A REVIEW OF MASTITIS DETECTION, PREVENTION, AND CONTROL IN DAIRY REPLACEMENT HEIFERS

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ABSTRACT

The prevalence of mastitis in breeding age and bred dairy heifers is higher than previously realized. Existing infections, which are primarily caused by the coagulase-negative staphylococci, *Staphylococcus aureus*, and environmental streptococci can be controlled through intramammary therapy. Nonlactating cow therapy administered during pregnancy but no sooner than 45 days prepartum or lactating cow therapy administered 2 weeks prepartum effectively eliminate the vast majority of infections while minimizing drug residues. In addition, milk production is increased approximately 10% and somatic cell counts are lowered. Prevention is the key to controlling heifer mastitis and can be implemented by vaccination and fly control programs.

INTRODUCTION

Replacement heifers, whether they are raised on the farm, purchased from other dairies, or contract raised by growers, are critical to herd productivity because they represent the future milking and breeding stock in all dairy operations. The goal should be to provide an environment for heifers to develop full lactation potential at the desired age with minimal expense. Animal health and well-being play vital roles in achieving this potential, and one disease that can influence future productivity is mastitis.

Unfortunately, most producers regard young heifers as uninfected, and the presence of mastitis is not observed until freshening or until the first clinical flare-up in early lactation. Thus, animals may carry intramammary infections for a year or more before they are diagnosed with mastitis. The greatest development of milk-producing tissue in the udder occurs during the first pregnancy, so it is important to protect the mammary gland from pathogenic microorganisms to ensure maximum milk production during the first lactation. Louisiana researchers found that if bred heifers infected with *Staphylococcus aureus* were left untreated, they produced 10% less milk in early lactation than those receiving therapy (Owens et al., 1991). Research in New Zealand has shown that *Staphylococcus aureus* mastitis in heifers results in significant production losses during the first lactation, which carries over into the subsequent lactation, even if infected quarters are successfully treated (Meany, 1981).

PREVALENCE OF HEIFER MASTITIS AND SOMATIC CELL COUNTS

Researchers became interested in heifer mastitis in the mid 1980s after several dairy producers complained that a large percentage of their heifers were freshening with clinical mastitis. Subsequent study of breeding age animals revealed that intramammary infections may be diagnosed as early as 6 months of age, and infections persist throughout pregnancy and into lactation. Other studies demonstrated that greater than 90% of breeding age and bred heifers (12 to 24 months of age) may be infected (Trinidad et al., 1990b). Most of the infections were shown to be caused by the coagulase-negative staphylococci (*Staphylococcus chromogenes* and *Staphylococcus hyicus*) followed by *Staphylococcus aureus* (20%). Mixed isolates of coagulase-negative staphylococci (CNS) and *Streptococcus* species were also found.

Somatic cell counts (SCC) are used to assess udder health status of mature, lactating cows, and this parameter has been examined in heifer mammary secretions. In secretions from uninfected quarters, SCC are approximately 5,000,000. The volume of mammary secretion is very low in breeding-age animals; thus, SCC become concentrated, resulting in high SCC. However, SCC may be 20,000,000 in quarters infected with *Staphylococcus aureus* and over 10,000,000 in those infected with the CNS and *Streptococcus* species. Such elevated SCC in infected quarters over a long period of time suggests that these mammary glands would be in a state of chronic inflammation, which would adversely affect development of milk-producing tissues. In fact, histological analysis of mammary tissues obtained from bred heifers chronically infected with *Staphylococcus aureus* demonstrated that the potential for milk production was reduced significantly compared with tissues from uninfected quarters Trinidad et al., 1990a).

EFFICACY OF NONLACTATING DRY COW ANTIBIOTIC TREATMENT

Because of the high level of infection commonly found in heifers at in some dairies, especially mastitis caused by *Staphylococcus aureus*, infected quarters should be treated. The testing of various staphylococcal isolates obtained from heifers for susceptibility to antibiotics commonly incorporated into mastitis infusion tubes has shown that antibiotic resistance is usually low. Greater than 90% of mastitis-causing staphylococci are generally killed by the drug preparations used (Watts et al., 1995). From a practical standpoint, the administration of antibiotics by a parenteral route would be preferred; however, neither subcutaneous nor intramuscular injections of drugs have been found to cure intramammary infections. Parenteral treatment is ineffective because sufficient antibiotic does not pass into the mammary gland to be bactericidal. Thus, intramammary infusion is the route of choice.

