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## **Ultrasonic Assessment of Teat Tissue Congestion**

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**Abstract.** *Four different milking treatments were applied to six cows at the pm milking. Ultrasonic imaging was used to measure teat wall thickness before milking, immediately after milking and 1, 2, and 4 hours after milking. Ultrasound measurement quantified changes in teat wall thickness during milking as well as the recovery rate of teat tissues after milking. The combination of milking vacuum level and b-phase duration had an effect on the degree of teat wall thickness after milking. An increase of about 25% was produced at a milking vacuum level of 44 kPa and B phase of 322 ms and an increase of about 35% at milking vacuum levels of 47 and 50 kPa and B phase of 500 ms or more. It appeared as if liner compression had an influence on the recovery rate of teat tissues. However, further experimentation is required to further investigate this effect.*

**Keywords.** *Ultrasound, Teat Congestion, Milking Machines*

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## Introduction

The trend on US dairies over the past 10 years has been to increase the speed of milking. A higher peak milk flow rate can be obtained by an increase in teat end vacuum level (Gleeson and O'Callaghan, 1999) which may also increase teat congestion or edema (Gleeson and O'Callaghan, 1999). Congestion is the buildup of blood and other fluids in teat tissue. Accumulation of fluid in the teat tissue is the direct result of the vacuum applied during the milking phase, which limits the ability of natural circulation mechanisms to remove blood via the vascular system and interstitial fluids from the teat via the lymphatic system. During the massage phase a compressive load facilitates venous flow and removal of interstitial fluid (IDF 1987). Congestion can be relieved by means of adequate magnitude and duration of liner compression around the teat end (Williams and Mein, 1982).

The importance of teat canals' natural defense mechanism against udder pathogens and in preventing udder infections has been demonstrated by Seykora & McDaniel, (1985); and Hamann & Østerås, (1994). When teats are congested after milking, the defense mechanism of the teat canal to resist invasion and removal of mastitis causing organisms from the canal is compromised (Mein et al., 1987; Hamann, 1989; 1990; Zecconi et al., 1992; Gleeson et al., 2004; Vinitchaikul and Suriyasathaporn, 2007). This is probably because the teat canal closes more slowly after milking when teats are congested (Neijenhuis et al., 2001; Mein and Reinemann, 2006). When teat end thickness changed by > 5%, higher infection rates of quarters and more ducts colonized in teats were observed compared with teats showing less congestion (Zecconi et al., 1992).

Several studies have been carried out to assess the acute response of teat tissue to machine milking (McDonald, 1975, Schultze & Bright 1983, O'Shea et al., 1987; Persson, 1991; Bramley et al., 1992). High vacuum levels in milking machines induce edema and results in increased teat wall thickness (Hamann et al., 1993). Increasing pulsator ratio, which increases the B and decreases the D phases of pulsation, was demonstrated to induce progressive increases in teat thickness. Increasing pulsation rate, which decreases the time of both B and D phases of pulsation, has also been shown to increase teat end thickness after milking (Hamann et al., 1993). The interaction between liner design, vacuum conditions at the teat-end and pulsation characteristics can influence the level of teat tissue reaction. Therefore, it is necessary to evaluate the effects of a combination of machine settings on the physiological status of teat tissue (Gleeson et al., 2004). Full tissue recovery after machine milking may take many hours (Gleeson et al., 2002).

There is also evidence that increased teat congestion leads to greater stripping yields, thus lowering milk yields (Hamann et al., 1993; Mein and Reinemann, 2007). Reduced peak milk flow rate results from congestion of tissue around the teat canal, reducing its effective diameter (Williams et al., 1981; Williams and Mein, 1982).

Teat end thickness is an indicator of teat tissue congestion and can be measured using skin-fold calipers or cutimeters (Hamann et al., 1988; Hamann et al., 1993). Radiographic techniques can also be used (McDonald, 1975). Ultrasound examination is another useful tool to monitor changes machine milking causes in teat tissue (Neijenhuis et al., 1999) and has been applied by Worstorff et al., (1986), Spencer et al., (1996), Gleason et al., (2002) and Vinitchaikul and Suriyasathaporn, (2007).

