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A Partial Budget Model to Estimate Economic Benefits of Lactational Treatment of Subclinical *Staphylococcus aureus* Mastitis

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ABSTRACT

Subclinical *Staphylococcus aureus* mastitis is rarely treated during lactation because it is widely believed to be uneconomical, although there are no economic studies that support this view. Partial budgeting was used to develop a deterministic simulation model to estimate the net cost or benefit of antibiotic treatment of subclinical *S. aureus* mastitis during lactation. Direct and indirect effects of treatment were taken into account, including prevention of clinical flare-ups and contagious transmission. Input variables were based on literature and on 2003–2004 prices in the Netherlands. When contagious transmission of *S. aureus* was likely (reproductive ratio R = 5.3), 3- and 8-d treatments resulted in an average net profit of €95.62 and €142.42, respectively, compared with no treatment. When the probability of *S. aureus* transmission was low (R = 0.32), the average economic benefit of 3- or 8-d treatment was –€21.12 and –€57.70, respectively. On low-transmission farms, 3-d treatment was profitable when the appropriate cows were selected for treatment using known risk factors for cure. Sensitivity analysis showed that the 6 most influential input variables in the model were chance of bacteriological cure, R, probability of culling, retention pay-off, and cost of antibiotics and bacterial culture. Although the economic outcome of lactational treatment of subclinical *S. aureus* mastitis is highly herd-, cow-, and strain-dependent, treatment is economically justified in many situations.
(**Key words:** *Staphylococcus aureus*, treatment, economic, partial budget)

Abbreviation key: BMSCC = bulk milk somatic cell count, **PC** = probability of cure, **PR** = penicillin-resistant, **PS** = penicillin-sensitive, **R** = reproductive ratio, **RPO** = retention pay-off.

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INTRODUCTION

Staphylococcus aureus mastitis is a highly prevalent and costly disease. Control of *S. aureus* mastitis through preventive measures, dry cow treatment, and culling of infected animals can be economically profitable (Goodger and Ferguson, 1987; Zepeda et al., 1998). In addition to dry cow treatment, treatment of clinical mastitis is part of most standard mastitis control programs. By contrast, treatment of subclinical *S. aureus* mastitis during lactation is generally considered ineffective (Fox and Gay, 1993) and not economically justified when used as a stand-alone mastitis control strategy (Allore et al., 1998).

When treatment of *S. aureus* mastitis is postponed until the dry period, duration of infection increases. Indicators of chronic infection include prolonged periods or heightened levels of shedding of bacteria or somatic cells, palpable tissue changes, and infection of multiple quarters within a cow. All of the aforementioned factors are associated with a low probability of cure (Sol et al., 1997, 2000; Deluyker et al., 2005). In addition, long periods of infection and bacterial shedding create a prolonged window of opportunity for clinical mastitis to develop and for contagious transmission to occur (Lam et al., 1996; Zadoks et al., 2002a). Indirect effects of mastitis treatment (i.e., the prevention of clinical mastitis and transmission to other cows) are often overlooked in cost-benefit analyses but might tip the balance in favor of treatment (St. Rose et al., 2003; Swinkels et al., 2005). Some authors state that better cure rates are obtained by treating subclinical infections in lactation than by treating clinical cases of *S. aureus* mastitis (Bramley and Dodd, 1984). The chances of cure for cows that are subclinically infected with *S. aureus* can be improved by use of extended treatment (Deluyker et al., 2005) and by selection of treatment-eligible cows using current knowledge of risk factors for cure (Sol et al., 1997; Deluyker et al., 2005). Like inclusion of indirect effects, consideration of treatment and cow selection options will affect the outcome of cost-benefit analysis for antimicrobial treatment.

To determine the profitability of lactational treatment with antimicrobials, potential benefits of treat-

ment must be weighed against costs such as the price of antibiotics and loss of milk due to withholding times. The economic profitability of lactational treatment of subclinical mastitis has been demonstrated for *Streptococcus agalactiae* (Yamagata et al., 1987) and for non-agalactiae streptococci (Swinkels et al., 2005), but the value of lactational treatment of subclinical *S. aureus* mastitis has not been examined.

