Fresh cow diseases and their economic impact on farm profitability

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1. Introduction

Metabolic and hormonal changes that occur during the peri-parturient period of the lactating dairy cow are both profound and significant. Transitioning into a non-pregnant, lactating state from a pregnant, non-lactating state results in a massive redistribution of body tissues that involves all major body systems. It has been reported that up to 60% of lactating cows may develop either metabolic or infectious diseases during the first 60 days of lactation (Bisinotto, 2012).

Given that potentially 60% of lactating dairy cows may be affected by at least 1 disorder during the first 60 days of lactation, the productivity costs associated with the diagnosis, treatment, labor, and infrastructure represent a significant profit opportunity for the dairy enterprise. These variables do not account for the ongoing biological cost of the disease itself which directly impacts the total production during the lactation, individual cow fertility, and culling risk. To provide a brief example, hypocalcemia (including subclinical hypocalcemia) has been one of the most extensively studied metabolic conditions for the modern dairy herd. It is now well understood that while only approximately 5% of cows in the US may be affected by clinical milk fever, almost 50% of periparturient cows may experience subclinical hypocalcemia. Early research suggested that a cow experiencing clinical hypocalcemia was 9 times more likely to exhibit symptoms of ketosis compared to cows not developing milk fever (Chamberlin et al 2013). Liang et al. reported that 1 case of hypocalcemia alone had an upfront cost (veterinary and labor) of approximately $102.00 and an additional $161.00 (culling risk, fertility, production) of future losses.

The goal of this report is to provide a comprehensive literature review of current data on transition cow health and its subsequent economic impact on the dairy herd. Ultimately our goal is to provide dairy managers with the tools necessary to weigh the cost of a given disease, on a single dairy, and utilize the corresponding models to decide which disease condition represents the most significant profit opportunity.

Abbreviations: BHBA (β-hydroxybutyrate), DIM (days in milk), DM (dry matter), SCK (subclinical ketosis), SCH (subclinical hypocalcemia).

2. Consequences and economics of health disorders during the postpartum period

a. Metritis

Acute puerperal metritis is an acute systemic illness whose main clinical symptoms are fever and signs of toxemia due to an infection of the uterus. Metritis usually occurs during the first 21 days after calving with a peak incidence to occur at day 5 to 7 of lactation. It is characterized by an enlarged uterus and a watery, red-brown fluid to viscous off-white purulent uterine discharge, which often has a fetid odor.

Infectious metritis is a prevalent and costly disease for the dairy industry around the world as it decreases production performance, survival, and welfare of dairy cows. Direct consequences of metritis include a reduction in cow's reproductive performance and milk production, as well as an increase in culling and antibiotic use. Given the US dairy cow population census and an average impact of metritis of 20%, US dairy industry suffers $665 million annual losses due to metritis (Soo Jin Jeon, 2018).

Konyves et al. (2009) evaluated the effects of puerperal metritis on reproduction and milk yield in dairy cows from a commercial 730-Holstein cow herd. Cows affected with metritis showed lower milk production (13% less) on day 4 after calving and lower milk production in the first 100 days of lactation than healthy cows (13%).

The effect of metritis on milk production was reported to be influenced by parity. Using data collected from 2,178 Holstein cows from 6 commercial herds, 3 herds in southwestern Ontario and 3 herds in western New York State, Canadian researchers (Dubuc et al., 2011) quantified the effects of metritis on milk production (first 4 monthly DHIA test-days) and culling. In multiparous cows, the effect of metritis on milk production was variable over time: it decreased milk production by 3.7 kg/cow at first test-day but was not different at the subsequent 3 tests. Based on projected 305-d production at the third test-day, multiparous cows with metritis produced 259 kg less milk per lactation than unaffected cows. In primiparous cows, metritis did not alter test-day milk production so 305-day projected production was unaffected by metritis.