Prior to treatment, heifers should be restrained in a squeeze chute equipped with a head gate. Teat ends should be scrubbed with cotton balls soaked in 70% alcohol or with the pledgets accompanying mastitis tubes in order to sanitize the teat orifice prior to infusion. While administering the antibiotic, the partial insertion technique must be used to avoid stretching the teat canal and the sphincter muscle as well as to avoid the introduction of bacterial contaminants. All quarters of each animal should be treated to cure existing *Staphylococcus aureus* infections and to prevent new ones. After infusion, teats should be immersed in a barrier teat dip to seal the teat orifice and prevent entrance of contaminating bacteria.

The cure rate for *Staphylococcus aureus* mastitis after use of nonlactating cow therapy in heifers is more than 90%. Therapies evaluated have included: (1) a product containing 1 million units of penicillin and 1 gram of streptomycin, (2) a product containing 300 mg cephapirin benzathine, and (3) a product containing 400 mg novobiocin with 200,000 international units (IU) of penicillin. This is far greater than the 25% cure rate observed after mature cows are treated during lactation for this disease using conventional lactating cow therapy. Reasons for this high cure rate are unclear, but the relatively small secretory tissue area of heifer mammary glands compared with mature cows might allow for greater drug concentrations in the udder of the heifer. Similarly, histological studies have demonstrated less scar tissue and abscess formation in the mammary glands of heifers compared with older cows, a condition which would allow for better drug distribution and better contact with colonized bacteria.

In one study, an economic analysis was performed to justify use of the heifer treatment program. Production data collected over the first 2 months of lactation demonstrated that *Staphylococcus aureus* infected heifers receiving nonlactating cow therapy during pregnancy produced an average of 5.5 pounds (2.5 kg) more milk per day than herdmates that did not receive treatment (Trinidad et al., 1990c). At the milk price received at that time, the greater milk yield translated to a $42.00 increase for treated heifers, which was well worth the $5.00 cost of treatment. Other advantages include a longer productive life and higher income due to quality milk premiums.

Treatment of animals 8 to 12 weeks prior to expected calving date with 300 mg cephapirin benzathine resulted in a cure rate of greater than 95% (Owens et al., 1991; 1994). An examination of SCC showed that at the time of treatment, SCC were 15,000,000/ml but decreased to 4,000,000/ml 1 wk later and to 700,000/ml on the day of calving. If infected quarters were left untreated, heifers freshened with *Staphylococcus aureus*-infected quarters with an average SCC of 5,000,000/ml. When these later animals were treated with lactating cow products immediately after calving, cure rate was only 56%. Thus, cure rates are much greater when a nonlactating cow products are administered 2 to 3 months prepartum than when a lactating cow product is given shortly after calving.

EFFICACY OF LACTATING COW PRODUCTS

Lactating cow products have been used successfully in heifers when treating infections caused by the coagulase-negative staphylococci immediately prior to calving. In one study, quarters of infected heifers were infused one time at approximately 1 week prepartum with either 200 mg sodium cloxacillin, 200 mg cephapirin sodium, or left untreated (Oliver et al., 1992). At the time of infusion, approximately 90% of heifers were infected in one or more quarters, and if left untreated, 78% of animals remained infected at time of calving. However, only 18% of the heifers remained infected at calving if they were treated prepartum, regardless of the treatment used. This study also examined the influence of prepartum antibiotic treatment on subsequent lactational performance and demonstrated that heifers receiving treatment produced approximately 1,000 pounds (455 kg) more milk per lactation than untreated controls.

Prepartum treatment with lactating cow therapy has been shown to be effective for quarters infected with coagulase-negative staphylococci, but waiting until this time to treat chronic *Staphylococcus aureus* mastitis might be too late. A mammary gland that has been infected with *Staphylococcus aureus* for several months to a year will not develop normally, and treatment during the immediate prepartum period would most likely be of little benefit in curing infections or salvaging mammary tissue. At this point, the tissue damage would have already been done, and affected quarters should have been treated earlier in gestation to: (1) cure existing infections; (2) reduce chronic inflammation; and (3) allow mammary tissue to develop normally during the later stages of pregnancy.