The objective of this study was to quantify the effects of milking vacuum, B=phase duration and liner compression on changes in teat wall thickness during milking and the recovery rate of teat tissues after milking.

## Materials and Methods

The experiment was carried out in the Dairy Cattle Center on the University of Wisconsin-Madison. Six Holstein cows with the following characteristics were selected for the study: no injured teats, no non-lactating quarters, and free of clinical mastitis. Other selection criteria to block cows were parity, days in milking (DIM), daily milk production, duration of milking, and teat size and shape. Of the 6 cows enrolled in the study, 3 were 2nd and 3 were 3rd parity and ranged from 31 to 127 DIM. The average milk production was 43 kg and ranged from 39 to 55 kg. Teat length was on average 5.2 cm for front teats (ranging from 4.5 to 6.0 cm) and 4.5 for rear teats (ranging from 4.0 cm to 5.3 cm). Teat width was on average 2.5 cm for front teats (ranging from 2.0 to 3.0 cm) and 2.4 for rear teats (ranging from 2.0 cm to 3.0 cm). Cow's teat-end shape was selected to be round (60% of teats) or flat (40% of teats). The cows had an average duration of milking of 6.1 minutes (ranging from 5.1 to 6.8 minutes). The cows were milked twice per day at 12 hour intervals. Automatic cluster removal was performed at a flow threshold of 0.5 kg/min (1.2 lb/min) with a 5 second delay.

Four different treatments were applied to each cow as follows

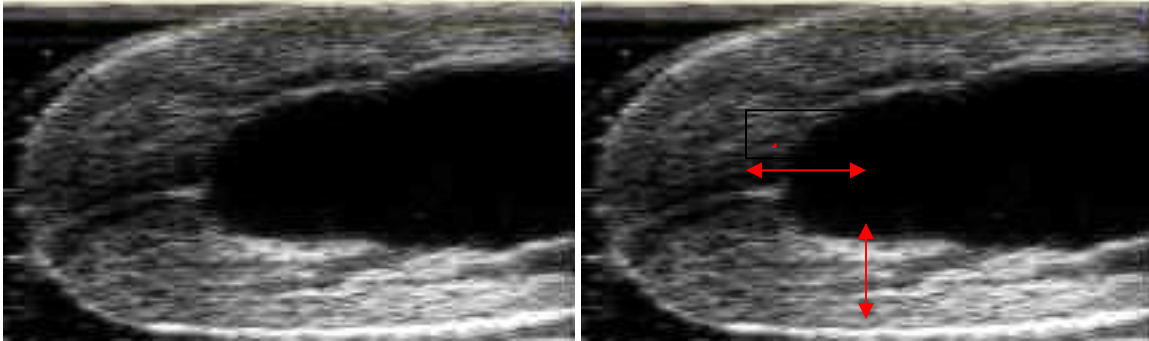
Treatment	Milking Vacuum level (kPa)	B-Phase Duration (ms)	Liner Compression (LC) (kPa)
A	44.2	322	9
B	47.5	500	11
C	50.8	678	9
D	50.8	678	13

Where liner compression (LC) was measured using the Start-of-Milk-Flow Method as described by Mein et al. (2003a). Treatments were applied once per day at the pm milking with at least one day between each treatment. The pre-milking routine was to pre-dip teats with a 0.5% disinfectant iodine solution, dry the teat with single use paper towel, strip the first three stream of milk and attach the milking unit. After unit detachment the teats were post dipped with a 0.5% iodine solution. Milk yield, peak flow, average milk flow and main milking duration were recorded with a Lactocorder ®.