Metritis was associated with reduced reproductive performance in this study. Pregnancy risk at first service (35.3 vs. 27.2%), 120 DIM (46 vs. 36.3%), and 300 DIM (82.6 vs. 80.4%) was lower in cows affected with metritis. Metritis can affect reproduction through multiple mechanisms. Reduced dry matter intake and energy-demanding immune processes associated with the release of cytokines interfere with energy metabolism, increasing the risk of fatty liver syndrome and ketosis. These conditions may delay the postpartum resumption of cyclic ovarian function and prolong the interval from calving to first ovulation. Interestingly, although production and reproduction performance were lower in cows suffering metritis, the authors did not find an association between metritis and culling risk at 30, 63 and 300 DIM.

Another study published in Journal of Dairy Science evaluated productive and reproductive consequences of metritis in dairy cows from 4 Holstein dairy farms in Isfahan, Iran (Mahnani et al., 2015). The incidence of metritis per cow per year in this dataset comprising 43,488 calvings was 13.2% on average and ranged from 9.0 to 15.8%. Overall, a case of metritis significantly reduced the 305-d milk yield in primiparous and multiparous cows by 129.8 kg/cow per lactation. The negative reproductive effects due to metritis were smaller and nonsignificant for primiparous cows compared with multiparous cows. Overall, a case of metritis increased days open and number of inseminations per conception by 16.4 and 0.1 per cow per lactation, respectively.

Economic model

Overton and Fetrow (2008) developed an economic model to estimate the total expected cost due to acute puerperal metritis. The dataset used to estimate milk loss, culling risk, and reproductive performance changes attributable to metritis was obtained from a large dairy herd in California and included 500 cows diagnosed with metritis within the first 10 DIM. The overall lactational incidence risk for metritis in this herd was 22%.

Milk production differences from the data set were incorporated into the model as follows:

a) data from the herd showed that cows with metritis that were culled during the first 30 DIM produced 6.9 kg less milk per day and had a median days-to-exit of 10,

b) cows with metritis that were culled during 31 - 60 DIM produced an average of 4.1 kg less milk per day and had a median days-to-exit of 42

c) cows with metritis that survived past 60 DIM experienced an average of 2.8 kg loss per day over the first 110 DIM and then no difference over the rest of lactation as compared to the normal cows.

A marginal milk value of $0.29 per kg was used, assuming a baseline milk price of $396/tn and an expected 2.5 kg of marginal milk produced per pound of marginal feed consumed. As a consequence, the total estimated milk loss (weighted average) attributable to metritis was $83/ case of metritis as shown in Table 1.

Table 1. Cost Associated with reduced milk production due to metritis

Marginal value of lost milk/metritis case culled (1^{st} 30 DIM)	$20
% of metritis cases culled/dead 1^{st} 30 DIM	6%
Marginal value of lost milk/metritis case culled (31 - 60 DIM)	$49
% of metritis cases culled/dead 2^{st} 30 DIM	4%
Marginal value of lost milk/cow with metritis retained past 60 DIM	$89
% of metritis cases culled/dead 1st 30 DIM	90%
Total milk loss/case (weighted avg)	$83

Reference: Overton and Fetrow, 2008.

The authors estimated cost of culling within the first 60 DIM was $85 per case of metritis. The salvage value for first lactation animals was $460 and for lactation two and above, it was $621, based on differences in body weight at the time of culling.

The metritis-related cost associated with reduced reproductive performance was estimated using a simulated Kaplan-Meier survival plot. Animals that failed to conceive within 12-21day breeding cycles were assumed culled as non-pregnant cows. Average and median days open were 16 and 33 days longer, respectively, for the metritis group. The predicted 21-d pregnancy rate was 17.5% for the normal cows and 13% for the cows experiencing metritis. A total of 73% of normal cows that calved became pregnant and survived for the entire lactation compared to only 59% for the cows with metritis. The modeled survival plot reveals an attributable culling risk of 8% due to metritis-associated infertility. Combining this 8% risk with the attributable culling risk during the first 60 DIM (5.3%) yields a total that approximates the 14% from the actual data (73% – 59%). As a consequence of the combined effects of excess culling and the costs of extra insemination and breeding program efforts, the predicted monetary loss was approximately $121 per cow in the breeding pool, or $109 per case of metritis, once the total was adjusted to account for the earlier culls. These values were calculated using a replacement cost of $2,200, herd level 305ME of 25,000, a milk price of $18, salvage value of $621, and an interest rate of 8% as inputs in the reproduction model.

