Background and Scoring

The skin is considered the largest organ that covers the entire surface of the body. The skin provides the interface between the organism and the environment and fulfills several physiological tasks. Therefore, the skin significantly contributes to the viability of the living individual. Its main task is to protect the body against harmful external influences. In addition to protecting the body to a high degree from mechanical, chemical, and physical influences, as well as the intrusion of parasites, bacteria, and viruses, the skin prevents water losses. It serves the stabilization of electrolyte levels and as a regulating organ for blood pressure. The skin is equipped with sensory and autonomic nerves and contains receptors for the detection of temperature, pressure, vibration, pain, and itching facilitating the contact between the individual’s central nervous system and his or her environment.

To keep the body temperature constant, the skin is equipped with hair, sweat glands, and blood vessels. In addition to nutrition, these blood vessels are primarily used for the vital temperature regulation of the body. Therefore, the skin has a much denser vascular system than is required for its nourishment.

Finally, the skin provides immunologic surveillance by means of the inclusion of immune cells such as Langerhans cells that are included in the epidermis. Furthermore, unsaturated fatty acids from the secretion of the sebaceous and sweat glands also have a bacteriostatic effect providing a protective mantel retarding the growth of pathogenic microorganisms.

The skin is organized into 3 layers: the epidermis, the dermis, and the hypodermis. Like the skin of other mammals, the bovine skin shows considerable regional variations in epidermal and dermal thickness. As such, the bovine teat skin is free from hair, has no sweat glands, and, unlike the skin covering the body of the mammary gland, is not movable. A special feature of the teat skin is the teat canal, a longitudinally folded cylinder-shaped body opening, located at the distal aspect of the teat that connects the external teat orifice with the teat cistern entrance.

Mastitis is one of the most frequent diseases in dairy cattle. It has well-recognized negative effects on animal welfare and on the profitability of the dairy industry. The treatment and prevention of this disease account for 80% of all antimicrobial drugs used on US dairies posing concerns for the development and transfer of antibiotic-resistant bacteria to the food supply.
intramammary infection, where pathogenic bacteria enter the mammary gland through the teat canal. Therefore, the teat canal, its surrounding tissue, and the teat skin are considered the cow’s first line of defense against mastitis pathogens. Sustaining their integrity and pliability is critical to resist intramammary infection. The teat skin is affected by the milking process, the general environmental conditions on the farm, and any agent applied to the teats.

Guidelines for the evaluation of the teat skin condition have been provided by the National Mastitis Council (NMC). Current industry guidelines recommend evaluating at least 80 cows or a minimum of 20% of cows in herds larger than 400 cows. Based on these guidelines, the evaluation of the teat skin should be conducted prior to machine milking and consists of manual evaluation of the teat skin and the visual inspection of the entire teat barrel and the teat orifice. A light source can facilitate the visual assessment during which the presence or absence of chaps and cutaneous damage (ie, teat open lesions [TOL], sucking, insect bites, abrasions, cuts, sunburn, and frostbite) are documented. The manual inspection is conducted using (latex) gloved hands and performed as follows: the examiner should drag the finger and thumb along the teat barrel with light pressure. The teat skin may be easily determined as (1) smooth, (2) slightly rough (ie, with some drag of the latex), or (3) very rough (ie, when the latex puckers). The presence of TOL is visually assessed, and the data are summarized by the cow for the herd being assessed. Based on current industry recommendations, a herd problem with TOL exists if more than 5 percent of the cows scored have 1 or more teats with a TOL.

**Presentation**

The TOL that we are focusing on in this narrative review are distinct from other types of previously described teat lesions that tend to occur more commonly in fresh first lactation animals such as herpes mamillitis, seasonal teat lesion syndrome, bovine ischemic teat necrosis, and self-inflicted trauma. The lesions seen with these syndromes may start with vesicles that rupture leading to ulceration and lesions that coalesce. Oftentimes, these lesions affect a large surface area of the teat and sometimes result in necrosis of the entire teat. The TOL that we are focusing on are also distinct from pseudocowpox in which papules, vesicles, and denuded circular raised areas develop leading to thick scabs. TOL can present in many ways, but the most typical presentation that we have seen in the Northeast United States is a herd-wide problem during the colder months of the year. The prevalence within a herd can vary widely, but 1 of the authors (PDV) has documented this as high as 45% of the cows that were scored on an individual herd having a TOL. In our experience and based on results from the NMC teat committee surveys, these TOL have been seen on all size herds, both Holstein and Jersey herds, in herds milked 2 and 3 times per day, in pasture and confined type of housing, and in different bedding types including sawdust, new sand, recycled sand, raw manure solids, and digested manure solids. In most herds, the TOL occur in cows of all lactations and throughout all stages of lactation. In some herd situations such as the one presented by the first author (PDV) as a case study at a regional NMC meeting, they can be more common in certain groups of cows due to differences in housing or bedding. This was a commercial dairy herd in central New York with approximately 2,400 cows milked 3 times per day in an 80-stall rotary parlor. Cows were housed in free stall barns either in deep bedded stalls or in stalls with water beds with raw manure solids with hydrated lime (calcium hydroxide) used for bedding. Hydrated lime (calcium hydroxide) was added daily at an approximate amount of 0.45 kg/stall. Cows housed in the deep bedded stalls exhibited a much higher percentage of TOL compared to the cows housed in the stalls with water beds. We have not observed any difference in the frequency of TOL among quarter positions within cows (ie, hind vs front teats) nor could we observe a predilected location of the TOL.