THE OPTIMUM TREATMENT SCHEDULE

The question arises as to when is the best time to treat bred heifers for optimizing cures against *Staphylococcus aureus* mastitis. A 2-year study involving 175 Jersey heifers was designed to answer this question (Owens et al., 2001). In the trial, heifers were sampled shortly after they were confirmed pregnant and at 4-week intervals thereafter. After the initial sampling, animals were treated with a one-time infusion of one of three nonlactating cow infusion products during the first (0 to 90 days), second (91 to 180 days), or third (181 to 270 days) trimester of pregnancy. Products evaluated were: (1) a combination of 1 million units of penicillin and 1 gram streptomycin, (2) 300 mg cephapirin benzathine, and (3) a combination of 400 mg novobiocin and 200,000 units of penicillin G. Cure rates among treatments indicated that all antibiotics were equally effective in curing infections, and there were no apparent effects of the timing of therapy on cure rate. Treatment efficacy ranged from 83.3 to 100%.

Because therapy during the first, second, or third trimester of gestation had no effect on treatment efficacy, the timing of treatment is best determined by what is most convenient for the management practices of a particular dairy. For example, heifers could be treated: (1) at time of artificial insemination, (2) during routine rectal palpation to determine pregnancy status, or (3) when moved to a close-up pen. Treatment should be administered no less than 45 days prior to expected calving date to prevent antibiotic residues at calving.

The treatment of heifers during pregnancy with a nonlactating cow product is advantageous because: (1) the cure rate is higher than during lactation, especially against *Staphylococcus aureus*; (2) there are no milk losses during therapy; (3) the risk of antibiotic residues is minimal; (4) SCC at calving is reduced; and (5) milk production is increased by approximately 10% in successfully treated cows. Treatment is indicated only in herds experiencing a 5% or greater prevalence of heifers calving with clinical mastitis caused by *Staphylococcus aureus*. The potential for residues at calving should be considered, especially in animals that calve early. Residue testing should be carried out before mixing milk from treated animals with herd milk.

INFLUENCE OF DIETARY SUPPLEMENTATION

Another management tool to reduce the level of infection and SCC when heifers calve as well as throughout lactation is through dietary supplementation with micronutrients. Diet plays a role in udder resistance to infection because certain nutrients affect various mammary resistance mechanisms, namely: (1) leukocyte function, (2) antibody transport, and (3) mammary tissue integrity. In one study, heifers received selenium (0.3 ppm/day) and vitamin E (50 to 100 ppm/day) supplementation starting 60 days prepartum (Hogan et al., 1993). A selenium booster injection (50 mg) was administered 21 days prior to freshening, and the dietary supplementation was continued throughout lactation. Dietary supplementation reduced staphylococcal and coliform infections at calving by 42%. Although rate of new infection during lactation did not differ from unsupplemented controls, the duration of infection caused by organisms other than *Corynebacterium bovis* was reduced 40% to 50% in supplemented heifers. Clinical mastitis in supplemented heifers was reduced 57% in early lactation and 3.2% throughout lactation, and the mean SCC was lower. Thus, vitamin E and selenium improved udder health of heifers, and the effect of dietary supplementation was most evident at calving and in early lactation.

ROLE OF VACCINATION IN MASTITIS CONTROL

Recent research has demonstrated that several experimental *Staphylococcus aureus* vaccines, as well as one commercial vaccine, can increase antistaphylococcal antibody titers and reduce the new infection rate in heifers. A *Staphylococcus aureus* vaccine formulated to stimulate pseudocapsule and alpha toxin antibodies was evaluated in heifers in New York (Sears et al., 1990). At 4 and 2 weeks prior to calving, heifers were given subcutaneous injections into the supramammary lymph node, and after calving, heifers were challenged with *Staphylococcus aureus*. Vaccinates demonstrated a 52% reduction in new IMI. In addition, 64% of IMI in control cows became chronic compared with only 12% in vaccinates.