The final area of consideration is the direct treatment cost associated with metritis which varied from $53 to $109 depending upon drug used and the utilization of any withheld milk.

By adding each of the components of the model together: the total cost due to culling in the first 60 DIM ($85 per case), the total milk loss ($83 per case), losses due to reproductive issues ($109 per case), and treatment cost ($81 per case), the total cost of metritis in this economic model was estimated to be approximately $358 per case.

b. Subclinical Ketosis

Subclinical ketosis (SCK) is characterized by elevated levels of ketone bodies in blood, and it is one of the most common metabolic disorders in dairy cows during early lactation. Cows with SCK reduce their dry matter intake and are more prone to develop other diseases such as metritis, and displacement of abomasum. Moreover, they decrease both production and reproduction performance during the lactation. Therefore, careful monitoring of SCK in dairy cows is vital for keeping cow health and productivity. Ketosis is measured by determining the level of β-hydroxybutyrate, a ketone body, in blood, urine or milk either in the laboratory or using cow-side ketosis test in the farm.

Researchers from Cornell University and University of Wisconsin (McArt et al., 2012) determined the association of SCK with cow's production and reproduction performance, removal from herd in the first 30 DIM in cows from 4 dairy herds (2 in New York and 2 in Wisconsin). Subclinical ketosis was defined as a BHBA concentration of 1.2 to 2.9 mmol/L. The authors reported that nonketotic cows produced 1.2 kg more milk per day in the first 30 days of lactation than SCK-positive cows (35.1 and 33.9 kg/day, respectively). Interestingly, SCK did not affect reproduction performance. Conception to first service did not differ between the 2 groups, with SCK cows equally likely to conceive as nonketotic cows. Similarly, days to conception within 150 DIM was similar between the 2 groups, with a median time to conception of 96 d and 104 d for nonketotic and SCK cows, respectively. However, cows with SCK were 3.0 times more likely to die or be culled than nonketotic cows during the first 30 DIM; 1.8% of nonketotic cows and 5.4% of cows that tested positive for SCK were removed from the herd.

Another study conducted at the University of Guelph (Duffield et al., 2009) evaluated the impact of SCK in early lactation dairy cows on milk production. The researchers found than greater serum BHBA measured during the first and second week post calving was associated with less milk yield. The greatest impact on yield occurred at 1,400 μmol/L (−1.88 kg/d) and 2,000 μmol/L (−3.3 kg/d) for sera from the first and second week post calving, respectively. Similarly, a meta-analysis of the literature conducted by French researchers (Raboisson et al., 2014), including 23 publications indicated that the direct and indirect 305-d milk loss associated with SCK was 340 kg of milk.

Researchers from Cornell University showed that the association between SCK and ME305 milk yield were different between first lactation and mature cows. In a prospective cohort study including 2,259 cows from 91 dairy herds, Ospina el al. (2010) reported that multiparous cows with BHBA ≥10 mg/dL had a 393-kg decrease in ME305 milk yield while first lactation cows with BHBA ≥9 mg/dL had an increase of 403 kg more ME305 milk. Moreover, animals with BHBA ≥10 mg/dL had a 13% decreased risk of conception.

Economic model

McArt et al. (2015) developed a deterministic model to estimate the costs associated with the component cost per case of SCK. The authors calculated marginal milk value using a feed price per unit of dry matter of $0.33 per kg, an energy density of feed (NEL per unit of feed) of 1.72 per kg, megacalories of NEL required per unit of marginal milk of 0.70 per kg, and a milk price of $0.53 per kg. The component cost per case of SCK was estimated at $134 and $111 for primiparous and multiparous animals, respectively; the average component cost per case of SCK was estimated to be $117 (Table 2). Thirty-four percent of the component cost of SCK was due to future reproductive losses, 26% to death loss, 26% to future milk production losses, 8% to future culling losses, 3% to therapeutics, 2% to labor, and 1% to diagnostics. However, when the researchers accounted for the costs related to SCK-attributable displaced abomasum and metritis cases, the total cost per case of SKC was estimated at $375 and $256 for primiparous and multiparous animals, respectively; the average total cost per case of SCK was $289.