We explored the economic benefits of treating subclinical *S. aureus* mastitis during lactation under European conditions [milk quota in place, legal limit for bulk milk somatic cell count (**BMSCC**) <400,000 cells/mL] using partial budgeting. In this analysis, effects at the cow level, such as bacteriological cure and prevention of clinical mastitis, and effects at the herd level, specifically reduced transmission potential, were taken into account. In addition, knowledge of risk factors for cure was incorporated in the economic model, resulting in cow-specific outcomes for the profitability of lactational treatment of subclinical *S. aureus* mastitis.

MATERIALS AND METHODS

Modeling Approach

Partial budgeting was used to develop a deterministic simulation model that estimates the net cost or benefit of treatment of subclinical *S. aureus* mastitis during lactation. Input variables were based on the literature and on dairy prices and conditions in the Netherlands from 2003 to 2004. The effect of 3-d treatment or 8-d treatment with antibiotics, both of which are registered for use in the Netherlands and other European countries, was compared with the effect of no treatment. In a partial budgeting model, economic effects are calculated as total revenues weighed against total costs. Treatment is profitable compared with no treatment when total revenues of treatment are higher than the total costs. Total revenues are calculated as extra revenue plus reduced costs. Total costs are calculated as reduced revenue plus extra costs. Costs and benefits of treatment were calculated at the cow level for one lactation.

First, a basic model was developed based on biological and economic parameters. Biological parameters included clinical outcome of infection with *S. aureus* and effects at herd level, specifically contagious transmission. The risk of transmission may vary considerably between herds, depending on herd management (Lam et al., 1996; Zadoks et al., 2002a) and strain factors (Smith et al., 1998; Zadoks et al., 2002a). Therefore, 4 scenarios were analyzed: 1) 3-d treatment in a herd with low risk of transmission, 2) 3-d treatment in a situation with high risk of transmission, 3) 8-d treatment with low risk of transmission, and 4) 8-d treatment with high risk of transmission. Economic parameters and calculations for each scenario are described. Numbers are rounded off in the text, but were not rounded off in calculations, which explains any discrepancies that may occur. Next, sensitivity analysis was performed for the 4 scenarios to identify input parameters with a strong impact on the model outcome. Finally, because cow and strain factors influence the probability of cure, the effect of these factors on economic benefits was explored.

Biological Parameters in Basic Model

Cure of persistent infections. In the Netherlands, the sampling interval for milk yield, SCC, and component testing is usually 4 wk. A cow is suspected of subclinical mastitis if at least 2 of 3 consecutive samples have cow-milk SCC above 250,000 cells/mL. It is recommended that a milk sample of such an animal be submitted for bacterial culture so that treatment and management decisions can be based on knowledge of the causative organism. If the causative organism is *S. aureus*, treatment can be considered. In this paper, we focus on treatment decisions for *S. aureus* infections that are detected using this sampling scheme, i.e., infections that have existed for at least 30 d (minimum of interval between 2 SCC measurements plus time needed for bacteriology). Such infections will be referred to as "persistent" throughout the paper.

Persistent subclinical mastitis may be left untreated, or a decision to treat can be made (Figure 1). Farmers can choose between short-term antibiotic treatment (3-d treatment) and extended treatment (8-d treatment). Treatment can result in cure or in failure to cure. Untreated infections and infections that do not cure in response to treatment can cure spontaneously, continue to persist as subclinical infections, or develop into a clinical case of mastitis. Persistently infected animals may infect other animals. New infections may result in subclinical mastitis that cures spontaneously within 30 d, in persistent subclinical mastitis, or in clinical mastitis (Figure 1). All clinical cases are assumed treated and the model does not cover remission of clinical mastitis to subclinical mastitis.

The probability of spontaneous cure of persistent infections is low. Deluyker et al. (2005) describe a best-case scenario of 6% cure for untreated *S. aureus* infections. This best-case scenario applies to heifers in late lactation with low levels of bacterial shedding. For older animals, animals at less than 200 DIM, and animals with higher shedding levels, the probability of cure (**PC**) is even lower than 6%. We assumed an average PC of 3% for untreated animals with persistent subclinical *S. aureus* infection (Figure 1). According to a meta-