A field study in Norway evaluated a *Staphylococcus aureus* vaccine that contained two strains of whole, formalin-inactivated bacteria with pseudocapsule, alpha and beta toxoids, and mineral oil as an adjuvant (Nordhaug et al., 1994). A total of 108 pregnant heifers on 16 farms with an average *Staphylococcus aureus* prevalence of 19.2% was used. Vaccinates were injected subcutaneously in the area of the supramammary lymph node with a dose of 2.5 ml at 8 and 2 weeks before calving. Results showed a 46% reduction in new IMI during the subsequent lactation. Antibody titers to *Staphylococcus aureus* pseudocapsule and alpha toxin were markedly elevated in the serum of vaccinates, and these titers remained significantly higher in serum and milk during the entire lactation compared with those of unvaccinated controls.

In Argentina, a vaccine was developed based on an inactivated, encapsulated *Staphylococcus aureus* strain, a crude extract of *Staphylococcus aureus* exopolysaccharides, and inactivated, unencapsulated *Staphylococcus aureus* and *Streptococcus* species in an aluminum hydroxide adjuvant (Giraudo et al., 1997). This formulation was evaluated in three groups of ten 24- to 26-month-old heifers each in a 7-month trial. The first group received an intramuscular injection of the vaccine in the neck at 8 and 4 weeks prepartum, the second group was vaccinated similarly at 1 and 5 weeks postpartum, and a third group (control) received placebo injections at 8 and 4 weeks prepartum. The research herd from which the heifers were selected had bulk tank SCC ranging from 480,000 to 730,000, and 19% of quarters were infected with *Staphylococcus aureus*. This immunization program showed that the frequency of new *Staphylococcus aureus* infection was reduced from 18.8% in controls to 6.7 and 6.0% for heifers vaccinated prepartum and postpartum, respectively; the protective effect was maintained for at least 6 months.

In view of more recent studies showing success of vaccines in heifers, researchers in Louisiana evaluated a commercially available *Staphylococcus aureus* vaccine in young dairy animals (Nickerson et al., 1999). The vaccine was a lysed culture of polyvalent somatic antigens in aluminum hydroxide. At 6 months of age, heifers were vaccinated using a 5-ml dose intramuscularly, and 14 days later, vaccinates received a booster dose, which was repeated at 6-month intervals. Results demonstrated that: (1) the number of quarters exhibiting chronic intramammary infection during pregnancy was reduced 43.1% in vaccinates compared with controls, (2) rate of new intramammary infection during pregnancy was reduced 44.8%, and (3) rate of new intramammary infection at freshening was reduced 44.7%.

It is obvious that use of experimental and commercially available *Staphylococcus aureus* vaccines can be used to prevent new infections, especially when used in heifers. Efficacy has been shown to range between 44 to 86%, and this prevention strategy may represent a major control mechanism for managing *Staphylococcus aureus* in the future, especially as new antigens and adjuvants are added to vaccine preparations.

OTHER FACTORS TO CONSIDER

Breed: In other investigations of mastitis in heifers, additional parameters have been evaluated. For example, the overall prevalence of infection was found to be approximately twice as high in Jerseys (68%) compared with Holsteins (35%).

Flies: Research has shown that horn flies transmit mastitis-causing bacteria as they feed on teat ends, causing lacerations of the tissue. Such lesions become an ideal place for bacteria to colonize, which eventually enter into the developing udder. Heifers with teat skin scabs and abrasions induced by flies have a higher frequency of infection (70%) than heifers with normal teats (40%). Moreover, herds using some form of fly control have been shown to have markedly fewer infections with environmental streptococci and *Staphylococcus aureus* and somewhat fewer coagulase-negative staphylococcal infections than those without fly control.

Insecticide-impregnated tail tags have been developed in attempts to control flies as well as mastitis in dairy heifers. In North Carolina, heifers reaching puberty in the summer months were fitted with tags, and the presence or absence of abnormal milk was noted at calving. Results indicated a beneficial effect of this control measure. A subsequent study conducted during the spring and summer in Louisiana demonstrated that the same tail tags were successful in reducing fly populations (60% decrease) and the incidence of new intramammary infections during the first 2 months after placement, but thereafter, there was little control of either parameter. In animals with tags, the incidence increased from 8.6 to 15% over 2 months, while in controls, incidence increased from 17.2 to 52.4%.