The TOL on individual teats appear like distinct cuts or incisions on the barrel of the teat (Figure 1).

**Figure 1**—Different stages of altered teat skin conditions. A through C—Different degrees of dry skin. D through G—Different stages of chronicity of TOL. H—Lesions due to chemical burn.
The TOL present in various stages of chronicity with some early lesions that look like a fresh scratch with frank blood present. Others are more chronic and have a bed of granulation tissue, whereas some are completely healed with only a white scar present. The orientation on the teat of these TOL has been highly variable with some horizontal, some vertical, and others at all points in between. Individual teats can present with single or multiple TOL but typically the lesions do not coalesce. In some herds as a sequel to these lesions, warts may develop in the same area as a healed lesion.

In individual farm situations that the authors have been involved in, extensive diagnostics have been performed on individual lesions in various stages of chronicity including histopathology, bacteriology, virology, and parasitology. Overall, the results from these diagnostics have been inconclusive and did not lead to the cause of these lesions. The main conclusion from the diagnostics is that these were nonspecific mammillitis with no definitive proof of a primary cause arising from viral, bacterial, or parasitic causes.

For the farms that the authors have been involved in, we have not recorded individual cow numbers when teat scoring and therefore cannot speculate on a correlation at the quarter or cow level between TOL and mastitis. Others have found a correlation between teat skin condition and colonization of the teat skin with Staphylococcus aureus. It has been our subjective observation that cows with TOL exhibit more abnormal cow behavior during milking than cows without TOL leading to challenges with the milking event. This abnormal cow behavior would include more kicking when being fore stripped and when the teat is cleaned prior to the attachment of the milking cluster, more shifting of weight on the rear legs, and more kicking at the cluster during milking. Based on our observations, this abnormal cow behavior can lead to an increased risk of dirt or manure from the lower legs ending up on the teat or teat end, an increased risk of liner slips during milking, an increased risk of poor cluster alignment, and an increased risk of the milking cluster being prematurely kicked off. Although all these outcomes could potentially increase the risk of mastitis, we have not investigated the association between TOL and mastitis by rigorous methods. Since an increase in liner slips during milking could lead to more vacuum fluctuation in the claw, this may affect udder health parameters as shown in previous research.

**Risk Factors**

To the best of our knowledge, no studies have been conducted to prove causation or even associations with the TOL. In our experience, an almost universal predisposing factor appears to be dry teat skin. We score numerous herds with dry skin in which we do not see TOL, but it is rare to see TOL without dry skin. In evaluating risk factors on individual herds with TOL, we have observed environmental conditions such as cold weather conditions or fluctuating temperatures as risk factors for TOL. One specific dairy in which this was observed was a Northern New York commercial dairy with approximately 1,300 cows milked 3 times per day in a double 24 parallel parlor. Cows were housed in free stall barns with deep bedded stalls with recycled sand as bedding. When teats were scored in early winter, 45% of the 260 cows scored had TOL on 1 or more teats. This is consistent with previous work from Iowa state, which showed that changes in teat skin condition were linked to weather or temperature shifts. Exposure to windy conditions also has been a risk factor for TOL. This has been particularly true in combination with the presence of long walkways to the parlor that are not shielded well or open barns in which the wind can freely move through.

