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The association between teat shape and clinical mastitis

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ABSTRACT

Conformational teat traits such as teat-barrel shape and teat-end shape have long been recognized as possible risk factors for elevated somatic cell count and clinical mastitis in dairy cows. However, the association between udder health and these teat traits is still under debate. Our objective with this ambidirectional cohort study was to investigate the relationship between teat shape and the occurrence of clinical mastitis in dairy cows. For this purpose, we analyzed quarter-level data from 14,948 quarters of 3,913 Holstein cows from 1 commercial dairy farm in New York State. Cows were milked 3 times daily, housed in freestall pens, bedded with manure solids, and fed a TMR. Teat shape was assessed visually and classified based on teat-barrel and teat-end shape into 1 of 4 categories as follows: (1) triangular barrel and pointed teat end (TP), (2) square barrel and round teat end (SR), (3) square barrel, round teat end, and flat in the area of the teat orifice (SRF), and (4) square barrel and flat teat end (SF). Data on the occurrence of clinical mastitis were obtained from the dairy management software. To test the hypothesis that teat shape was associated with the occurrence of the first clinical mastitis event during the first 305 d in milk, a multivariable semiparametric proportional hazards model was built. Our results showed that teat shape was associated with the occurrence of clinical mastitis. Compared with SR, the clinical mastitis hazards (95% CI) were TP, 1.66 (1.25–2.19); SF, 1.58 (1.14–2.18); and SRF, 1.05 (0.88–1.26). We conclude that teat shape could be useful to identify cows at increased risk of clinical mastitis. This could allow farmers to employ targeted monitoring of these high-risk animals and develop management strategies that mitigate their risk.
Key words: bovine, mastitis, teat shape, udder health

INTRODUCTION

Mastitis, which is the inflammation of the mammary gland, is one of the most common diseases in dairy cattle (Ruegg, 2012). It causes economic losses for the dairy producer in multiple ways. These can be attributed to direct costs for diagnostics, therapeutics, veterinary services, labor, loss of salable milk, and increased mortality (Seegers et al., 2003; Bar et al., 2008; Rollin et al., 2015), as well as indirect costs due to reduced milk production (Gröhn et al., 2004; Schukken et al., 2009), premature culling (Beaudeau et al., 1995; Gröhn et al., 1998; Cha et al., 2013), and reduced reproductive performance (Chebel et al., 2004; Santos et al., 2004; Ahmadzadeh et al., 2009). Furthermore, mastitis accounts for the majority of antimicrobial treatments in the US dairy industry (Pol and Ruegg, 2007) and is considered to diminish animal well-being (Fitzpatrick et al., 2013; Fogsgaard et al., 2015), both of which have become an increasing public concern.

The most common cause of mastitis is intramammary infection with bacterial pathogens entering the mammary gland through the teat canal (Quinn, 2011). Therefore, the teat canal is considered the first barrier against pathogens that cause mastitis (O'Shea, 1987). In that light, the anatomical structure of the teat canal, as well as of its adjacent tissues, has been subject of multiple investigations seeking for teat traits that are associated with increased resistance to intramammary infection. Grindal et al. (1991) investigated the influence of milk flow rate and teat canal length on new intramammary infection in 18 dairy cows. They concluded that an inverse relationship might exist between teat canal length and the risk of a new intramammary infection, although this relationship was considered of secondary importance compared with peak milk flow rate (Grindal et al., 1991). Researchers from Belgium used 72 Holstein-Friesian cows from 6 Flemish dairy herds to study the association between teat dimensions and quarter-level SCC and found that teats with a wider teat barrel had a higher SCC (Zwertvaegher et al., 2013). In a Wisconsin study, the investigators examined the association of anatomi-

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cal characteristics of teats with quarter-level SCC using data from 3,713 quarters of 959 dairy cows (Guarín et al., 2017). They found that, for front quarters, a greater teat apex diameter was associated with increased SCC (Guarín et al., 2017).

