Ultrasound measurement of sole horn thickness in trimmed claws of dairy cows

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Objective—To determine whether ultrasound could be used to measure sole horn thickness in dairy cattle after claw trimming with an adaptation of the Dutch method.

Design—Case series.

Animals—24 adult Holstein dairy cows.

Procedure—Cows were restrained in a standing position, and claws were trimmed with an adaptation of the Dutch trimming method. B-mode ultrasonography was then performed. The transducer was placed on the sole just caudal to the apex of the toe and immediately medial and parallel to the abaxial white zone. The inner margin of the sole was identified as a thin hyperechoic line. Soles were considered to be too thin if sole horn thickness, determined by use of ultrasonography, was < 5 mm.

Results—Sole horn, underlying soft tissues, and the distal surface of the third phalanx were imaged in 151 claws. The inner margin of the sole could not be identified in 4 claws, and 37 claws could not be imaged because cows collapsed in the restraining chute. Mean ± SD sole thickness for all claws was 7.1 ± 1.3 mm. Only 1 sole was < 5 mm thick. The lateral front claws were significantly thicker than the medial hind claws.

Conclusions and Clinical Relevance—Results suggest that ultrasound imaging can be used to determine sole thickness in dairy cattle after routine claw trimming. (*J Am Vet Med Assoc* 2003;223:492–494)

A thickness of 5 to 7 mm has been described as the minimum recommended thickness for the horny sole in cattle kept in semiconfinement systems.[1] Multiple factors contribute to the development of thin soles, but inappropriate trimming techniques are thought to play an important role.[2]

Currently, the most common noninvasive method for estimating sole horn thickness in cattle involves compression of the sole horn with a finger or hoof nippers, with palpable elasticity considered an indication that the sole is too thin.[2] However, this method is subjective and cannot be used to accurately judge sole thickness, particularly in the toe area of the sole.[2] Another indirect method of estimating sole horn thickness relies on the relationship between dorsal wall length and sole thickness, with a wall length of 7.5 cm associated with sole thickness of 5 to 7 mm in 1 study[2] and a sole thickness of 4 to 14 mm (mean, 8.2 mm) in another.[3]

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Ultrasonographic methods for measuring sole horn thickness in cattle have been discussed[4,5] but were considered impractical because of problems with achieving adequate restraint; the cost, bulk, and lack of mobility of the equipment; a perception that claw horn would be too hard and too thick for adequate ultrasound penetration; and a lack of knowledge with respect to the use of various ultrasound transducers. However, with the introduction of effective leg restraint systems for cattle and the availability of high-quality portable ultrasound units, interest in ultrasound measurement of sole horn thickness in cattle has been renewed.[4,5]

The purpose of the study reported here, therefore, was to determine whether ultrasound could be used to measure sole horn thickness in dairy cattle after claw trimming with an adaptation of the Dutch method.

Materials and Methods

Twenty-four healthy adult cattle randomly selected from a commercial dairy herd of 100 Holstein cows were used in the study. Lame cows and cows with grossly abnormal claws (eg, cows that had recovered from laminitis) were excluded from the study. Stage of lactation was not considered in selection of the cows, because horn growth does not appear to be associated with stage of lactation.[6] The study was carried out during the summer, which is the time of peak horn growth.[6]

Cows used in the study were brought to a free stall area for milking twice a day and fed a mixture of grain and silage with free access to grass hay. The concrete surface between feed bunks, cubicles, and the holding area at the milking parlor had a grooved concrete surface free of aggregate. When not in free stalls for milking or in the holding area prior to milking, cows had access to cultivated pastures. For all cows, claws were trimmed approximately twice a year on the basis of gross signs of overgrowth. An adaptation of the Dutch trimming procedure[5] was used.

Each week for 4 weeks, 6 cows underwent claw trimming and ultrasound measurement of sole horn thickness. Claws of the 6 cows in each group were trimmed on the same day by 1 of the authors (SRvA) who was certified in the Dutch trimming procedure. Each cow was restrained in a standing position with a hydraulic chute. In addition to a leg restraint mechanism, the chute was equipped with a sling consisting of two 30-cm-wide, hydraulically operated body support bands to prevent cows from falling while in the chute. In all cows, the right hind claws were trimmed first, followed by the left hind, right front, and left front claws. This order was used to facilitate recording of data and movement of equipment. A 4-step procedure was used to trim the claws.[5] For each foot, the medial claw was trimmed first. The length of the dorsal wall was reduced to 7.5 cm, and the weight-bearing surface, including the wall and sole, was pared flat until it was judged to be 5 to 7 mm thick at the toe. With the previously trimmed medial claw as a guide, the lateral claw was trimmed to the same length as the medial claw.

