DECISION TREE ANALYSIS OF TREATMENT STRATEGIES FOR MILD AND MODERATE CASES OF CLINICAL MASTITIS OCCURRING IN EARLY LACTATION

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Abstract

The objective of this study was to develop a decision tree to evaluate the economic impact of different durations of intramammary treatment for the first case of mild or moderate clinical mastitis (**CM)** occurring in early lactation with various scenarios of pathogen distributions and variable use of on-farm culture. The first decision node in the tree evaluated use of on-farm culture (**OFC**) (two programs using OFC and one not using OFC) and the second decision evaluated treatment strategies (no intramammary antimicrobials or antimicrobials administered for 2, 5 or 8d). The tree included probabilities for realistic distributions of etiologies, bacteriological cure and recurrence. The economic consequences of mastitis included costs of diagnosis and initial treatment, additional treatments, labor, discarded milk, milk production losses due to clinical and subclinical mastitis, culling and transmission of infection to other cows (only for CM caused by *S. aureus*). Pathogen specific estimates for bacteriological cure and milk losses were used. The economically optimal path for several scenarios was determined by comparison of expected monetary values. For most scenarios, the optimal economic strategy was to treat CM caused by Gram-positive pathogens for 2 days and to avoid antimicrobials for CM cases caused by Gram-negative pathogens or when no pathogen was recovered. Use of extended intramammary antimicrobial therapy resulted in the least expected monetary values.

Introduction

Mastitis has a negative economic impact on dairy farms in terms of discarded milk, lost production, reduced milk quality and treatment costs (Gröhn et al., 2004). While antimicrobial therapy is not necessary for successful treatment of CM caused by all pathogens, most cows with cases of CM are treated with intramammary antimicrobials (Pol and Ruegg, 2007). The evaluation of treatment strategies for CM can be at the cow level and is based on biological and economic factors. In recent years, the use of extended duration therapy has been recommended and some studies support the concept that extended therapy significantly increases treatment efficacy for some mastitis pathogens (Deluyker et al., 2005; Gillespie et al., 2002; Oliver et al., 2003; Oliver et al.,2004ab). However, the economic impact of mastitis treatments that are administered for extended durations has not been evaluated. Decision tree analyses have been successfully used to evaluate economic decision making for treatment of various diseases of dairy cows (Ruegg and Carpenter, 1989; Dorshorst et al., 2006). The objective of this study was to develop a decision tree to evaluate the economic impact of different durations of intramammary treatment for the first case of mild or moderate clinical mastitis occurring in early lactation with various scenarios of pathogen distributions and use of on-farm culture.

