Mastitis and the Dry Period

R. J. Eberhart, *V.M.D., Ph.D.*
Department of Veterinary Science
The Pennsylvania State University
University Park, Pennsylvania 16802

Introduction

Today many of us are apt to think of the dry period, as it relates to mastitis, as a time for effective therapy of the chronic infections present at drying off. Sometimes overlooked is the fact that the dry period is a time of high risk of new infections. Many of the intramammary infections (IMI) that will cause problems in the next lactation, especially the troublesome clinical cases so common just after calving, are due to infections established during the dry period.

The emphasis of this presentation is on new infections during the dry period, and it will consider times of high susceptibility in the dry period, the types of infections most likely to occur, factors in susceptibility, dry period therapy as a prophylactic measure, and some management practices that may influence the new infection rate.

Importance of new infections in the dry period.

Much of the available information on the natural rate of new infection in the dry period comes from the untreated control cows in studies of dry period therapy. Sinkevich *et al,*[19] in a review, found reported new infection rate in untreated cows ranging from 4 to 35% of quarters. Overall, it seems likely the average new infection rate over the dry period is between 8 and 12% of quarters. This high rate of new infections means that in the absence of effective control practices the prevalence of infection will be higher at calving than at drying off.

Another way to assess the importance of the dry period in the mastitis complex is to compare the number of infections established during the dry period with those originating during lactation. In an early study in a herd in which neither dry cow therapy nor teat dipping was practiced, Neave *et al*[11] found that 48% of all infections occurred while cows were dry. More recently, in a teat dipped herd with dry cow therapy limited to cows shown to be infected by culture, 42% of all infections were established during the dry period.[4]

Dry period infections are also the cause of most of the clinical mastitis that affects many cows in early lactation. This is illustrated in Table 1 which shows results of a study in which cows were cultured at drying off, at calving and periodically through the first 9 weeks of lactation. Often, quarters infected at calving appeared normal and developed clinical signs only after several weeks of lactation.

Time of new dry period infections

It is often said that the early dry period, especially the first 3 weeks, is a time of high susceptibility to infection. This concept arises from the 1950 work of Neave *et al.*[11] In that study new infection rates (expressed as infection/week in 89 cows) were as follows:

Period	Infections/week
21 days after last milking	7.0
Remainder of dry period	.18
Total dry period	1.64
Previous lactation	1.12

These data indicated that cows were highly susceptible during the early dry period, that the infection rate was low for the remainder of the dry period and that the infection rate for the dry period as a whole was substantially higher than for the preceding lactation. Since that early study there have been a few attempts to determine the times of new infection during the dry period; in each case the high rate in the early dry period has been confirmed.[18,22]

Results of a recent study we conducted suggest that the prepartum period may also be important in this respect. In this trial the right front and right rear quarters of untreated cows were cultured at drying off, after 1, 2, 3 and 4 weeks of the dry period and at 2 day intervals beginning 2 weeks before expected calving. The times when new infections by major pathogens were established are presented in Table 2. These data show a high number of new infections in the week after drying off. New infections declined rapidly thereafter and during the fourth week no new infections were detected. These data also reveal a returning susceptibility during the

Table 1. Time of clinical mastitis and time of establishment of infection in the dry period and the first 9 weeks of lactation of 106 cows not treated in the dry period.

Period	Clinical mastitis	Infections established
Previous lactation	—	5
Dry period	14	40
Post-calving	47	4
Unknown (No bacteria isolated)	—	12
TOTAL	61	61

Table 2. Number of persistent new infections established at different times in the dry period in 212 untreated quarters of 106 cows*.

	Week after drying off				Weeks before calving	
No. of	1	2	3	4	2	1
infections	18	7	1	0	2	9

* Eight additional infections occurred in the period between 4 weeks after drying off and 2 weeks before calving. The length of this period varied among cows with the total length of the dry period.

precalving period. This finding agrees with the work of others who found that bacteria injected through the teat canal are more likely to cause infection if the challenge is given in the prepartum period than in the mid-dry period.[1,8] Taken together these results suggest that in designing mastitis control measures to prevent new infection we should concentrate on the period just after drying off and on the prepartum period.

