorders at the 5% significant level \((P<0.05)\) and also the correlation coefficient \((r)\) for direction of the associations. The second stage was multiple logistic regression models that factored all the claw disorders against subclinical and chronic phases of laminitis. These also revealed both the strength and direction of the associations using \(\beta\)-estimate \((\beta\)-e\) and odds ratio \((O.R.)\). The third stage was stepwise logistic regression models, which revealed the claw disorders that were invariably associated with the two phases of laminitis. The effects of confounding among the claw disorders in contributing to the associations were dealt with in the analysis through the stepwise selection of the factored claw disorders.

RESULTS

The results of this study revealed that the dairy cows in the smallholder zero-grazing units in the urban and peri-urban areas of Nairobi had a 70.3% prevalence of laminitis of which 49.3% was subclinical and 21% was chronic. There were also relatively high percentages of occurrence of claw disorders other than laminitis, such as haemorrhages (52%), sole bruising (45%), overgrown claws (30.3%), heel bruising (27%), white line separation (18%), horizontal ridges (17.8%), double (underrun) soles (17%) and flattened claw (12%). Claw infections had low percentage (4.7%). The percentages of occurrence of these claw disorders are summarized in Table 2.

Correlation coefficient \((r)\) and chi-square \((\chi^2)\) statistics indicated that subclinical laminitis has significant positive and strong association with sole haemorrhages \((r = 0.5, \chi^2 = 89.45, P<0.0001)\). The haemorrhages associated with subclinical laminitis were invariably observed in zone 4 of the weight-bearing surface of the claw and this was significant \((r = 0.3, \chi^2 = 22.83, P<0.001)\) and occasionally but significantly in zone 6 \((r = 0.1, \chi^2 = 5.87, P = 0.0154)\) (Table 3).
The degree of haemorrhages associated with subclinical laminitis was slight to moderate (scores 1 and 2) as described in Table 1. However, through multiple logistic regression and stepwise logistic regression models, it was found that the only claw disorders having significant strong positive association with subclinical laminitis were the occurrence of sole haemorrhages ($\chi^2 = 3.672$, O.R. = 39.33, $p = 0.0007$), particularly in zone 4 ($\chi^2 = 1.399$, O.R. = 4.05, $p<0.0001$) as shown in Table 3.

The claw disorders that had weak positive significant association with subclinical laminitis were sole bruising ($\chi^2 = 0.821$, O.R. = 2.27, $p = 0.0093$) and heel bruising ($\chi^2 = 0.820$, O.R. = 2.27, $p = 0.0139$) (Table 4). The rest of the claw disorders were all found to have strong positive significant association with chronic laminitis (Table 5). Unlike in subclinical laminitis, the sole haemorrhages associated with chronic laminitis were found to be severe (scores 2 and 3), which was significant ($\chi^2 = 50.16$, $P<0.0001$). These haemorrhages were widely distributed in most zones on the weight-bearing surface of the claws and had varied strength of associations with chronic laminitis as follows: zone 2 ($\chi^2 = 18.24$, $P<0.0001$), zone 3 ($\chi^2 = 23.45$, $P<0.0001$), zone 4 ($\chi^2 = 11.05$, $p = 0.0009$), zone 5 ($\chi^2 = 5.23$, $p = 0.0222$) and zone 6 ($\chi^2 = 4.48$, $p = 0.0304$) as shown in Table 6. Sole ulcer was weakly but significantly associated ($r = 0.1$, $\chi^2 = 4.16$, $p = 0.0412$) with chronic laminitis. Although multiple regression models showed that all these claw disorders were significantly associated with chronic laminitis, stepwise logistic regression models indicated the only claw disorders that were invariably significant with chronic laminitis were overgrown claws ($\chi^2 = 3.006$, O.R. = 10.93, $P<0.0001$) and deep horizontal grooves on the dorsal wall of the claws ($\chi^2 = 2.196$, O.R. = 12.30, $P<0.0001$).
The high prevalence of laminitis and non-infectious claw disorders has been attributed to presence of cow-level and farm-level risk factors prevailing within the smallholder dairy systems in the zero-grazing units (Nguhiu-Mwangi et al., 2008). The low plane concentrate feeding in these smallholder dairy systems only predisposes to the occurrences of subclinical and chronic laminitis rather than acute laminitis, which is normally associated with high level of grain feeding.

The results of this study indicate that all cows with subclinical and chronic laminitis invariably had sole haemorrhages as previously documented (Nociek, 1997; Belge and Bakir, 2005). However, the severity of haemorrhages and the zones on the weight-bearing surface of the claw in which the haemorrhages were found varies between subclinical and chronic laminitis. Strong positive association between sole haemorrhages and laminitis could be attributed to changes in pododermal microvasculature that occurs in laminitis, which results in transvascular seepage of serum that manifests as microvascular damage in the corium, leading to more severe and widespread sole haemorrhages in chronic laminitis than in subclinical laminitis (Greenough and Vermunt, 1991; Nociek, 1997).