In addition to the metrical teat traits that necessitate measurements of different anatomical structures, conformational traits such as teat shape or teat-end shape have been the focus of recent research on udder health parameters (Hodgson and Murdock, 1980; Seykora and McDaniel, 1985; Chrystal et al., 1999; Chrystal et al., 2001; Miles et al., 2019). However, there is little consensus in the literature, and controversial results have been reported. Chrystal et al. (1999, 2001) found no relationship between SCC and teat-end shape. Other investigators found no association between teat shape and SCC, but documented a relationship between teat-end shape and SCC; for example, flat teat ends were associated with higher SCC (Seykora and McDaniel, 1985). Miles et al. (2019) reported increased odds of an elevated SCC (≥200,000 cells/mL) event and clinical mastitis diagnosis for teats with flat teat ends. Similarly, Hodgson and Murdock (1980) concluded that quarters with flat and cone-shaped teats had a higher average SCC than those with other teat shapes. The objective of this study was to investigate the association between teat shape and the occurrence of clinical mastitis. We hypothesized that teat shape would be associated with clinical mastitis occurrence of individual quarters over the course of the first 305 DIM.

MATERIALS AND METHODS

This study was conducted with the oversight of the Cornell University Institutional Animal Care and Use Committee (protocol no. 2013-0064) at a commercial dairy farm in Central New York. The study herd was selected based on the owners' willingness to participate in the study and consisted of approximately 4,100 lactating Holstein cows, which were fed a TMR formulated in accordance with the requirements set out by the National Research Council (NRC, 2001). The animals were housed in freestall pens bedded with manure solids. The farm collected herd data with Dairy Comp 305 (Valley Agricultural Software, Tulare, CA) and was enrolled in monthly DHIA services, which included individual-level SCC data. The 305-d mature equivalent milk yield was 14,294 kg, the mean test day SCC was 227,000 cells/mL, the monthly clinical mastitis rate was 11% (including repeat cases, gap of 10 d within the same quarter; that is, 2 affected quarters within 10 d were regarded as 2 cases), and the 21-d pregnancy rate was 29.0%.

Milking System and Routine

Cows were milked 3 times daily at 8-h intervals in a 100-stall parallel rotary parlor (RP3100HD, DeLaval International AB, Tumba, Sweden). The vacuum pump (22.4 kW; 30 horse power) was set to a level of 46.1 kPa (13.6 in. of Hg). The pulsators (EP100, DeLaval International AB) operated at a pulsation rate of 60 cycles/min, a ratio of 65:35, and used a side-to-side alternating pulsation. The pulsation phases under load, assessed with a digital vacuum recorder (VPR200, DeLaval International AB), were 177 ms for the a-phase, 470 ms for the b-phase, 115 ms for the c-phase, and 238 ms for the d-phase. The farm used the MC70 milking cluster (DeLaval International AB) and a round barrel milking liner (LS-01 NC, DeLaval International AB) for its milking units. During the peak milk flow period, the average claw vacuum was 38.9 kPa (11.5 in. of Hg). This was calculated from 10 milking observations using a digital vacuum recorder (VPR200, DeLaval International AB) according to the guidelines outlined by the National Mastitis Council (NMC, 2012). Once milk flow fell below a threshold of 1.3 kg/min, the clusters were automatically removed. There was a set 2-s delay and a vacuum decay time of 1.5 s. The milking parlor was equipped with electronic on-farm milk flow meters (MM27BC, DeLaval International AB). The milk sweep was inactivated. Milking system settings and milking characteristics were monitored with a dairy farm management software program (DelPro, DeLaval International AB).