Types of bacteria causing new dry period infections

In attempting to prevent new dry period infections it is also useful to know the types of bacteria most likely to cause infection. This information is helpful primarily because the epidemiology of various pathogens differs. Some bacteria, such as *Streptococcus agalactiae* and *Staphylococcus aureus*, are contagious and are transmitted from infected to uninfected quarters mainly during the milking process. Other bacteria, including most of the streptococci other than *S. agalactiae* and the coliform bacteria are more likely to reach the cow's udder from the environment. Clearly, control measures effective against one of these categories of bacteria will not necessarily be so effective against the other.

In Neave's early study the types of bacteria causing infections during lactation were compared with those in the dry period.[11] The numbers of *S. agalactiae* and *S. aureus* infections occurring during lactation and during the dry period were nearly equal. However, infections caused by "green streptococci" (probably comprised largely of *Streptococcus uberis)* were more common in dry than in lactating cows. More recent studies have suggested that in some herds environmental bacteria are the cause of most dry period infections. For example, Schultze and Mercer[18] reported that in one herd there were 0 *S. agalactiae*, 7 *S. aureus*, 70 other streptococcal and 25 coliform infections established over the dry period; here the predominance of environmental pathogens was very striking.

In Penn State work we also found the environmental pathogens predominating among dry period infections. In that study there were 2 *S. aureus*, 21 other streptococcal and 20 coliform infections. The numbers of streptococcal and coliform infections were nearly equal, and the distribution of the two types was similar at the beginning and the end of the dry period.

Both the Schultze and Mercer work and the Penn State study were conducted in institutional herds in which *S. agalactiae* and *S. aureus* were maintained at low levels. The relatively few dry period infections caused by these bacteria may, therefore, have been due to a low degree of exposure to these pathogens. In addition, the germicidal teat dipping practiced in these herds would result in low populations of these contagious bacteria on the teat skin at drying off. However, these herds are not unique, for with widespread adoption of teat dipping and dry cow treatment many commercial herds have achieved excellent control of *S. agalactiae* and *S. aureus*. It is reasonable to expect that as present mastitis control programs are successful in reducing the prevalence of *S. agalactiae* and *S. aureus* the importance of the environmental bacteria as dry period pathogens will increase.

Factors in susceptibility and resistance in the dry period

From the foregoing discussion it is apparent that the new infection rate is very high in the early dry period, decreases as involution is complete and then rises again as parturition approaches. Reasons for this changing susceptibility are only poorly understood. For purposes of discussion, factors influencing susceptibility might be broadly grouped as follows:

1) changes in bacterial populations on the teat skin
2) changes in the penetrability of the teat canal by bacteria
3) changes in the effectiveness of defense mechanisms within the mammary gland itself

With respect to the importance of bacterial populations on the teat skin, Neave and Oliver[12] showed a strong relationship between the numbers of bacteria applied to the teat skin and the number of IMI resulting from such a challenge. Thus they affirmed that the new infection rate is markedly influenced by the bacterial load on the teat skin. In the same study they reported that *S. aureus* was commonly isolated from teat skin at drying off but could be found only rarely on the teats of uninfected quarters after 28 days of the dry period. Therefore, it appears that when teats are not repeatedly contaminated by *S. aureus* during milking, teat skin populations of these bacteria decrease. On the other hand, *S. uberis* were rarely found on the teat skin or teat orifice during lactation but were present in high numbers on some teats 21 days later. These changes in the bacterial flora of the teat skin over the dry period very likely influence the types and numbers of IMI that occur. Further work in this area appears to be warranted.

It is also quite likely that the high susceptibility in the early dry period is related to changes in the penetrability of the teat canal. Changes in penetrability might be affected by many factors, some purely physical in nature, other related to functional and morphological changes in the teat canal during involution. Several studies have shown that an unmilked gland is more vulnerable to infection than is one milked at regular intervals.[13,14,21] One obvious explanation is the absence of the flushing of the canal that occurs with regular milking. Another hypothesis is that the increase in intramammary pressure that occurs for several days after drying off might shorten and dilate the teat canal, thus increasing its penetrability. However, Thomas *et al*[21] were unable to show that intramammary pressure, amount of milk leakage, milk yield at drying off or teat patency were related to susceptibility to new dry period infection.