Materials and Methods

A comprehensive presentation of the materials and methods has been previously described (Pinzón-Sánchez, et al., 2011). In brief, a decision tree analysis was performed at the cow level for primiparous and multiparous cows that were affected at 30 DIM with mild or moderate clinical mastitis in a single quarter. The economic impact for the remainder of the 305 d lactation was determined using economic values and probabilities that were derived from research literature. The first decision node evaluated diagnostic strategies: 1. Use OFC, wait 24 hours before initiating treatment (**OFCW**); 2. begin treatment before results known, after 24 hours adjust treatment based on results of OFC (**OFCT**); or 3) treatment without diagnosis of causative pathogen (**NOOFC**). The second decision evaluated 4 treatment strategies (no antimicrobials or antimicrobials administered for 2, 5 or 8d). The tree included probabilities for realistic distributions of etiologies, bacteriological cure (**BC**) and recurrence. The distribution of etiologies was modeled for 3 scenarios: 1) baseline – 35% Gram-positive (only 2% Staph aureus), 30% Gram-negative and 35% no growth; 2) Greater contagious – 70% Gram-positive (40% Staph aureus), 15% Gram-negative and 15% no growth; and 3) Greater coliform – 15% Gram positive, 70% Gram-negative and 15% no growth. For each scenario, parity and pathogen specific weighted average probabilities of BC for each treatment strategy were calculated using data from peer-reviewed literature (references are in Pinzón-Sánchez et al., 2011). The probability of recurrence was estimated based on Pinzón-Sánchez & Ruegg, 2011. For primiparous cows, the probability of recurrence was assumed to be 2% for cases that resulted in BC or 25% for cases that experienced persistent infection. For multiparous cows, the probability of recurrence was assumed to be 12% for cases that resulted in BC or 35% for cows that experienced persistent infection. The economic consequences of mastitis included costs of diagnosis, treatment, labor, discarded milk, milk production losses due to clinical and subclinical mastitis, culling and transmission of infection to other cows (only for CM caused by *S. aureus*). Milk production losses included milk loss due to CM, discarded milk, and milk loss due to chronic subclinical mastitis. Pathogen specific milk production losses due to CM were estimated separately for primiparous and multiparous cows based on Gröhn et al. (2004). Production losses due to persistent subclinical infection were calculated for cows that did not experience BC. For CM caused by Gram-positive bacteria, milk production losses were assumed to persist for the remainder of the lactation while for CM caused by Gram-negative bacteria or when no pathogen was recovered, milk production losses were assumed to occur for only 2 months after occurrence of the case (DeHaas et al., 2004). Treatment costs included the cost of diagnosis (when OFC was used), discarded milk and the cost of using a generic IMM treatment (labor and drug costs). Cows infected with *S. aureus* that did not experience BC were assumed to remain subclinically infected, and the potential transmission of contagious pathogens to herdmates was estimated per Swinkels et al. (2005b). The cost of premature culling was based on Dorshorst et al. (2006). There is no research literature that describes milk production subsequent to drying off an infected quarter so it was assumed that 10% of cows experiencing a recurrent case resulted in drying off of the quarter and a subsequent 15% reduction in milk yield. The costs due to recurrent cases included the total cost of 5d IMM treatment, potential loss of a mammary gland quarter and potential transmission (for cases caused by *S. aureus*). Sensitivity analyses were performed by modeling minimum and maximum values for milk price, cost of labor, cost of antimicrobials, cost of OFC and for the varying distributions of etiologies.

Results

The economically optimal path for several scenarios was determined by comparison of expected monetary values (**EMV**). In this model, EMV are negative and represent reduction in milk income, thus an EMV of -$5 would be more optimal than -$10. The decision tree had 144 terminal values that represented the sum of the partial cash flow (total costs) of each possible outcome. Economic consequences were modeled for four possible states after treatment: 1) Cow experienced BC and CM did not recur, 2) Cow experienced BC but CM recurred, 3) Cow did not experience BC and CM did not recur or 4) Cow did not experience BC but the CM did recur. The least economic losses were observed for cows that experienced BC and did not have recurrent cases of CM (best case scenario) for primiparous cows (4-15% of potential milk income was decreased) and for multiparous cows (3-9% of potential milk income was decreased). The greatest proportion of losses was observed for cows that did not experience BC and had recurrent cases of CM (worst case scenario) for primiparous cows (17-23% reduction of potential milk income) and multiparous cows (12-23% reduction of potential milk income).

For the baseline distribution using all OFC systems and including all etiologies, a large difference was observed in EMV of extended treatments compared to the least negative EMV. For primiparous and multiparous cows the difference in EMV ranged from $33.50 to $163.28 per case greater for extended treatments. When OFC systems were used, the greatest difference was observed for treating Gram-negative (-$460) and no growth (-$508) for 8 days compared to no treatment ($-384). When OFC systems were used and the etiology of CM was Gram-positive, the treatment strategy with the least negative EMV was 2d treatment (EMV of about -$250 and -$355 for primiparous and multiparous cows, respectively). When NOOFC was used, the EMV per case were least for 2 days of treatment for multiparous cows (-$267). For primiparous cows the least EMV per case was for no treatment (-$323), however, the EMV for 2 days of treatment was only $3.65 greater than the EMV for no treatment.