The ultrasound scans were performed with a portable ultrasound scanning system (SonoAce PICO, Medison America) using a 7.5 MHz linear probe. The technique was a modified version of the one described by Gleeson et al. (2004). A plastic transparent teatcup shell was lined with a rubber condom. A vertical slot was cut in the barrel to allow the head of the probe to contact the condom's surface. The condom was filled with warm water mixed with iodine solution and placed around the cow's teat. This device reduced the pressure applied by the US probe to the teat, reducing deformation of the teat during imaging. A film of gel was placed on the probe head and the probe was held to the teat by means of the condom surface. A vertical cross-section of each teat was scanned before pre-milking preparation (t-), immediately after milking (t-0), one hour after milking (t+1), two hours after milking (t+2) and four hours after milking (t+4). The operating time to scan each teat ranged from 30 seconds to one minute.

Measurements of teat-wall thickness were taken from each scan 1 cm above the top of the teat canal (Fig. 1).

**Figure 1. Example ultrasound scans. Teat wall thickness was measured 1 cm above the top of the teat canal.**



Teat wall thickness was expressed as percentage change compared to the pre-milking values. Repeatability of teat scanning over the experimental period was assessed by comparing the teat wall thickness measured before milking. An analysis of variance was performed to compare the initial teat wall thickness measurements on the 4 different test days. A mixed model with repeated measure was performed to assess the effect of treatment and time after milking on teat wall thickness (SAS version 8.2, SAS Institute, 1999).

## Results

Of the possible 384 data points (6 cows x 4 quarters x 4 treatments x 4 times), 375 measures were used for the statistical analysis. Two cows had unusable measurements from treatment C two hours and four hours after milking. One cow had an unusable measurement for treatment A one hour after milking.

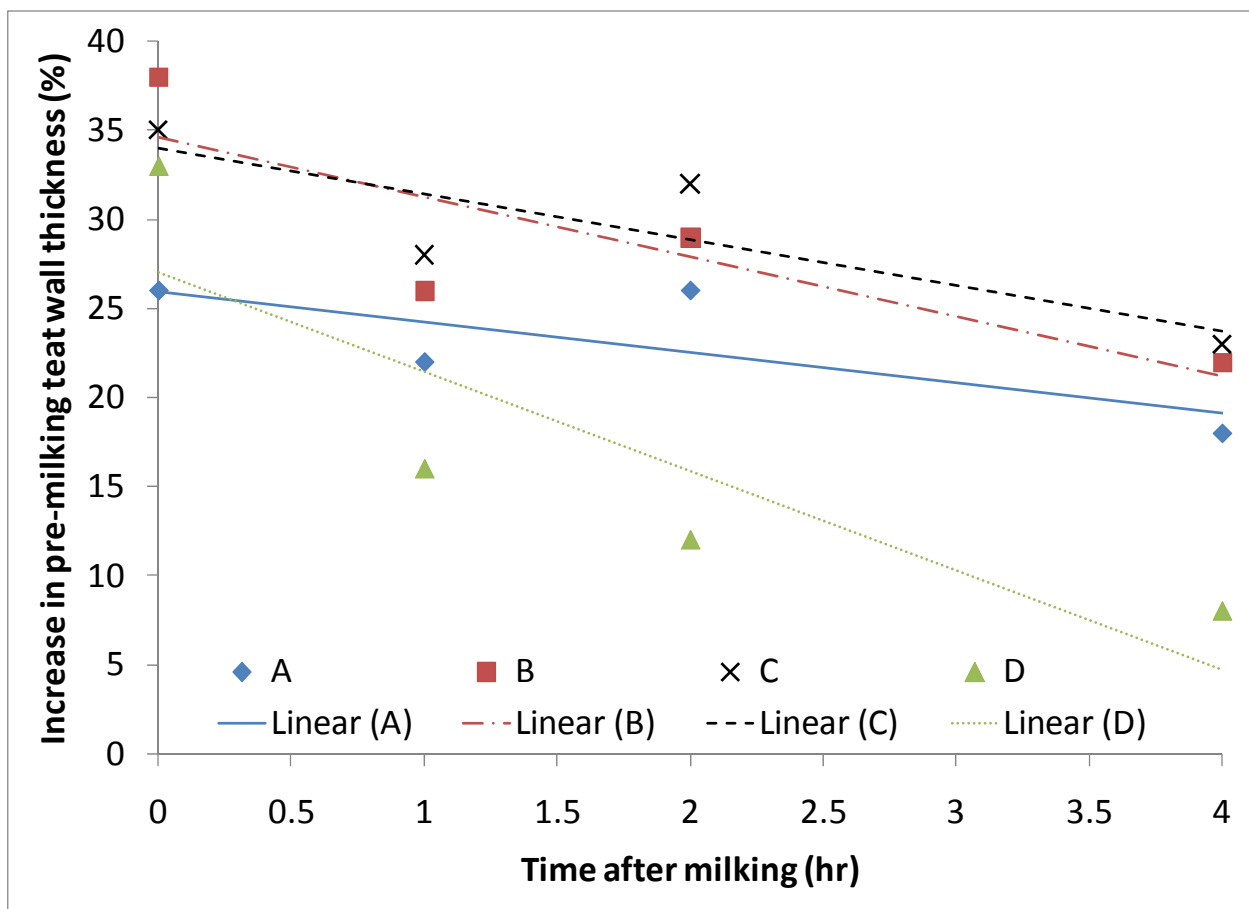
The average teat wall thickness for teats in right front (RF), left front (LF), right rear (RR) and left rear (LR) position in the four different teat days are presented in Table 1. No significant difference ( $p > 0.05$ ) was found in the mean teat wall thickness at time zero (before milking), measured by ultrasound of the quarter in the same position in all the cow enrolled in the experiment through the four days of testing. The detectable difference (80% power) was 0.053 cm for the right front teat, 0.048 mm for the left front teat, 0.047 for the right rear teat and 0.056 the left rear teat.