Recently Cousins *et al*[3] presented new and convincing evidence that heightened susceptibility in the dry period is due to enhanced penetrability of the streak canal. They showed that bacteria placed in the teat canal at drying off multiplied and sometimes penetrated the teat sinus. However, in cows dry for 28 days before inoculation, the bacteria were usually restricted to the site of inoculation or did not survive at all. These workers postulated development of bacterial inhibitors within the teat canal at later stages of the dry period.

In an effort to follow up the work just described, we undertook a study of the microscopic anatomy of the teat canal during the early dry period.[2] One teat from each of 6 cows was surgically removed[a] on the day of drying off (Day 0) and on days 7, 16 and 30 of the dry period. Histologic and morphometric studies of the teat canal and scanning electron microscopic studies of the teat cistern epithelium were carried out. Perhaps the most interesting finding was that the diameter and cross-sectional area of the teat canal were significantly greater on day 7 than on days 0, 16 or 30. This result suggests a temporary dilation of the streak canal during the first week of the dry period, a time of very high susceptibility.

Changes in the histology of the teat canal epithelium were also noted. The thickness and area of the stratum granulosum, which gives rise to the teat canal keratin, decreased throughout involution. This change was probably a result of continuing keratinization which sometimes resulted by day 16 of the dry period in the formation of a plug of loose keratin completely occluding the teat canal. This greater mass of keratin may be a factor in reduced penetrability of the canal at later stages of involution.

Also of interest in this study were the changes in the teat cistern epithelium detected by scanning electron microscopy. The epithelium lining the teat cistern is arranged in numerous longitudinal folds. The surface of the epithelium is made up of flattened hexagonal cells usually with prominent microvilli on their surfaces. Some cells however, do not have these microvilli. These nonmicrovilliated cells are thought to be mature cells in the early stages of degeneration. Their importance in mastitis arises from the fact that some bacteria adhere preferentially to these nonmicrovilliated cells.[6] This adherence may be an important factor in the pathogenesis of infection. In these studies it was shown that the proportion of these nonmicrovilliated cells decreases as involution progresses, possibly resulting in increased resistance to infection. Such basic studies of the teat canal and its adjacent structures may help to explain the changing susceptibility to infection during the dry period and may eventually suggest methods for prevention of these infections.

A third group of factors in susceptibility to infection is the resistance mechanisms within the mammary gland itself. Smith and Todhunter[20] recently reviewed current information on these resistance factors during the dry period. They noted that when the gland is fully involuted most of these resistance factors including phagocytic cells, immunoglobulins and lactoferrin are present in high concentrations. However, they suggested that at the beginning and end of the dry period, which are periods of both functional transition of the mammary gland and of high susceptibility to infection, these systems may be compromised.

Antibiotic therapy during the dry period

There is no doubt that antibiotic therapy during the dry period is one of the most effective mastitis control measures now available. Its advantages are the higher cure rates than obtained with lactational therapy without the need to discard milk from treated cows and with only minimal risk of antibiotic contamination of salable milk. One remaining point of controversy relates to whether it is necessary to treat all dry cows even when the level of infection in a herd has been reduced to low levels. In my opinion, the weight of the evidence available indicates that continued treatment of all cows is the preferred approach. This conclusion is based largely on two factors. The first is that no screening method, or combination of screening methods, presently available will detect all infected cows; at the same time these screening methods will identify many uninfected quarters as infected.[17] Even by resorting to culture of all cows we cannot be certain that we correctly identify all those infected since errors in culture results will also occur.

A second argument for treatment of all dry cows is that the maximum prophylactic effect, i.e., the prevention of new infection, can only be realized by treatment of all dry cows. In clean herds, those with a low prevalence of infection, new dry period infections make up a very large proportion of the infections present at calving. In such herds the prophylactic effects of dry period therapy are of potentially greater benefit than curing the infections present when the cows were dried off.

One shortcoming of conventional dry cow therapy is that some cows treated at drying off do have mastitis at calving. Frequently these cases are due to new infections contracted during the dry period, and they indicate a failure of the prophylactic effect of dry period therapy. A possible reason

[a]*Appreciation is expressed to Dr. L. C. Griel, Jr. for performing the surgery.*

for these failures is that dry cow products are formulated for effect against gram-positive bacteria even though in some herds gram-negative bacteria comprise many of the new dry period infections. A second reason may be that antibiotics infused at drying off provide protection in the early dry period but not in the prepartum period.