Clinical Mastitis: An examination of the frequency of clinical mastitis during pregnancy among bred heifers in one field trial revealed a level of 7.5%. At the time of calving, frequency of clinical cases increased to 24%, indicating that either the presence of new infections during the prepartum period led to flare-ups of clinical mastitis at freshening or that chronically infected quarters in heifers should be controlled prepartum rather than at or following freshening. Somatic cell counts in uninfected quarters decreased from

7,600,000/ml at the initial sampling during pregnancy to 1,500,000/ml at time of calving. In infected quarters, SCC decreased from 23,100,000/ml during pregnancy to 4,100,000/ml at calving. This again indicates the need for infected heifers to be treated in order that they enter the milking herd with low SCC.

Secretion Characteristics: The monitoring of mammary secretion characteristics demonstrated that quarters with a honey-like consistency exhibited low frequencies of infection (10%), whereas those with a thin, watery secretion with clots and flakes exhibited a high frequency of infection (78%).

Season: The effect of season on prevalence of infected quarters in breeding age heifers demonstrated that level of infection increased from winter to spring and summer and decreased in the fall.

SOURCES OF INFECTION

How do heifers contract intramammary infections? No one knows for sure. Sources may include: (1) bacteria that are the normal flora on udder skin, which are in an opportunistic position to colonize the teat end and enter the teat orifice; (2) bacteria harbored in the oral cavities of calves, which suckle other calves; (3) bacteria present in the heifers' environment, such as those found in soil, manure, and bedding materials; and (4) bacteria present on biting flies that congregate on teat ends.

Normal flora would be almost impossible to control, as these microorganisms are naturally found on the udders and teat skin. Perhaps daily teat dipping would reduce bacterial populations, but this practice would be highly impractical. The transfer of mastitis-causing bacteria through cross-suckling of calves fed mastitis milk can be prevented by housing calves in individual hutches, and this management practice has become fairly routine. As with attempts to control normal udder flora, the control of environmental mastitis-causing bacteria has its limitations; however, the percentage of intramammary infections caused by environmental streptococci and coliforms in heifers is low, except just prior to freshening. Flies have certainly been implicated in the spread of mastitis-causing bacteria among heifers and should be a major focus of control.

TREATMENT AND PREVENTION MANAGEMENT STRATEGIES

Currently, there are no established management practices to prevent young dairy heifers from contracting intramammary infections, other than use of individual calf hutches to prevent cross-suckling. As stated above, whether such infections are caused by flies, bacteria in the environment, or natural oral and udder skin flora remains to be proven. However, once an intramammary infection is diagnosed, the use of nonlactating cow therapy has proven highly effective in curing this disease. The producer has the responsibility of ensuring that an animal remains healthy in his care, and this responsibility should include udder health. It is his responsibility to culture any new animals that are brought into his herd to avoid the introduction of contagious mastitis-causing microorganisms such as *Staphylococcus aureus*. Some producers and veterinarians worry that sampling heifers for presence of mastitis may destroy the keratin plug, leading to new infections. However, studies designed to test this theory have demonstrated that as long as: (1) teat ends were properly sanitized; (2) samples were taken aseptically; and (3) teats were dipped in a barrier type product after sample collection, there was no effect on the development of new infections.

CONCLUSIONS

Whether heifers are raised on the dairy or in grower operations, managers of these young dairy animals should be vigilant of udder health. Visual and manual examination of the developing udders, mammary fluid, and teat skin will help identify swollen quarters, abnormal secretions, and presence of teat scabs. Individual swollen quarters with abnormal secretions (clots and flakes) and those with teats exhibiting scabs and abrasions are most likely to be infected and should be treated. It is suggested that nonlactating cow therapy of heifers be carried out if greater than 5% of animals are freshening with *Staphylococcus aureus* mastitis. Managers should be cautioned, however, that treatment of bred heifers may constitute extra-label drug use and should be carried out under the supervision of the herd veterinarian and within the context of a valid veterinary/client/patient relationship. Prevention strategies may best be applied through vaccination and fly control programs. However, at present, few commercial vaccines are available, and the optimal fly control program has yet to be demonstrated.

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