Table 2. Estimated component cost per case of hyperketonemia (blood BHBA ≥ 1.2 mmol/L) in early lactation dairy cattle

Item ($)	Cost per case		Average cost per case
	Lactation= 1	Lactation > 1	
Direct cost of Hyperketonemia			
Diagnostic	-1	-1	-1
Therapeutic	-3	-3	-3
Discarded milk	0	0	0
Veterinary service	0	0	0
Labor	-2	-2	-2
Death loss	-36	-29	-31
Indirect cost of hyperketonemia			
Future milk production losses	-30	-30	-30
Future culling losses	-19	-5	-9
Reproduction losses	-41	-39	-40
Total	-$134	-$111	-$117

Reference: McArt et al. (2015)

c. Subclinical Hypocalcemia

At calving, calcium requirements are quadrupled, which results in cows experiencing variable degrees of subclinical to clinical hypocalcemia. Subclinical hypocalcemia (SCH) is normally defined as calcium concentrations in blood lower than 2.1 mmol/L (8.5 mg/dL). Previous research conducted in Holsteins reported that number of lactations and prepartum calcium status were the most important factors associated with having SCH at parturition. Cows in third or greater parities were 70% more likely to have SCH than second-lactation cows. Similarly, multiparous cows with low blood calcium levels in the prepartum period were 40% more likely to have SCH at parturition than cows with normal calcium concentrations.

Using a prospective observational cohort study in 407 Holstein cows in 2 dairy herds in New York, researchers from Cornell University (McArt et al., 2020) evaluated the association of SCH dynamics with the risk of early lactation disease, removal, and milk production. The authors defined SCH differently depending on parity: calcium concentration lower than 2.15 mmol/L at 1 and 2 day in milk in primiparous cows, and lower than 1.77 at 1 day in milk and 2.20 mmol/L at 4 days in milk in multiparous cows. This study demonstrated that SCH increases the risk of culling. Primiparous and multiparous cows with SCH were 4.1 and 1.8 times, respectively, more likely, to have a disease (hyperketonemia, metritis, DA) or removal event in the first 60 DIM than normocalcemic cows. Interestingly, no difference was observed in average daily milk production across the first 10 week of lactation based on calcium status group.

Similar results were reported in a recent article published in Journal of Dairy Science. German researchers (Venjakob et al., 2018) conducted a prospective cohort study including 125 dairy herds from 8 federal states of Germany. Cows with SCH (serum calcium concentration <2.0 mmol/L) had a 1.69 times greater hazard of being culled within the first 60 DIM compared with normocalcemic animals. Additionally, calcium status was associated with reproduction performance. Compared with animals with a serum calcium concentration ≥1.8 mmol/L, the hazard of becoming pregnant within 150 DIM was reduced when cows had a serum calcium concentration <1.8 mmol/L (hazard ratio = 0.68). The effect of SCH on milk yield was conditional on parity. In primiparous cows a serum calcium concentration <2.0 mmol/L had no effect on milk production, whereas there was a tendency for multiparous cows with a serum calcium concentration <2.1 mmol/L to produce 0.80 kg/day more milk compared with multiparous cows at or above the threshold.

University of Missouri researchers (Chamberlin et al., 2013) also reported greater milk production in SCH cows from the Foremost Dairy Research Center farm. Average peak test-day milk yield was 48.0 kg in SCH cows and 46.6 kg in cows with normal calcium levels. Thus, average 305-d mature-equivalent 4% fat-corrected-milk yield was 10,207 kg in SCH cows and 10,383 kg in healthy cows. Moreover, in this study, the authors did not find effect of SCH in reproduction performance. There were no detectable differences between hypo calcemic and normocalcemic cows in the proportions of cows cycling by 50 to 60 days postpartum, days to first service, services per conception, or days open.

Although the data for both clinical and subclinical hypocalcemia it is the author's impression that economic losses (or gains) are primarily associated when other concurrent diseases develop as a result. The lone study willing to provide financial losses attributable to hypocalcemia as mentioned in the introduction can be contrasted with other literature reporting milk production increases for cows in a hypo calcemic state when compared to their norm calcemic counterparts.

d. Mastitis

The most common cause of morbidity in adult dairy cattle has been reported to be mastitis. Survey data that has been completed over the last 20 years, demonstrates that the herd level frequency for cases of mastitis continues to increase (NAHMS, 2007). Mastitis has also been identified as one of the primary drivers of mortality in the adult dairy cow herd.