The rotational speed of the milking parlor was 4.9 s/stall (530 s/complete rotation), resulting in a theoretical throughput of 679 cows/h. Farm workers operated the parlor in two 12-h work shifts, with 4 milking technicians performing the following tasks at the 4 following stations: (1) at stall 3, clean all teats of lactating quarters with an automated teat brush (MTech Dairy Solutions, Cashton, WI) that was rinsed with a custom-made chorine solution at a concentration of 2,500 mg/kg; (2) at stall 5, manually forestrip 2 teats (3 strips per teat) and apply an iodine-based teat disinfectant to all teats with a teat dip cup; (3) at stall 16, wipe all teats with an individual clean cloth towel; and (4) at stall 22 for early- and mid-lactation cows and at stall 27 for late-lactation cows, attach and align the milking unit. With this setup, the dip contact time was 54 s, the total tactile stimulation duration (sum of brush contact time and forestripping duration) was approximately 6 s, and the preparation lag time, that is, time from the first tactile stimulation (cleaning with automated teat brush) until milking unit attachment, was approximately 93 s (early- and mid-lactation cows) or 118 s (late-lactation animals). The forced retraction of the milking unit was initiated at stall

90, resulting in a maximum milking unit-on time of 333 s (early- and mid-lactation animals) or 309 s (late-lactation cows). Iodine-based postmilking teat dips were applied at positions 92 through 93 and 94 through 95 by 2 teat spray robots (TSR, DeLaval International AB) before cows exited the milking parlor at stalls 96 through 100.

The detection of clinical mastitis was performed by the milking technicians. A clinical mastitis case was considered present if milk from a quarter was abnormal, with or without signs of local inflammation of the affected quarter (Erskine et al., 2003). To ensure consistent monitoring of quarters for the presence of clinical mastitis, the teats were forestripped in an alternating fashion, such that the side (i.e., left side or right side) was changed for each milking session. For subsequent analyses, the first clinical mastitis case at the quarter level was considered. All milking technicians were trained monthly and all milking routine tasks were reviewed. New farm employees received an on-boarding training to ensure compliance with all tasks of the milking routine. The farm management employed pathogen-based mastitis treatment. As such, an aseptic milk sample was taken from mastitic quarters at the time of detection and submitted to the Animal Health Diagnostic Center (Cornell University) for bacteriological testing.

Data Acquisition

Teat Shape. Teats were visually assessed for shape and the presence of a blind (nonlactating) quarter by one trained investigator (MW) on December 12, 2021. The observations were made during a single milking session between stations 3 and 4; that is, after the teats were dried and cleaned but before the units were attached. Teat shapes were classified by both teat-barrel shape and teat-end shape, following the principle outlined by Seykora and McDaniel (1985). This rendered 4 categories as follows: (1) triangular barrel and pointed teat end (**TP**), (2) square barrel and round teat end (**SR**), (3) square barrel, round teat end, and flat around the teat orifice (**SRF**), and (4) square barrel and flat teat end (**SF**; Figure 1). The teat shape of nonlactating quarters was not assessed.

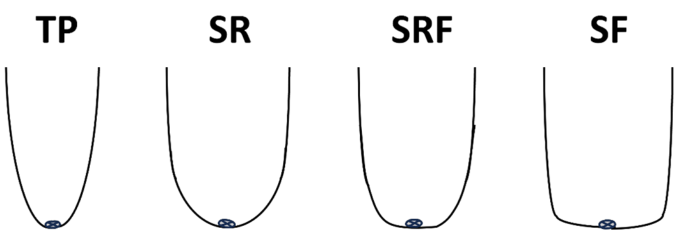

Figure 1. Classification system of teat shapes. TP = triangular barrel and pointed teat end; SR = square barrel and round teat end; SRF = square barrel, round teat end, flat in the area of the teat orifice; and SF = square barrel and flat teat end.

Cow Characteristics and Health Events. Cow characteristics and events, that is, parity, fresh date, dry date, date culled (i.e., sold or died), and occurrence of mastitis, were obtained from the dairy management software program (DairyComp 305, Valley Agricultural Software, Tulare, CA).