In a recent trial we examined whether a dry cow product containing cephapirin sodium[a] given 30 days before expected calving would reduce new coliform infections. This treatment, either alone or in combination with therapy at drying off, did not reduce new gram-negative infections as compared to treatment at drying off only. In addition about 1/3 of the cows treated in the prepartum period had bacterial inhibitors in their milk for more than 1 day after calving, and in some cases these were detectable for more than 10 days. On the other hand Pankey *et al*[16] recently reported that administration of a lactating cow product containing novobiocin and procaine penicillin G 1 to 3 days before calving appeared to be effective in reducing new *S. uberis* infections present at calving. Possibly a lactating cow product containing a broad spectrum antibiotic given shortly before calving would reduce new gram-negative infections. However, given the difficulty of predicting exactly when cows will calve, this procedure may pose some difficulties.

Other methods for reducing new dry period infections

Early work on germicidal teat dips indicated that teat dipping at drying off reduced new *S. aureus* but not new *S. uberis* infections.[15] This result is plausible as teat dipping should be effective in reducing *S. aureus* populations remaining on the teats from the preceding lactation but might be less effective against continuing streptococcal contamination from the environment. In more recent studies, teat dipping during the dry period was ineffective.[22,23] However, English workers recently suggested that persistence of the germicide might be an important factor in reducing infections by environmental pathogens.[7] Development of teat dips with very persistent germicides might lead to improved control of new dry period infections.

Teat sealers have been reported to reduce new coliform infections during lactation.[5] Products that would effectively seal the teat orifice during the critical times of the dry period might reduce new infections. However, to be effective, the sealers would need to be more persistent and durable than those available now. An internal sealer, which is reported to form a physical barrier inside the teat sinus, has been tested in Ireland with promising results.[9] Should sealers prove to be practical and effective, it will still be necessary to identify quarters already infected at drying off for antibiotic therapy.

Some dairymen prefer to dry cows off by intermittent milking, that is, to reduce the frequency of milking gradually over a period of days. Natzke *et al*[10] reported that in untreated cows, intermittent milking resulted in fewer new infections and in a lower level of infection at calving than abrupt cessation of milking; therefore, they concluded that in untreated cows intermittent milking was preferred. However, in cows treated at drying off the method of drying off had little effect on new infections and either the intermittent or abrupt method was satisfactory.

Other suggestions for control of new infections in the dry period relate to providing a clean dry environment for dry and calving cows. Since many of the bacteria causing dry period infections are of environmental origin, reducing the cow's exposure to these organisms will likely reduce these infections. As the prepartum period is a time of high susceptibility to infection, special attention should be paid to calving cows. Because sawdust is known to harbor large coliform populations, clean dry straw is probably a preferred bedding for maternity stalls.

[a] *Cefa-Dry, Bristol Laboratories, Syracuse, N.Y.*

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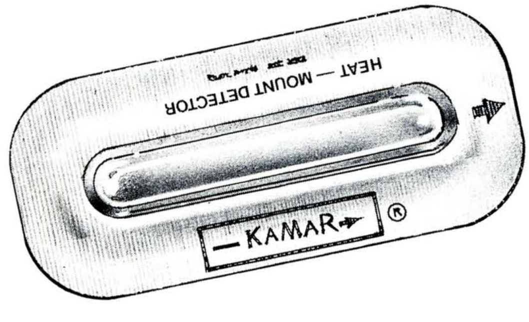

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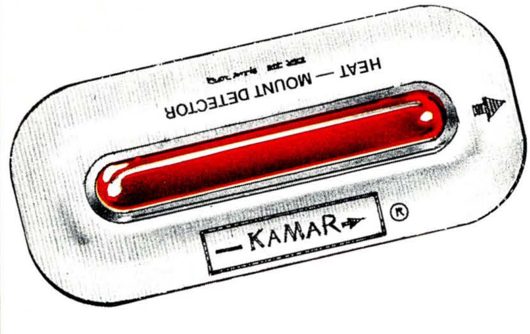

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