When assessing the entire lactation, the periparturient period is the most likely time period for the mammary gland to become infected (Natzke, 1981). Periparturient hypocalcemia (and SCH) impairs the effectiveness of the innate immune system by liming the ability of the teat sphincter to close. The cow is also undergoing systemic immunosuppression by entering a ketogenic state during the transition period, further inhibiting the adaptive immune response. Santos et al. (2004) reported the effects of periparturient mastitis events on reproduction. Cows affected by clinical mastitis during the transition period had a 4-day delay in time-to-first-insemination and a 25% decrease in 1st service conception risk.

Economic model

Rollin et al. (2015) created a deterministic partial budget model to estimate direct and indirect costs per case of clinical mastitis occurring during the first 30 days of lactation. The authors reported that multiparous cows affected with clinical mastitis during the first 30 days were 8% more likely to be culled (sold or died) during the subsequent lactation than their uninfected herd mates. Similarly, primiparous cows affected with clinical mastitis during the first 30 days were 5.8% more likely to be culled than their herd mates.

Rollin et al. (2015) reported that a single case of clinical mastitis incurs both direct and indirect costs (Table 3). The average case of clinical mastitis resulted in a total economic cost of $444, including $128 in direct costs and $316 in indirect costs.

Table 3. Breakdown of estimated cost per case of clinical mastitis in the first 30 days of lactation1

Item		Lact = 1	Lact > 1	Overall	
		Cost per incident case ($)	Cost per incident case ($)	Cost per incident case ($)	% of total cost
Direct cost	Diagnostic	9	11	10	2.3
	Therapeutic	30	40	36	8.1
	Non-saleable milk	18	30	25	5.7
	Veterinary service	4	4	4	0.9
	Labor	19	22	21	4.7
	Death loss	19	40	32	7.2
	Direct cost/case	100	146	128	28.9
Indirect cost	Future milk production losses	149	111	125	28.2
	Premature culling loss	176	185	182	40.9
	future Reproduction loss	9	9	9	2.0
	Indirect cost per case	333	305	316	71.1
Average cost per case				444	

Reference: Rollin et al. (2015)

Dairy producers generally recognize the direct costs associate with a single case of mastitis. These costs are associated with the diagnosis, treatment, and immediate revenue lost from discarded milk. Indirect costs (milk production loss for the whole lactation, increased culling risk, and reduced fertility) associated with clinical mastitis cases often go unnoticed by the dairy producer but represent almost 72% of the cost associated with a case of clinical mastitis in early lactation.

3. Effects of postpartum clinical disease on milk production, reproduction, and culling of dairy cows

During the last 3 weeks of gestation, energy requirements increase due to fetal development and colostrum production. The mammary gland at 4 days post calving increases demands for glucose by 3 times, amino acids by 2 times, and fatty acids by 3 times when compared to the uterus at 250 days of gestation (Bell, 1995). At the same time, dry matter (DM) intake is reduced at the beginning of lactation. This mismatch between nutrient intake and demand generates a negative energy balance toward the end of the pregnancy that is prolonged for several weeks after calving (Grummer, 1993), and the early-lactation period is typically characterized by an increase in the incidence of disorders that compromise production and survival. In a review of 26 experiments, a positive energy balance was achieved at 50 DIM with a maximum negative energy balance at 11 days post calving (Brixy 2005).

a. Short-term effects

Pérez-Baez et al. (2019) performed a retrospective longitudinal study using the data from 476 cows from 9 experiments conducted at the University of Florida research dairy unit, Hague, Florida. The authors evaluated the effect of metritis, ketosis and clinical mastitis on milk yield during the first 28 days of lactation. In summary, these were the main results:

- Cows that developed metritis produced 4.5 kg/d of ECM compared with cows that did not develop metritis (29.0 vs. 34.5 kg/day).
- The ECM yield for cows that developed clinical mastitis was less than that for cows that did not develop clinical mastitis (28.7 vs. 33.6 kg/d).
- Interestingly, the researchers reported that ECM was greater in cows with ketosis. There was an interaction between ketosis and parity, which showed that ECM production for primiparous cows that developed ketosis was greater than that for primiparous cows that did not develop ketosis (38.1 vs. 28.6 kg/day), whereas the ECM for multiparous cows that developed ketosis was similar to that for multiparous cows that did not develop ketosis (36.4 kg/day).