Study Design. This ambidirectional cohort study lasted from August 17, 2019 to October 22, 2022. All lactating cows that had teat shape information available were included in the study population. To give each cow equal weight to the analysis, we included only the current lactation (during which the teat shape assessment occurred) of each cow in the analysis.

Statistical Analyses

We used Microsoft Excel (Microsoft Corp., Redmond, WA) and JMP Pro (version 17, SAS Institute Inc., Cary, NC) for data maintenance. Before analyses, data were monitored for missing and erroneous values. Descriptive statistics were generated with JMP. All subsequent statistical analyses were performed with SAS (version 9.4, SAS Institute Inc.). We used GraphPad Prism (version 10.2.1, GraphPad Software, San Diego, CA) to generate Kaplan-Meier survival curves for the time to the first quarter-level clinical mastitis occurrence. To test our hypothesis that teat shape was associated with the occurrence of the first quarter-level clinical mastitis during the first 305 DIM, we built a semiparametric proportional hazards model according to Cox (1972) with PROC PHREG. Quarter was the unit of analysis. To account for the clustering of quarters within cow, we included a random effect of cow. We used Efron's approximation to handle ties. Days to occurrence of mastitis was the dependent variable. Teat shape was the independent variable of interest and was forced into the model. Parity (first, second, and third or greater), quarter position (left hind, left front, right front, and right hind), and presence of a nonlactating quarter (present vs. absent) were included as covariates. Finally, the 2-way interaction between quarter position and teat shape was tested. Quarters from cows that had no mastitis event by the end of the follow-up period (i.e., 305 DIM) and quarters from animals that were dried or left the herd before 305 DIM before a mastitis event were right-censored.

RESULTS

Study Population

Teat shape data were available from 3,917 cows. Data from 4 cows were excluded due to erroneous records. Table 1 depicts the frequency distribution of teat shape and nonlactating quarters stratified by quarter posi-

Table 1. Frequency distribution of teat shape stratified by quarter position from 3,913 dairy cows

Teat characteristic	Quarter position[1]				Overall
	Left front	Left hind	Right front	Right hind	
Triangular barrel and pointed teat end	318 (8.1)	126 (3.2)	312 (8.0)	127 (3.2)	883 (5.6)
Square barrel and round teat end	2,370 (60.6)	2,233 (57.1)	2,371 (60.6)	2,250 (57.5)	9,224 (59.0)
Square barrel, round teat end, and flat at the teat orifice	945 (24.2)	1,105 (28.2)	957 (24.5)	1,106 (28.3)	4,113 (26.3)
Square barrel and flat teat end	67 (1.7)	301 (7.7)	68 (1.7)	292 (7.5)	728 (4.7)
Nonlactating quarters	213 (5.4)	148 (3.8)	205 (5.2)	138 (3.5)	704 (4.5)

[1]Values given as number of teats and percentage of teats, n (%).

tion for all 3,913 cows included in the final analyses. Cows were in their first (1,233; 31.5%), second (1,139; 29.1%), and third or greater (1,541; 39.4%) lactation. The mean (±SD) projected 305-d mature equivalent milk yield was 13,302 ± 3,482 kg. A total of 704 (4.5%) nonlactating quarters were excluded, resulting in 14,948 quarter observations that were available for the final analyses. We documented 1,038/14,948 (6.9%) first quarter-level mastitis cases within the first 305 DIM. The mean (± SD) DIM at which the clinical mastitis cases occurred was 111 ± 76 d. The frequency distribution of clinical mastitis among quarters with different teat shapes was TP, 97/883 (11.0%); SR, 611/9,224 (6.6%); SRF, 268/4,113 (6.5%); and SF, 62/728 (8.5%). The distribution of mastitis occurrence among different quarter positions was left front, 257/3,700 (7.0%); left hind, 267/3,765 (7.1%); right front, 256/3,708 (6.9%); and right hind, 258/3,775 (6.8%). Table 2 shows the results from bacteriological testing. A total of 13,910/14,948 (93.1%) quarter observations were right-censored. Among the right-censored quarter observations, 4,992/13,910 (35.8%) were due to drying of the cow, 1,252/13,910 (9.0%) were due to culling of the animals (n = 316), and 7,677/13,910 (55.2%) quarters had no mastitis event by 305 d. Among the 316 cows that were culled, 53/316 (16.8%) died due to injury (n = 25), mastitis (n = 12), and unknown reason (n = 16); 263/316 (83.2%) cows were sold due to mastitis (98), undefined sickness (57), injury (34), low productivity (33), reproductive performance (15), abortion (11), teat injury (9), lameness (3), and aggressive behavior (3).