For both other scenarios (herds with greater proportion of *S. aureus*, and herds with a greater proportion of coliforms) using all OFC systems and all etiologies large differences were observed for EMV of extended treatments compared to the least negative EMV. Similar to the baseline distribution, the EMV for extended therapy always resulted in the greatest losses. For both primiparous and multiparous cows, milk price had the greatest effect on the model cost of drug or cost of OFC, since minimal differences in EMV were observed for the extremes of the other variables.

Discussion

Decision tree analysis is used to combine biological knowledge with economic considerations and allows for the comparison of the economic impact of a variety of scenarios such as the various mastitis treatment strategies included in this model. Assumptions were made based on peer reviewed research and were performed for a case of mastitis that occurred in early lactation in a single mammary quarter. Early lactation was chosen so that the impact of mastitis on production would be maximized. Much of the commonly accepted knowledge about mastitis treatment is derived from research conducted when contagious pathogens caused most infections. In this study 3 separate scenarios of pathogen distribution were modeled to better reflect the situation on modern dairy farms.

Using model assumptions, only modest differences in EMV were observed based on use of OFC systems but large differences were observed based on duration of treatment. The small differences in EMV based on use of OFC were a result of the model selecting shorter duration treatments (or no treatment) as the optimal economic pathway to calculate overall EMV. In reality, cost savings that occurs when OFC is used is associated with reduced milk discard. In this model, those savings were not apparent because the model generally recommended no treatment or short duration therapy. If a farm was using short duration therapy (or no treatment) as the primary mastitis treatment strategy, this model indicates that OFC is not likely to result in additional economic benefits. In contrast, herds that routinely use extended duration therapy without regard for pathogen diagnosis could incur considerable savings by adopting OFC.

The cost per case of clinical mastitis varies widely among studies due to the inclusion of different costs and diverse objectives and populations studied. The total cost per case of CM in our model ranged from $106 to $867 and included costs of drugs, labor, discarded milk, milk losses due to clinical and subclinical mastitis, culling and recurrences. Pathogen specific milk production losses were estimated based on research conducted by Gröhn et al. (2004). However, these estimates included CM cases of all severities and in various stages of lactation, in contrast to the mild and moderate cases occurring at 30 DIM evaluated in this model, thus costs attributed to mastitis in this model may have been overestimated. The effects of subclinical mastitis were included in the calculations for this model for cases of CM that did not result in bacteriological cure and were also based on pathogen specific research (DeHaas, et al., 2004).

Extended duration IMM therapy has been shown to result in increased BC for mastitis caused by *S. aureus* and some environmental streptococci but routine use of extended duration therapy was not economically optimal under any circumstance evaluated in this model. Previous researchers have used partial budgeting to evaluate the economic impact of different treatment strategies for subclinical IMM infection caused by environmental streptococci or *S. aureus* (Swinkels et al., 2005ab). Similar to the results reported herein, Swinkels et al. (2005a) concluded that extended treatment is not economically feasible, due to increased cost of antimicrobials and increased losses due to milk discard. The same authors (Swinkels et al., 2005b) reported that extended duration treatment of subclinical mastitis caused by *S. aureus* was economically justified only in circumstances when the risk of transmission to other cows was great. When CM is treated without knowledge of etiology, it is difficult to justify the routine use of extended duration therapy for treatment of the first case of CM. While the least overall economic loss was typically associated with either a no treatment option or a 2d course of therapy, the differences in EMV between no treatment and 2d treatments were generally very small. Based on existing research, BC rates were only marginally improved by 5d of therapy relative to 2d of therapy and this is especially true when applied without regard to etiology. These small increases (5-10%) in bacteriological cure were not sufficient to offset the larger losses attributable to more days of discarded milk. In light of the limited amount of pathogen specific research and the uncertainty inherent in models, it is not prudent to conclude that no treatment is preferred but care should be taken to recommend extended duration therapy only in circumstances where etiologies and clinical experience suggest that a beneficial economic impact will result. Likewise, research should be conducted to identify cow level risk factors that may reduce the probability of BC when standard therapy is considered.

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