Association of sole bruising and heel erosion with subclinical laminitis may result as a cascade of processes. In these processes, subclinical laminitis causes production of weak horn that is easily bruised or eroded at the sole and the heel. Bruised and eroded horn of the sole and heel become excessively thin, allowing easy transmission of pressure to the corium from the weight of the animal against treading ground particularly in zones 4 and 6 (Shearer and van Amstel, 2000). This causes microvascular damage within the corium, which predisposes to occurrence of subclinical laminitis, subsequently leading to production of weak horn. This cascade cycle continues.

Claw deformity disorders shown to have positive strong association with chronic laminitis can probably be attributed to the disruption of the growth of keratinized horn during laminitis, which subsequently alters the shape of claws, thus making them longer, flattened and broadened (Nociek, 1997). The dorsal angle becomes markedly reduced, while the dorsal wall becomes shaped to concave (Weaver, 1993). It is this misshaping of the claws that makes chronic laminitis be mistaken for claw deformity (Rhebus and Pearson, 1982; Greenough, 1987) with the affected cow developing abnormal gait and lameness. Presence of any of these claw shapes concurrently with characteristic rippled appearance of the dorsal surface due to prominent horizontal grooves (Weaver, 1993; Nociek, 1997), could positively indicate presence of chronic laminitis. Moreover, laminitis is incriminated as a predisposing cause for development of claw deformities (Greenough, 1987; Weaver, 1993).

The association of some claw conditions such as double (underrun) soles, white line separation, sole bruising, white line separation, sole ulcer and heel erosion could be attributed to changes in pododermal microvasculature that occurs in laminitis, which results in extravascular seepage of blood components into the tubules of the horn of the sole and the heel bulb (Greenough and Vermunt, 1991), with haemorrhages gradually becoming visible on the surface of the sole as time continues, hence sole haemorrhages are a good indicator of subclinical laminitis (Shearer and van Amstel, 2000; Nguhiu-Mwangi et al., 2007). This explains the fact that by the time laminitis advances to chronic phase, the haemorrhages are widely spread to most zones of the weight-bearing surface of the claw.
with chronic laminitis is probably related to the fact that chronic laminitis is reported to be a predisposing cause to these conditions (Nocek, 1997; Smilie et al., 1999; Belge and Bakir, 2005). Severe microvascular haemorrhages in the corium leads to accumulation of blood/serum between the corium and the horn of the sole. This eventually causes separation of the horn from the underlying corium. The new inner horn produced by the corium is separate from the old outer horn and this results in double soles with outer old horn and inner new thin horn (Nocek, 1997). The formation of double soles is a process that occurs in chronic laminitis and not in subclinical laminitis, which explains its strong association with chronic laminitis.

Similarly, the white line zone is naturally the weakest point of impact on the weight-bearing surface of the claws and easily succumbs to avulsion under pressure of the weight of the animal against the treading ground (Baggott and Russell, 1981). During laminitis, the white line zone becomes even more vulnerable to avulsions owing to softening and impairment of the horn, which is more prevalent in chronic laminitis (Nocek, 1997; Smilie et al., 1999; Belge and Bakir, 2005).

The cows found with sole ulcers in this study had very advanced laminitis. It has been reported that in chronic laminitis, the pedal bone changes its configuration and drops distally, compressing the corium towards the horn of the sole. The horn then gives way at the axial part of zone 4 and 5, hence resulting in sole ulcer that exposes the corium to protrude externally, which explains how sole ulcer is associated with chronic laminitis (Baggott and Russell, 1981; Hull, 1993; Nocek, 1997).

It is therefore concluded from the findings of this study that non-infectious claw disorders in cattle are strongly associated with laminitis. The subclinical phase of laminitis being strongly and invariably associated with sole haemorrhages particularly in zones 4 and 6 of the weight-bearing surface of the claw, while chronic laminitis being strongly associated with deformities that cause disorders of the claws. However, laminitis can be the “cause” or the “effect” of non-infectious claw disorders. The main risk factors of laminitis and non-infectious claw disorders in the dairy cows in the smallholder zero-grazing units are comprehensively described in a previous publication (Nguhiu-Mwangi et al., 2008).

Acknowledgements
The authors are grateful to the Deans Committee of the University of Nairobi for financial support to carry out this study. We also appreciate the farmers who gave permission for data collection from their smallholder zero-grazing units.

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