Teat Shape and Time to Mastitis

Kaplan–Meier survival analysis of time to clinical mastitis is depicted in Figure 2. The final multivariable proportional hazards regression model included parity ($P < 0.0001$), quarter position ($P = 0.98$), presence of a non-lactating quarter ($P < 0.0001$), and teat shape ($P < 0.0001$). Compared with quarters from cows in parity ≥3, the hazards (95% CI) of mastitis were 0.27 (0.21–0.34) for first-lactation animals and 0.65 (0.54–0.78) for cows in second lactation. There was no association between quarter position and the occurrence of clinical mastitis. Compared with right hind quarters, the hazards of clinical mastitis were 1.03 (0.86–1.24) for left front quarters, 1.03 (0.87–1.12) for left hind quarters, and 1.00 (0.83–1.19) for right front quarters. Quarters from cows with a nonlactating quarter had higher hazards of clinical mastitis compared with those with 4 lactating quarters (hazard ratio [**HR**; 95% CI], 1.72 [1.41–2.10]). We found an association between teat shape and clinical mastitis. Compared with teats with SR, the HR were TP, 1.66 (1.25–2.19); SF, 1.58 (1.14–2.18); and SRF, 0.99 (0.83–1.18; Figure 3). The hazards (95% CI) of clinical mastitis for teats with TP were 1.05 (0.70–1.58) compared with teats with SF and 1.57 (1.16–2.14) compared with teats with SRF. In comparison with teats with SRF, teats with SF had higher odds of clinical mastitis (HR [95% CI], 1.50 [1.08–2.09]).

DISCUSSION

In this study, we investigated the association between teat shape and the occurrence of clinical mastitis. For this purpose, we employed high-producing Holstein

Table 2. Frequency distribution of culture results from milk samples collected from 1,038 clinical mastitis cases

Culture result	Number	Percentage
Negative	374	36.0
Streptococcus uberis	307	29.6
Escherichia coli	91	8.8
Streptococcus spp.	72	6.9
Klebsiella spp.	43	4.1
Streptococcus dysgalactiae	38	3.7
Staphylococcus aureus	34	3.3
Mixed	19	1.8
Contamination	16	1.5
Staphylococcus spp.	14	1.3
Pasteurella spp.	8	0.8
Other	7	0.7
No culture results available	6	0.6
Enterococcus spp.	5	0.5
Mycoplasma spp.	2	0.2
Yeast	2	0.2

