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Association between metabolic diseases and the culling risk of high-yielding dairy cows in a transition management facility using survival and decision tree analysis

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ABSTRACT

The objective of this study was to assess the association between individual metabolic diseases (MD) and multiple MD (MD+) in the transition period (±3 wk relative to calving) and the culling risk in the first 120 d in milk (DIM) in Holstein-Friesian dairy cows. Health records from a transition management facility in Germany with 1,946 calvings were analyzed in a 1-yr cohort via survival analysis and a decision tree model. The recorded MD were milk fever (MF), retained placenta (RP), metritis (METR), ketosis (KET), displaced abomasum (DA), twinning (TWIN), and clinical mastitis (MAST). The overall culling within 120 DIM was 18%. The 120 DIM culling risk for healthy cows (64.8% of the total) was 13%, whereas it was 25% for MD (24.5%) and 33% for MD+ (10.7%) cows. The 120 DIM culling risk (%) for each MD and MD+, respectively, was 34.6 and 48 for MF and MF+, 15 and 31.5 for RP and RP+, 9.4 and 22.2 for METR and METR+, 30.7 and 37.3 for KET and KET+, 56.1 and 46.8 for DA and DA+, 30.3 and 34 for TWIN and TWIN+, and 36.6 and 27.8 for MAST and MAST+. Moreover, the incidence risk (%) for each MD and MD+, respectively, was 4 and 2.6 for MF and MF+, 1 and 2.8 for RP and RP+, 8.7 and 6 for METR and METR+, 4.5 and 6.1 for KET and KET+, 0.8 and 2.4 for DA and DA+, 1.7 and 2.7 for TWIN and TWIN+, and 3.6 and 1.8 for MAST and MAST+. Setting the healthy cows as the referent, the 120 DIM hazard ratios (HR) for culling were MD 2.1, MD+ 2.9, MF 3.3, MF+ 4.6, RP+ 2.7, METR+ 1.8, KET 2.6, KET+ 3.3, DA 5.5, DA+ 4.5, TWIN 2.8, TWIN+ 3.0, MAST 3.1, and MAST+ 2.3. According to both decision tree and random forest analyses, MF was the most significant disease influencing survival, followed by DA, MAST, METR, and TWIN. In conclusion, the presence of MD or MD+ during the transition period was associated with increased culling risk in the first 120 DIM. The culling hazard was greater when an MD was complicated with another MD. In this study performed in a well-managed large farm, uncomplicated cases of RP (HR = 1.2) and METR (HR = 0.7) did not have an influence on the 120 DIM culling risk. Interestingly, both decision tree and random forest analyses pointed to MF and DA as main culling reasons in the first 120 DIM in the present dairy herd.

Key words: transition period, metabolic disease, survival analysis, decision tree

INTRODUCTION

The identification of early predictors for the productive life of cows is of great interest to improve dairy herds' profitability. The availability of quality replacement heifers, appropriate management to mitigate transition cow disease risk, and good culling decision making profoundly influence the productivity and profitability of the herd. An elevated culling rate is associated with high replacement costs, whereas a low culling rate might impair milk production, reproduction, and genetic improvement (Hadley et al., 2006). Culling decisions are made based on cow factors as well as external factors that are often specific to the herd or even country (De Vries, 2017). In this regard, Fetrow et al. (2006) suggested that culling can occur voluntarily due to low production, cow aggression, and sales to other dairy farms or involuntarily due to disease, injury, infertility, or death. Metabolic diseases (**MD**) are significant causes of involuntary culling (Esslemont and Kossaibati, 1997; Essl, 1998; Seegers et al., 1998; Bell et al., 2010; Pinedo et al., 2010; Chiumia et al., 2013). They occur mainly during the transition period, defined as the time from 3 wk precalving until 3 wk

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postcalving (Sundrum, 2015). This period is characterized by marked changes in the endocrine status and a reduction in feed intake (Grummer, 1995), resulting in a negative energy balance of varying duration and intensity. Concomitantly, endocrine immunosuppression and environmental stressors such as group changes during the transition period make the dairy cows prone to develop infectious diseases (Mulligan and Doherty, 2008; Ingvartsen and Moyes, 2015). Due to the combination of the aforementioned factors centralized around parturition, the transition period is characterized by an elevated risk for MD.