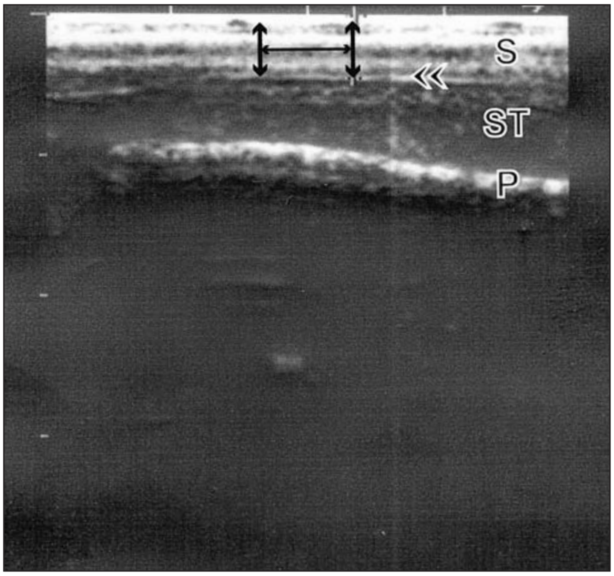

Figure 1—Longitudinal B-mode ultrasonogram of the weight-bearing surface of the claw of a cow. The horny sole (S), soft tissue (ie, corium and connective tissue; ST), and ventral surface of the third phalanx (P) can be seen. The inner margin of the sole can be seen as a thin hyperechoic line (double arrowheads). Thickness of the sole horn was measured from the bearing surface to the inner margin of the sole (arrows). Marks on the left represent centimeters.

Finally, the weight-bearing surface of the lateral claw was pared to the same level as the surface of the medial claw. After completion of the trimming procedure, the weight-bearing surfaces of both claws were observed for proper balance and corrected if necessary. After trimming, all claws had a clean, even sole surface.

For ultrasound measurement of sole horn thickness, the sole surface was sprayed with alcohol. B-mode ultrasonography was performed[7] with a 7.5-MHz linear transducer.[a] The transducer's contact surface was 5 × 0.08 cm; measurement accuracy reportedly was 0.1 mm. After application of transmission gel to the contact surface of the transducer, it was placed on the sole just caudal to the apex of the toe and immediately medial and parallel to the abaxial white zone. Static B-mode images were obtained as soon as the inner margin of the sole could be seen as a thin hyperechoic line. Slight rotation of the probe along its longitudinal axis or movement axially but parallel with the white line was sometimes necessary to clearly image the inner margin of the sole. Sole horn thickness was measured in the center of the image, which coincided with the start of a curvature in the ventral surface of the third phalanx.

Data analysis—Descriptive statistics (mean, SD, and range) were calculated for the medial front, medial hind, lateral front, and lateral hind claws, and 1-way ANOVA, followed by the Tukey highest significant difference post hoc test, was used to compare values among groups. The Levene test was used to ensure that the assumption of homogeneity of the variances was met. Data were then grouped, and values for front claws were compared with values for hind claws, and values for medial claws were compared with values for lateral claws. All analyses were performed with commercial software.[b] Values of $P \leq 0.05$ were considered significant.

Reported values for sole thickness at the apex of the toe in healthy cattle ranged from 5 to 7 mm in 1 study,[1] from 5 to 10 mm in a second study,[8] and from 4 to 14 mm in a third study.[3] In the latter study, only 1 of 90 claws had a sole thickness < 5 mm. On the basis of results of these studies, we considered the sole to be too thin if sole horn thickness, determined by use of ultrasonography, was < 5 mm. Proportions of medial front, medial hind, lateral front, and lateral hind claws with too thin soles were calculated.

Table 1—Sole thickness measured ultrasonographically in 24 Holstein dairy cows trimmed by use of the Dutch method

Claw location	No. of claws	Sole thickness (mm)
Medial front claws	29	7.2 ± 1.2 (5.0–9.3)[a,b]
Medial hind claws	46	6.6 ± 1.2 (4.4–9.6)[a]
Lateral front claws	30	7.7 ± 1.0 (5.7–9.6)[b]
Lateral hind claws	46	7.2 ± 1.5 (5.0–10.7)[a,b]
All front claws	59	7.5 ± 1.1 (5.0–9.6)*
All hind claws	92	6.9 ± 1.3 (4.4–10.7)
All medial claws	75	6.8 ± 1.2 (4.4–9.6)†
All lateral claws	76	7.4 ± 1.3 (5.0–10.7)
All claws	151	7.1 ± 1.3 (4.4–10.7)

Data are given as mean ± SD (range).
[a,b]Values with different letter superscripts are significantly ($P < 0.05$) different. *Significantly ($P < 0.05$) different from value for hind claws. †Significantly ($P < 0.05$) different from value for lateral claws.

Results

Ultrasound images were obtained from 155 of the 192 (81%) claws, and the sole horn, underlying soft tissues, and third phalanx could be imaged in 151 of the 155 (97%) claws from which images were obtained. Ultrasound images were not obtained from the remaining 37 (19%) claws because 8 cows could not be positioned appropriately to complete the procedure owing to excessive weight being placed on the supporting body sling.

Sole horn had a heterogeneous, hypoechoic appearance **(Fig 1)**. The inner margin of the sole was identified as a thin hyperechoic line.