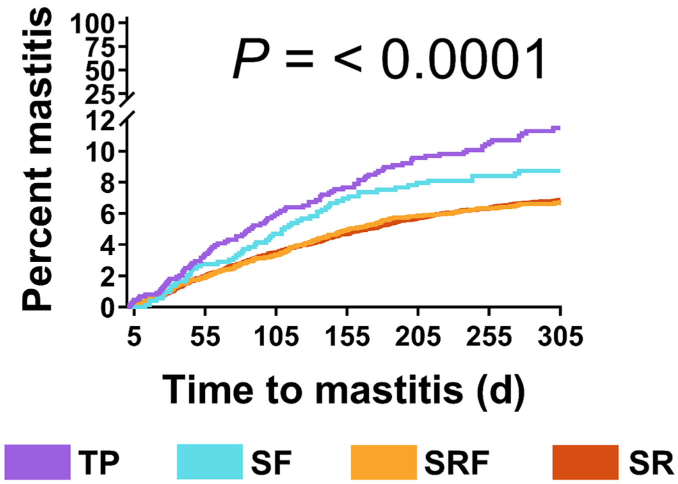

Figure 2. Kaplan-Meier survival analysis of time to clinical mastitis event within the first 305 d after calving for 14,948 quarters from 3,913 cows stratified by teat shape. TP = triangular barrel and pointed teat end; SR = square barrel and round teat end; SRF = square barrel, round teat end, flat in the area of the teat orifice; and SF = square barrel and flat teat end. *P*-value derived from log-rank test statistics.

dairy cows from a dairy operation in New York with a thrice-daily milking schedule. We followed cows for a maximum duration of 305 DIM and used time-to-event analysis to determine whether differences in the hazards of mastitis occurrence between quarters with different teat shapes existed. Our data showed that quarters with teats with TP and SF had higher hazards of the occurrence of clinical mastitis than those with SR teats. Controlling for the effects of parity and quarter position, the hazards of occurrence of clinical mastitis were 66% higher for quarters with a teat with TP and 58% higher for quarters with a teat with SF. The association between teat characteristics and udder health has been demonstrated previously (Seykora and McDaniel, 1985; Zwertvaegher et al., 2013; Guarín and Ruegg, 2016; Miles et al., 2019). Our results reinforce these findings and suggest that certain teat shapes can put cows at a greater risk of clinical mastitis. Our findings could allow dairy producers to increase monitoring of these high-risk animals and develop management strategies to mitigate their risk. Teat-barrel shape and teat-end shape are heritable phenotypes with a reported heritability of 0.38 and 0.55, respectively (Seykora and McDaniel, 1985). Thus, this risk factor could serve as a criteria to guide breeding decisions as discussed previously (Miles et al., 2019).

We believe that the increased hazards of clinical mastitis for quarters with a teat with TP can be attributed to the following facts. First, teats with a pointed teat end have been reported to have higher teat-end callosity thickness and roughness compared with teats with flat or inverted teat ends (Neijenhuis et al., 2000, 2001a). Increased teat-end callosity thickness and roughness affect teat canal closure, enhance the lodging of pathogenic bacteria, and consequently increase the risk of new intramammary infection (Neijenhuis et al., 2001a,b). Second, in a recent study (Wieland et al., 2018), we observed that teats with pointed teat ends had higher odds of experiencing machine milking-induced short-term changes to the teat tissue (i.e., congestion) compared with teats with flat and round teat ends. The teats' defense against pathogens depends on adequate blood circulation (Hamann et al., 1994), which is impeded by such congestion. Differences in the teats' circulatory impairment between teats with different teat shapes therefore help explain the observed differences in the hazards of clinical mastitis (Wieland et al., 2020). However, because we did not assess teat-end

