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Diagnosing intramammary infections: Evaluating expert opinions on the definition of intramammary infection using conjoint analysis

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ABSTRACT

The primary purpose of this study was to develop a set of criteria to serve as a pseudo-gold standard for what constitutes an intramammary infection using data from 3 consecutive quarter milk samples taken 1 wk apart. Data from lactating cows in 90 dairy herds in 4 Canadian provinces were used to generate the data sets (profiles) used in the conjoint analysis to elicit expert opinions on the topic. The experts were selected from the participants (n = 23) in the 2007 Mastitis Research Workers' Conference in Minneapolis and from a series of mastitis laboratory courses for bovine practitioners (n = 25) in the Netherlands. Three-week udder quarter profiles with specific combinations of somatic cell count, bacterial species isolated, and plate colony count were selected and included in the conjoint analysis based on the desire to achieve even distributions in the categories of 6 constructed variables. The participants were presented with 3 sets of cards with 20 cards in each set. On each card, they were asked to assign a probability of infection on the middle day (test day) in the 3-wk profile. Depending on the set of cards, they were asked only to be concerned with the probability of infection with coagulase-negative staphylococci, *Escherichia coli*, or *Staphylococcus aureus*. These 3 organisms were chosen to represent a minor pathogen, a major environmental pathogen, and a major contagious pathogen, respectively. The assigned probabilities for each organism were cross-tabulated according to the number of times the organism of interest was isolated in the 3-wk period, how many colonies of the organism of interest were isolated on the test day, and the somatic cell count (≤ or >200,000 cells/mL). There was considerable variation in the assigned probabilities within each of the combinations of factors. The median, minimum, and maximum values of the assigned probabilities for each combination were computed. The combinations with a median probability >50% were considered intramammary infection-positive and included as a criterion in the consensus standard. This yielded 4 possible criteria, which were condensed to the following 2 by consensus at the 2008 Mastitis Research Workers' Conference in Toronto: 1) the organism of interest was isolated on the test day with at least 10 colonies (1,000 cfu/mL), and 2) the organism of interest was isolated at least twice in the 3-wk period.
Key words: intramammary infection, definition, conjoint analysis, gold standard

INTRODUCTION

Mastitis is one of the most important diseases in dairy production, causing substantial economic losses to the industry worldwide. The primary pathway for these losses is the decrease in milk production, mainly caused by subclinical mastitis, making up an estimated two-thirds of the total annual loss caused by mastitis (Bramley et al., 1996).

There is a large volume of literature in which IMI has been defined for different purposes. However, the terminology is not always consistent. Notably, the terms IMI and subclinical mastitis are used almost interchangeably (Barkema et al., 1997; Deluyker et al., 2005). Intramammary infection entails presence of an infectious organism (Berry and Meaney, 2006). The definition is sometimes augmented with a requirement for an increased SCC. Subclinical mastitis indicates inflammation but not necessarily infection of the udder (International Dairy Federation, 1987); however, subclinical mastitis is most often caused by a bacterial infection (Djabri et al., 2002) and this may explain the frequent use of the term subclinical mastitis when referring to an IMI.

Definitions

In a selective review of the recent literature, several definitions of IMI were identified. These typically varied

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[2]Participants at Mastitis Research Workers' Conferences of 2007 and 2008 are recognized for their contributions to the process and their endorsement of the consensus views expressed in this manuscript. A complete list of participants is included in the Appendix.

with respect to the number of samples used to determine IMI status whether an indication of inflammation (usually SCC) was required (and the upper-limit SCC that differentiated a healthy quarter from an infected), the number of organisms cultured, and the number of colonies of the organisms cultured. Single, duplicate, and triplicate quarter milk samples over various time periods have been used to determine IMI status (Dingwell et al., 2003; Bansal et al., 2005; Hillerton et al., 2007).

In papers published in the last 5 yr, the SCC used as a cut point (i.e., minimal value required for a positive classification) varied between 100,000 and 300,000 cells/mL (Schukken et al., 2003; Bansal et al., 2005; Deluyker et al., 2005). With respect to the number of organisms cultured in the samples, some researchers considered a sample contaminated if 3 or more species were cultured (Parker et al., 2008) and others did not make any restrictions to the number of bacterial species cultured (Berry and Meaney, 2006). Several of the reviewed papers used the NMC (1987) guidelines for diagnosing a quarter as IMI-positive or IMI-negative as reference. These guidelines base the confidence of diagnosis on the following criteria: purity of culture (pure, mixed 2 types, mixed several types) and number of colonies isolated (1, several, more than 10). Only 1 of the reviewed papers published during the last 10 yr made use of a minimum colony count for mastitis pathogens: Zadoks et al. (2001) used a minimum colony count of 1,000 cfu/mL when using single samples to determine infection status with *Streptococcus uberis*.

Objectives

This study was conducted as the initial step in a 2-part process with the overall goal of determining the operating characteristics of various definitions of IMI. The second step was to use the consensus standard derived from this study to determine the operating characteristics of the definition of an IMI based on a single quarter milk sample.

The primary objective of this study was to develop a set of rules for classifying the infection status of an udder quarter based on 3 consecutive weekly tests using information about the organism(s) isolated, the number of colonies cultured, and the SCC on each of the 3 test days. To do this, we wanted to identify the factors and the levels of these factors most consistently used by mastitis experts to determine whether a quarter is IMI-positive. This set of rules would serve as the standard for the next part of the research process.

In addition, we documented the level of agreement with regard to the definition of an IMI among mastitis experts, both researchers in the mastitis field and bovine practitioners involved with udder health work.

MATERIALS AND METHODS

Conjoint Analysis

Conjoint analysis is a survey tool commonly used in marketing analysis that originated in mathematical psychology (Luce and Tukey, 1964). A conjoint analysis is often carried out before launching a new product or changing the price of an existing product to determine what factors influence consumer preference. The big advantage of the method is the opportunity to present the survey respondent with constructed combinations of several factors (e.g., price, color, and gas mileage of a new car model) that might influence consumer choice, and the analysis of the responses determines which factors are important in the consumer decision (Cattin and Wittink, 1982). The scenarios in a conjoint analysis survey will typically be a series of theoretical products displaying different levels of the key attributes to be analyzed. Another feature of conjoint analysis is the ability of the method to take interaction between factors into account. This puts the respondent in a situation that simulates the decision making process taking place in real life, in contrast to surveys in which the preference among levels of a single factor is the outcome. The conjoint analysis is carried out by asking the respondents to rank the items with different factor combinations presented to them. The process requires the respondents to make a series of trade-offs when doing so. These trade-offs can be analyzed to reveal the importance of the factors involved (Armstrong, 2001). Thus, the preferences of the respondents are revealed by their selection rather than direct statements about preference of a specific level of a single factor (Churchill, 1999).

Data for Conjoint Analysis

Profiles consisting of organism (a mastitis pathogen), colony count, and SCC for each of 3 weekly samples from a single udder quarter were generated. Three different mastitis pathogens were chosen for the profiles included in the conjoint analysis: *Staphylococcus aureus* represented a major contagious pathogen, *Escherichia coli* represented a major environmental pathogen, and coagulase-negative staphylococci represented a minor pathogen.

Three sets of 20 profiles, 1 for each of the 3 different pathogens, were prepared. Each profile showed information about the organism isolated, colony count, and the