This study showed a reduction in production performance during the first 4 weeks of lactation in cows that developed metritis or mastitis during the postpartum period.

b. Long-term effects

Most of the metabolic problems of the dairy cow happen during the first two weeks of lactation. In a review of several experiments, researchers found that approximately one out of three fresh cows have at least one clinical disease during the first 3 weeks of lactation. Consequently, culling rate increases during early lactation. It has been reported nearly 25% of the cows that leave herds do so during the first 60 DIM.

A recent study conducted in a 5,000-cow dairy from Florida evaluated the effects of clinical diseases during the fresh period (21 DIM) on milk production, reproduction, and culling rate of Holstein cows through the entire lactation (305 DIM). The researchers (Carvalho et al., 2019) classified 5,085 cows (1,814 primiparous and 3,271 multiparous) according to the incidence of clinical disease during the first 21 DIM as healthy cows or cows with either single or multiple clinical diseases: retained placenta/metritis, clinical mastitis, lameness, digestive problems, and respiratory problems.

During the first 21 DIM, 30.2% of the fresh cows had at least one clinical disease: retained placenta/metritis 21.6%, mastitis 5.7%, lameness 1.5%, digestive problem 5.5%, and respiratory disease 0.6%.

Milk production: clinical disease during the first 21 DIM decreased the 305-d yields of milk. While healthy fresh cows produced 10,499 kg of energy-corrected milk during 305 DIM, cows with a single or multiple clinical disease during the fresh period produced 10,104 and 9,783 kg (3.8 and 6.8% less), respectively.

Reproductive performance: although no differences in time to first breeding were observed (averaged 81 days), cows that had one or multiple clinical diseases had a reduction (6.6 and a 17.8%, respectively) in pregnancy rate through 305 DIM. In addition, pregnancy loss after day 45 of gestation for all breedings performed through 305 DIM was greater in cows with clinical diseases (23.6%) than in healthy cows (13.9%).

Culling rate: as expected, a greater proportion of cows that suffered clinical diseases during the fresh period left the herd. The percentage of cows culled by 305 DIM increased from 23% in healthy fresh cows to 36% and 54% in those diagnosed with a single and multiple clinical disease during the first 21 DIM, respectively.

In conclusion, this study shows the long-lasting detrimental consequences of clinical diseases during the fresh period in milk production, reproduction, and culling of dairy cows. Good management practices along with an adequate nutrition program should be implemented during the transition period to prevent clinical diseases and the economic losses associated with them.

4. Conclusion

Up to this point, the discussion has primarily focused on the cost of the most common transition cow diseases through the transition period. The literature is generally consistent for metritis, ketosis, and mastitis. Hypocalcemia presents a unique challenge. Although there is definitively a cost associated with the disease, that cost generally corresponds to whether or not a cow is affected by another disease and which condition it is.

As people who are not only professionals, but also actively engaged on dairy herds daily, our opinion is that one of the most significant challenges on a commercial dairy is disease identification and recording. For this reason, it is the authors' impression that the final paper (Carvalho et al. 2019) provides the most immediate, applicable economic model for a modern commercial dairy. This model accounts for human variability by allowing the herdsman or dairy staff to simply identify that the cow is sick, instead of relying on the herdsman to differentiate correctly between two closely related disease (ex: ketosis and hypocalcemia). Individual disease models may incorrectly project economic losses if records are inadequate or if the disease processes are incorrectly identified. This final model is able to remove some of this variability, assuming that farm staff can adequately identify simply that a cow is healthy or sick. With that in mind, the ability to train staff correctly to identify, record, and treat diseases has the ability to significantly improve farm profitability when paired with an appropriate economic model.

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