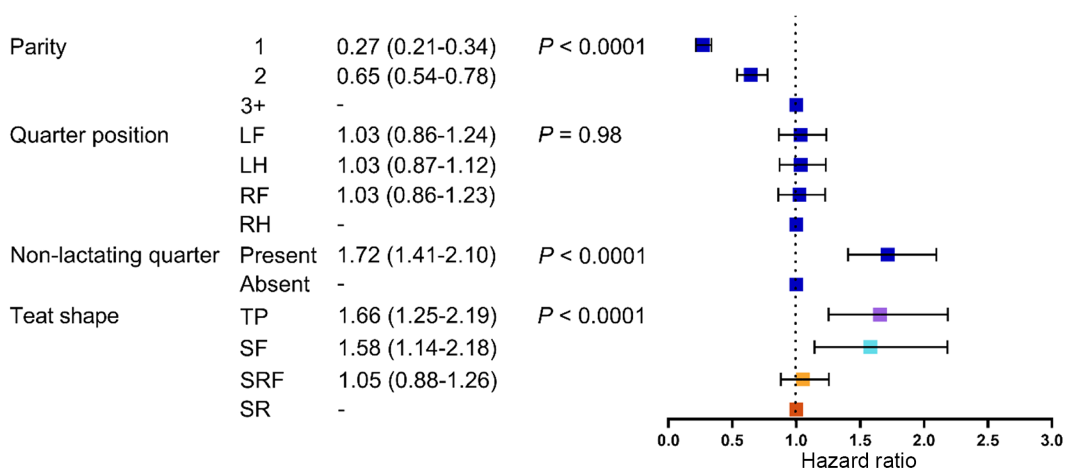

Figure 3. Hazard ratios (95% CI) of clinical mastitis occurrence within the first 305 d after calving from semiparametric proportional hazards model for 14,948 quarters from 3,913 cows stratified by teat shape. Teat shape: TP = triangular barrel and pointed teat end; SR = square barrel and round teat end; SRF = square barrel, round teat end, flat in the area of the teat orifice; and SF = square barrel and flat teat end. Quarter position: LF = left front; LH = left hind; RF = right front; and RH = right hind.

callosity or the occurrence of machine milking-induced short-term changes in the current study, these possible explanations remain speculative.

The increased hazards of clinical mastitis occurrence in quarters with SF teats could also be due to differences in the ability to clean teats with different teat-end shapes. That is, in our experience it is more difficult to achieve good teat-end cleanliness in teats with flat teat ends because it requires a different set of motions compared with teats with pointed or round teat-end shapes. This lack of cleanliness could increase the risk of intramammary infection. The relationship between teat-end shape and cleanliness has not been rigorously investigated, but it could explain the observed differences in mastitis risk among teats with different shapes. An additional reason could be the differences in teat canal dimensions among teats with different teat-end shapes, including teat canal length and teat canal diameter. Previous researchers reported that differences in teat canal length (Grindal et al., 1991) and teat canal diameter (Rathore and Sheldrake, 1977; Hebel, 1978) exist. The teat canal is one of the teats' first barriers against infection (O'Shea, 1987). We speculate that in the current study cohort differences in teat canal length and diameter existed among teats with different teat shapes and that these differences were associated with different susceptibilities to intramammary infections. Specifically, we believe that SF teats had wider and possibly shorter teat canals facilitating the invasion of mastitis causing pathogens into the mammary gland, thereby increasing the risk of intramammary infections and subsequent clinical mastitis. This theory is supported by our previous work showing that teats with a flat teat ends had the largest relative change in teat canal diameter after machine milking compared with teats with pointed and round ends (Melvin et al., 2019). Another possible explanation could be due to differences in peak milk flow rate among teats with different teat-end shapes. Grindal et al. (1991) reported that the risk of new IMI increased with increasing peak milk flow rate, and in a recent study from our group, we showed that cows with flat teat ends had higher peak milk flow rates (Wieland et al., 2024). However, these possible explanations remain speculative in the absence of teat canal measurements in the current study cohort, as well as conflicting results from a more recent study showing no association between peak milk flow rate and clinical mastitis risk (Penry et al., 2017).