Bedding characteristics are also risk factors that we have observed. Moisture content in the bedding has appeared to play a role on some farms, especially with sand, recycled sand, manure solids, and recycled manure solids. This was true for 1 commercial dairy in Northern New York with approximately 3,500 cows milked 3 times per day in 2 separate double 24 parallel parlors. Cows were housed in free stall barns with deep bedded stalls with sand as bedding. Teat open lesions had not been a problem on this dairy over the previous 3 years. In early fall, prior to any significantly cold weather, the percentage of cows with TOL increased to 31% of the cows scored. The 1 major change identified was that the sand going into the stalls was significantly wetter. During the winter, in many herds in the Northeast United States, the barns are closed-up, and the bedding does not dry out once it is put into the stall. Along with the cold weather, this may be 1 reason why we observe more TOL in the wintertime. It appears that the rule for the risk of mastitis that drier bedding is better would also be true for the risk of open lesions. We have speculated that the pH of bedding could play a role, but only within the last few years have we started to measure this in bedding samples submitted to our lab. We have also investigated the particle size of bedding as a risk factor for TOL but have not come to a definitive conclusion. Additives to bedding may also influence teat skin condition and therefore potentially affect the risk of TOL. The authors have been involved in farms in which a chlorine bedding additive, hydrated lime (calcium hydroxide), or quick lime (calcium oxide) have been used and influenced the teat skin condition. In some cases, though, these bedding additives were used in certain pens without leading to the TOL.

The authors have also been involved in events involving thermal or chemical damage which has led to a pen or herd-wide problem with TOL within 1 to 2 weeks postevent. One of the thermal situations involved an inappropriate use of a singeing tool and another involved bedding that heated to a temperature high enough to negatively affect teat skin. The chemical situation that we were involved in was using chlorinated alkaline detergent solution accidentally as a postmilking teat disinfection (PMTD).
Mechanical brushes to clean teats prior to milking have become more common in the Northeast in the last 10 years. Some of these are handheld brushes used by milking technicians on individual cows, and others are automatic robotic brushes used to replace labor especially on rotary parlors. Although the authors have seen these being used successfully on many dairies, there have been situations in which these mechanical brushes have been a risk factor for TOL. One situation involved the wrong stiffness of brushes being used and another the wrong rotation speed of the brushes leading to more TOL on an individual dairy.

Treatment and Prevention

Treatment measures for the individual animal should be aimed at supporting skin healing and regrowth and controlling the environment that the teat is exposed to. This can be very difficult as many times there is not a separate space for individual animals or time to deal with these situations. Ideally, the milking event for the injured teat should be highly controlled to minimize any additional trauma related to the milking event. Specifically, the cow should be well stimulated and have sufficient lag time from stimulation to unit attachment to minimize the time the injured teat would spend at high vacuum with no milk flow. The milking liner should be removed from the injured teat as soon as milk flow slows to minimize any additional trauma. Furthermore, the teat should be postdipped with a high emollient PMTD to promote tissue healing and to keep the skin soft and pliable. Some of these high emollient PMTD are labeled as winter dips, although this term is not standardized and the manufacturer should be consulted. The teat should then be kept from being exposed to any dirty bedding to minimize the risk of secondary skin infections. If possible, the teat should be cleaned off multiple times during the day and the high emollient PMTD reapplied. This should be continued until the TOL has been fully resolved.

In a herd situation with TOL, our recommendation has been to increase the percentage of the emollients in the PMTD to promote skin healing. Individual companies have achieved this goal in various ways such as adding extra emollients to an existing PMTD or switching to a different PMTD with a better emollient package. It is important to note that there can be some compatibility issues with adding emollients to premixed PMTD so the manufacturer of the PMTD should be consulted and ideally perform the mixing. The label on the PMTD usually gives the emollient percentage but it should be noted that there are different types of skin moisturizers such as occlusives, humectants, and emollients that may be included under the term “emollient.” Depending on the local climate and season, there may be benefits in targeting one type of skin moisturizer although this practice is not supported by rigorous studies.

In addition, reviewing the dip application method is also important to maximize the coverage of both the teat end and the entire barrel of the teat. Coverage can be a challenge with certain application methods such as spraying PMTD on teats, especially if the amount of product applied is restricted. In the authors’ experience, dip cups lead to better coverage with less PMTD used compared with spray systems. Training of milking technicians is also important to help them understand how to properly apply the PMTD and why it is important to cure and prevent TOL. Application by robotic methods is becoming more common in rotary parlors, and coverage of the entire teat can be a problem in these systems. These systems need to be monitored closely over time and preventative maintenance performed as specified by the manufacturer. There has also been a movement to more foamed PMTD over the last 10 years. The authors are not aware of any published data that have examined how foam may affect PMTD drying time but have speculated that this may have played a role in poor teat skin conditions in colder weather in certain individual farm situations.