The results of the percentage change in teat wall thickness by treatment and time are presented in Figure 2. The results of the mixed model analysis indicated that the effect of treatment and time were both highly significant ( $p = 0.008$  and  $p = 0.0025$  respectively), though the interaction term was not.

**Table 1. Mean teat wall thickness (cm) by teat by test day.**

Day test	Teat wall thickness			
	RF	LF	RR	LR
1	0.5966	0.5917	0.6366	0.5667
2	0.5700	0.5800	0.5916	0.5217
3	0.6015	0.6017	0.6116	0.5967
4	0.5633	0.5500	0.6300	0.5550
p value	0.7515	0.7259	0.7779	0.6164

**Figure 2. Percentage change in teat wall thickness after milking.**



## Conclusion

This first experiment indicates that ultrasound measurement is a useful method for quantifying changes in teat wall thickness during milking as well as the recovery rate of teat tissues after milking. The combination of milking vacuum level and b-phase duration had an effect on the degree of teat wall thickness after milking with an increase of about 25% at a milking vacuum level of 44 kPa and B phase of 322 ms and an increase of about 35% at milking vacuum levels

of 47 and 50 kPa and B=phase of 500 ms or more. The teat wall may have been approaching its maximum possible thickness increase under the more aggressive milking conditions. The interaction between treatment and time was not significant, most likely because the slopes of the recovery lines for treatments A, B, and D were quite similar. The steeper recovery slope for treatment D many indicate that liner compression had an influence on the recovery rate of teat tissues. After the most aggressive milking condition (50.8 kPa and 678 ms B-phase) the lower liner compression had recovered from a 35 % increase to about 25 % of their initial thickness. These same vacuum and b-phase conditions but with higher liner compression resulted in a similar increase in teat wall thickness immediately after milking (about 35%) while 4 hours after milking teats had returned to about 7% of their initial thickness. We intend to perform further studies to obtain better estimates of the individual effects of milking vacuum, b-phase duration and liner compression on teat congestion and tissue recovery rates.

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