Several research groups studied the association of teat shape (Seykora and McDaniel, 1985; Guarín et al., 2017) or teat-end shape (Seykora and McDaniel, 1985; Chrystal et al., 1999; Chrystal et al., 2001; Miles et al., 2019) with udder health parameters and found conflicting results. Seykora and McDaniel (1985) studied the relationship between teat-barrel shape, teat-end shape, and SCC in 898 Holstein cows from 6 herds in North Carolina. They found no meaningful relationship between teat-barrel shape and SCC, whereas teat-end shape was related to SCC in that teats with flat teat ends had higher SCC. Chrystal et al. (1999) categorized teat-end shapes for 1,740 Holstein dairy cows from 5 commercial and 4 university herds in Minnesota and Wisconsin, adapting the scoring system from Seykora and McDaniel (1985). The results of their investigation indicated no meaningful association between teat-end shape and linear SCS (Chrystal et al., 1999). Using data from 1,443 Holstein cows from the dairy breeding research herd of the Iowa State University (Ankeny, IA), Chrystal et al. (2001) employed a scoring system with 5 different categories and found no association between teat-end shape and linear SCS. In another Wisconsin study, investigators assessed the teat dimensions of 959 cows from 9 different herds (Guarín et al., 2017). The teat shape was classified into square or triangular and based on the teat-barrel diameter and the diameter at the teat apex. They found no association between teat shape and quarter-level SCC (Guarín et al., 2017). A research group from New York State used 523 Holstein cows from 2 commercial herds to study udder and teat conformational risk factors for elevated SCC and clinical mastitis (Miles et al., 2019). Teat-end shape was scored as pointed, round, and flat, but categorized into 2 groups for subsequent analysis (flat vs. pointed and round). Their analysis showed that teat-end shape was associated with SCC and the incidence of clinical mastitis. Flat teat ends increased the odds of both an elevated SCC event and the occurrence of clinical mastitis (Miles et al., 2019). We speculate that the disparity among the results of these previous studies, and those described herein can be attributed to differences in the scoring systems used, case definitions, and study populations, as well as milking routines. The importance of farm size and management practices in mastitis risk has been recognized previously (Miles et al., 2019).

Our data show that cows in parity 1 and 2 had lower hazards of clinical mastitis compared with those in parity 3 or greater. This finding is consistent with those from previous studies (Zadoks et al., 2001; Elghafghuf et al., 2014) and has reportedly been due to changes in the anatomy of the mammary gland and the teats as well as parity-associated metabolic changes, such as the disruption of the calcium homeostasis (Lean et al., 2023), which has been related to mastitis risk (Curtis et al., 1983). Last, we found that that quarters from cows with a nonlactating quarter had higher hazards of clinical mastitis compared with those from cows with 4 lactating quarters, which is consistent with results from a recent study from our group (Wieland and Skarbye, 2024).

Our study had several limitations. First, the generalizability of our results is limited because this study was conducted at a single commercial dairy in New York State. Therefore, this study needs to be replicated considering different study populations, regions, and management systems before results can be extrapolated. Second, the scoring of the teat shape was performed visually by 1 investigator during a single milking session. This may have led to operator fatigue and information bias. Opportunities for additional research abound. First, adding other phenotypes such as teat length and diameter could provide a more robust model and explain some of the residual variability of the current model presented herein. Second, to facilitate the standardized assessment of teat shapes, researchers should seek to use automated techniques such as machine learning approaches. Such work could also facilitate the serial assessment of teat shape and capture changes in teat traits over time. Last, work should be conducted to identify management strategies that can mitigate the risk of clinical mastitis in TP and SF teats.

CONCLUSIONS

In the current study cohort, teat shape was associated with the occurrence of clinical mastitis such that quarters with teats with TP and SF had higher hazards of clinical mastitis than those with SR teats. We attributed the observed differences in the hazards of encountering clinical mastitis among teats with different teat shape to the interrelationship between teat shape and machine milking-induced changes to the teat tissue condition, differences in teat canal dimensions, and different degrees of cleanability by means of premilking teat sanitization among teats with different shapes. Teat shape could be an important factor to consider when identifying and managing cows at risk of clinical mastitis.

NOTES

This study received no external funding. The authors thank the farm owners for providing their farm data and the farm workers for their care of the cows. This study was conducted with the oversight of the Cornell University Institutional Animal Care and Use Committee (protocol no. 2013-0064) at a commercial dairy farm in central New York. The authors have not stated any conflicts of interest.

Nonstandard abbreviations used: HR = hazard ratio; SF = square barrel and flat teat end; SR = square barrel and round teat end; SRF = square barrel, round teat end, and flat around the teat orifice; TP = triangular barrel and pointed teat end.

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