Mean sole thickness was significantly ($P = 0.01$) greater in the front claws than in the hind claws **(Table 1)** and in the lateral claws than in the medial claws ($P = 0.008$). Sole thickness of the medial hind claws was significantly ($P = 0.001$) less than sole thickness of the lateral front claws. Only 1 of the 151 claws was found to have a sole < 5 mm thick; this was a medial hind claw and was 1 of 46 (2%) medial hind claws from which measurements were obtained.

Discussion

In the present study, ultrasonography was successfully used to image the sole horn, underlying soft tissue, and third phalanx in 151 of 192 (81%) claws in 24 dairy cattle. In some claws in the present study, the inner margin of the sole was not a continuous line, as has been reported previously.[4] However, this was not an obstacle in obtaining measurements of sole horn thickness. Although we did not compare ultrasonographic measurements of sole horn thickness with anatomic measurements, a previous study[4] found that ultrasonographic measurements of sole horn thickness correlated well with anatomic measurements in cadaver claws and a small number of live cows.

In this study, ultrasonographic imaging was performed under optimal conditions. The sole surface was

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clean and flat, preventing entrapment of air beneath loose horn and ensuring adequate moisture content of the sole horn.[4] Ultrasonographic imaging may be difficult in cattle with dry, hard sole horn, potentially limiting this technique to use in cattle maintained in areas with a high environmental moisture content, such as dairies. In a previous study,[9] however, water was rapidly absorbed by immersed claw horn samples with maximum water uptake within 48 hours. This finding may be particularly useful for individuals animals, such as beef bulls on dry pasture, where sole thickness evaluation can be useful in the application of corrective trimming procedures, such as for screw claw.[10]

We were unable to obtain ultrasound images of 37 of the 192 (19%) claws in the present study because of excessive pressure on the body sling. We used a chute that restrained the cows in a standing position, and several cows collapsed, probably because of the duration of the procedure. For this reason, it may be better to use a tilt table when both trimming and ultrasound are to be done. However, it has been shown that better balance of the weight-bearing surfaces can be achieved with trimming chutes that restrain cattle in a standing position.[5]

We were unable to measure sole horn thickness in only 4 of the 151 (2.6%) claws from which ultrasound images were obtained in the present study. This differs from a previous report[4] in which no ultrasound images could be obtained for 6 of 20 (30%) front claws of cows kept in tie stalls. The hind feet of cows maintained in tie stalls have greater exposure to wet conditions, compared with the front feet, which usually remain dry and hard. In our study, cows were housed in a semiconfinement system (pasture and free-stalls), allowing equal exposure of all claws to environmental moisture.

Mean sole horn thickness after trimming for all claws in the present study was 7.1 mm, which is within the range of values reported for normal sole horn thickness (5 to 7 mm in 1 study[1] and 5 to 10 mm in a second study[6]). In a previous study[3] of 86 cadaver claws trimmed with the same trimming method, mean ± SD sole thickness, measured anatomically, was 8.2 ± 2.5 mm (range, 4 to 15 mm). The same study found that untrimmed cadaver feet with a dorsal wall length of 7.5 cm had a mean sole thickness of 8.2 mm (range, 4 to 14 mm).

The significant differences in sole thickness between front and hind claws and between medial and lateral claws in the present study were attributed to a significant difference in thickness between medial hind and lateral front claws, with lateral front claws being significantly thicker than medial hind claws. Because the medial hind and lateral front claws bear less weight than the other claws,[1] this difference in balance between front and back feet probably does not play any important role in the overall biomechanics of weight bearing. The difference in sole thickness between the medial and lateral hind claws, although not statistically significant, should be noticed. The biomechanics of normal weight bearing result in unequal weight bearing between the claws of the hind limbs,[1] as a cow's frame displaces more weight onto the lateral hind claws. This imbalance results in overgrowth of the lateral hind claws, predisposing them to claw horn lesions such as sole ulcers.[1] During trimming, balance should be restored between the medial and lateral hind claws.[2]

The protective function of the sole of any individual claw may be affected by small differences in sole thickness.[1] The frequency of thin soles (< 5 mm) was only 0.7% (1/151) in the present study, and the only thin sole involved a medial hind claw. In a comparison of 2 trimming techniques, the Dutch method of trimming resulted in significantly fewer thin soles (2%) than did a technique in which the white line was used as an estimate of sole thickness (15%).[3] Application of an adaptation of the Dutch trimming technique provided sufficient sole horn thickness for cattle in a commercial semiconfinement system.[1] However, it seems that different criteria for acceptable sole thickness may be necessary for diary cows in different housing systems, particularly cows in large total confinement dairies with high levels of moisture and concrete walking surfaces. Results of the present study suggest that ultrasound imaging can be used to determine sole thickness in live cattle after routine trimming procedures and, thus, may serve as a useful tool to create awareness and reduce the future occurrence of overtrimming. It may also serve as a useful tool for evaluating various trimming techniques currently practiced and studying the effects of various housing and nutritional management systems on sole horn growth and wear.

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[a]Aloka 500, Aloka, Tokyo, Japan.
[b]SPSS version 10.0, SPSS Inc, Chicago, Ill.

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