Most often, the annual culling risk among dairy cows is reported to be about 22 to 25% (Esslemont and Kossaibati, 1997; Hare et al., 2006; Bell et al., 2010), but in production systems with a great supply of replacement heifers (due to high reproductive performance or lower rearing costs) it reaches 35 to 36% (De Vries, 2017; Haine et al., 2017a). A recent study (Dubuc and Denis-Robichaud, 2017) identified prevalence alarm levels of postpartum diseases based on association with a high prevalence of postpartum culling. However, reports on the association between specific disease and culling rates are scarce and mostly published before 2000 (Milian-Suazo et al., 1988; Beaudeau et al., 1995; Gröhn et al., 1998), whereas more recent literature often focuses on 1 specific transition disease (e.g., metritis: Dubuc et al., 2011; Wittrock et al., 2011; or mastitis: Haine et al., 2017b).

As comprehensively discussed by Mulligan and Doherty (2008), transition diseases are often complexly linked to each other. Unravelling these interactions on different aspects of dairy cow management has become a research area in its own. In a previous study, Hostens et al. (2012) used a lactation curve modeling approach on high-quality milk production data from a transition management facility (Fetrow et al., 2004) to study the interactive effects of transition diseases on milk production. Recently, data mining techniques such as decision trees have regained popularity through their ease of gaining insight in complex operational research (Rokach and Maimon, 2014). These methods provide variable importance measures that have been acknowledged as valuable tools in applied sciences such as genetics and bioinformatics (Holzinger, 2015). These importance measures may help us better understand and visualize interactions, including the relative importance of interconnected disease events.

Thus, the objectives of the current study were (1) to retrospectively evaluate the incidence of uncomplicated (single) and complicated (multiple; **MD+**) cases of MD and (2) use survival analysis and decision tree modeling to assess the order of importance of MD on survival in the first 120 DIM in high-yielding Holstein-Friesian dairy cows in a transition management facility.

MATERIALS AND METHODS

Study Design

This retrospective observational study consisted of the analysis of health records collected during a 1-yr period (April 2009 to April 2010). Data records were obtained from a dairy herd located in Mecklenburg-Vorpommern, Germany, by using the on-farm computer system Dairy Comp 305 (Valley Ag Software, Tulare, CA). The herd consisted of approximately 2,450 Holstein-Friesian cows during the timeframe of data collection (herd size constantly expanding during this time). The average milk production per lactation (305 d) was 11,085 kg/cow (3.64% milk fat, 3.32% milk protein). Transition cow management was as described by Hostens et al. (2012). Briefly, heifers and multiparous cows (40 and 42 d before expected parturition, respectively) were transferred to specially designed transition facility barns. These barns comprised sand-bedded freestall pens with a maximum of 32 animals per group, and special efforts were made to closely monitor the transition cows. Cows and heifers were housed separately until 10 to 21 DIM. All animals were fed a TMR once daily according to their transition status (far-off, close-up, and fresh-cow diets). Between 10 and 21 DIM, cows and heifers were moved to freestall milking barns, fed a TMR (in groups) according to the production level of the pen, and milked twice daily.

Transition Diseases: Diagnosis and Treatments

A fresh cow protocol was established immediately after parturition involving oral administration of 500 mL of propylene glycol (Bernd-Dieter, Dusseldorf, Germany) in 50 L of warm (37–38°C) water to all cows. Additionally, all cows with parity >1 were provided with 500 mL of a 38% calcium borogluconate solution intravenously (Calcilift Forte, Albrecht GmbH, Aulendorf, Germany). All the transition problems (after calving) were diagnosed and treated by specially trained personnel according to specific protocols. The monitored transition problems in this study were milk fever (**MF**), retained placenta (**RP**), metritis (**METR**), ketosis (**KET**), displaced abomasum (**DA**), twinning (**TWIN**), and mastitis (**MAST**).

Diagnosis of MF was based on clinical signs (within 48 h of calving): cold ears and extremities, muscular tremor, ataxia, decreased ruminal motility, and incapability of rising. The MF treatment consisted of 500 mL