In terms of preventative measures for TOL, one of the primary measures in the authors’ experience is controlling the environment that the teats are exposed to. This starts with reducing the exposure to wind and major temperature fluctuations, which have been shown to be related to poor teat skin condition. The exposure may occur in the actual barn or in walkways to and from the parlor and both should be considered. In addition, controlling the dry matter (DM) of the bedding that is in direct contact with the teats is critically important. This is particularly true during the colder weather. As anyone who has spent time in the northern climate knows, having wet skin in colder weather can lead to dry and cracked skin. This appears to be true as well for teats that are exposed to beddings at lower DM concentrations (< 35% DM) during the colder weather. If bedding additives are used that are known to cause dry skin, such as hydrated or quick lime, then these products need to be fully mixed with bedding prior to going into the stall to minimize direct exposure to teat skin. Cow positioning in the stalls should also be considered since it significantly influences the level of contamination of the bedding that the teats are exposed to. If cows are positioned too far forward, then urine and manure are deposited in the back of the stall rather than in the alleyway. This then changes the bedding that the teat skin is exposed to and therefore has an influence on the risk of TOL. Cow positioning is influenced by various factors such as the length of the stall bed, presence of any brisket locator, size of animal, bedding levels, and potentially comfort of the stall bed. Although some of these factors do not change, others such as bedding levels are constantly changing and therefore the risk of urine and manure in the back of stalls changes over time. Helping the farm recognize if cow positioning is a problem and how to correct this can greatly help control the risk of contamination of the bedding in the back of the stalls.

As of publication, work is underway on whether pH of bedding is playing a role and whether this should be monitored or adjusted to help prevent TOL.
Controlling the emollient package of the PMTD is important for not only curing TOL but also for preventing them. For herds that have a seasonal pattern of TOL, it is important to adjust the emollient package of the PMTD early enough prior to the highest risk period to try and prevent as many TOL from occurring as possible. Having a monitoring plan in place for assessing PMTD coverage over time is important as well since this can help prevent TOL if the coverage stays adequate on the teat barrels throughout the year. In the authors’ experience there also has been value in performing triannual or quarterly teat scoring as a preventive measure for TOL. This information provides a baseline of data and an early warning system that allows for corrective measures to be implemented, such as adjustment of the emollient package of the PMTD, prior to a major problem occurring (Figure 2). As shown in Figure 2, there is a relationship between TOL and dry skin for this herd which has helped the authors to appropriately advise the herd on when mitigation strategies involving the PMTD are necessary as well as document if these strategies are making a definable difference in TOL.

To prevent the accidental point source occurrences such as from using an inappropriate PMTD or incorrectly singeing udders, it is important that management considers how these situations could occur. Properly labeling all chemicals on the farm and controlling the PMTD distribution center on the farm could go a long way in preventing the wrong product from being dipped onto teats. Proper training and supervision of those who perform singeing of the udders could help prevent a disaster from occurring with this procedure.

**Knowledge Gaps and Future Research**

As the reader can tell, there is a great need for more research on this topic as much of the current information is from field experience rather than controlled scientific experiments. One primary area of research that the authors feel is needed is a detailed evaluation of how the moisture level and pH of the bedding material relate over time to the pH of teat skin and whether these are primary predisposing factors for TOL. There are some dairy professionals that believe the problem of TOL is similar to a problem in humans called incontinence-associated dermatitis.27 This problem in humans relates to skin damage associated with exposure to stool or urine for prolonged periods. As stated earlier, the authors have collected some data on the pH of bedding but have not tracked this on specific farms with TOL in any detail.

A second area in which more research is needed is what type of skin moisturizers are needed in the PMTD to prevent or correct TOL. There is much anecdotal information available on this topic from individual companies, but controlled experiments are lacking.

Another area that the authors have explored is whether scoring of the udder skin would help explain possible causes of TOL. Since the udder skin is exposed to a very similar environment as the teat skin, the thought would be that scoring udder skin

---

**Figure 2**—Percentage of cows with abnormal teat skin condition (dry teat skin and teat open lesions) from 1 commercial dairy operation over time.
would be easier and may predict the risk of the teats developing TOL. Also, udder skin scoring could help sort out if the TOL problem is related to a combination of the environment and the physical forces applied to the teat by the milking machine or if it is solely related to the environmental exposure.

A fourth area of research is to investigate TOL at the individual quarter level and determine if there is an association between TOL and mastitis. Although the complaint on many of the TOL herds that we have investigated is for an increased level of subclinical or clinical mastitis, we have not recorded individual cow identification numbers when teat scoring and therefore do not have individual cow data to correlate TOL with mastitis.

At the time of publication, the NMC teat health committee has been working on compiling data on TOL, which may help to further clarify the extent of the TOL problem across the United States and globally.

The results of the current review suggest that the literature about TOL in the bovine species is scarce. The description of clinical signs, risk factors, treatment options, and preventative measures are therefore based on the author’s experience in the field. Future work should focus on the investigation of factors that put cows at risk of TOL, determine their relationship with mastitis risk, identify treatment options that are supported by controlled studies, and help develop management strategies to prevent TOL on dairy operations.

Acknowledgments

This project received no external funding. The authors have not stated any conflict of interest.

References