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Clinical and metabolic indicators associated with early mortality at a milk-fed veal facility: A prospective case-control study

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ABSTRACT

Antimicrobial use and resistance, in combination with high levels of mortality, are important challenges facing the veal industry. To improve both the economic sustainability of the industry and animal welfare, measures need to be taken to explore and address reasons for these challenges. Health status at arrival may be an important predictor of calf mortality because substantial mortality occurs early in the growing period on veal operations. The objective of this observational case-control study was to identify clinically measurable variables and metabolic indicators associated with mortality in the first 21 d following arrival at a veal facility. Calves were evaluated using a standardized health scoring system, blood was collected, calves were weighed, and the supplier of the calf was recorded at arrival. The calves were followed until death or 21 d after arrival. Cases were defined as calves that died ≤21 d following arrival. Two controls for every case were randomly selected from calves that survived >21 d, arrived on the same day, and were housed in the same barn as cases. Stored serum harvested at arrival from cases and controls was submitted for measurement of concentrations of nonesterified fatty acids, β-hydroxybutyrate, glucose, cholesterol, urea, haptoglobin, and immunoglobulin G. A conditional logistic regression model was built to evaluate factors associated with mortality ≤21 d following arrival. A total of 4,825 calves were evaluated from November 2015 to September 2016. The mortality risk in the first 21 d was 2.8%, giving 135 cases, which were compared with 270 controls. Six variables were significant in the final multivariable model. Calves with a slightly enlarged navel with slight pain or moisture, and those with severe dehydration had increased odds of mortality ≤21 d following arrival. Drover-derived calves, calves that weighed more, and calves that had higher concentration of immunoglobulin G or cholesterol at arrival were less likely to die. The results demonstrate that calves at elevated risk for early mortality can be identified at arrival using both health and hematological factors. Early recognition of high-risk calves may allow for an intervention that could result in improvement in survival rates; however, prevention of these abnormalities before arrival at veal facilities needs to be further explored.

Key words: antimicrobial use, veal industry, calf health status, case-control study

INTRODUCTION

Calf morbidity and mortality represent a significant cost to calf-rearing industries (Mohd Nor et al., 2012) and an important concern for animal welfare (Ortiz-Pelaez et al., 2008). With mortality ranging from 5 to 8% in conventional veal housing (Pardon et al., 2012a; Winder et al., 2016) and 4% in animal welfare–specific housing (Bähler et al., 2012; Lava et al., 2016), there is a clear need to address its occurrence. The intensive use of antimicrobials is another important challenge faced by the veal industry (Pardon et al., 2014). In Europe, the veal calf sector uses high levels of antimicrobials (Pardon et al., 2012b; Bos et al., 2013; Lava et al., 2016); however, in Canada and the United States, the amounts used are unknown. The level of antibiotic use in the veal industry has been associated with the emergence of antimicrobial resistance in commensal, pathogenic, and zoonotic bacteria (Catry et al., 2007, 2016; Cook et al., 2011). This highlights the urgent need for change in the veal industry (CVMP-BIOHAZ, 2017), but for the industry to remain viable, controllable risk factors need to be identified and modified to decrease morbidity and mortality.

Because most mortality occurs during the early portion of the growing period, this may provide an initial area of focus (Pardon et al., 2012a; Winder et al., 2016). Health status and weight upon arrival at a veal facility can aid in the prediction of mortality early in the growing period (Bähler et al., 2012; Winder et al., 2016; Renaud et al., 2018). However, metabolic indicators may also play a role in identification of calves that are at increased risk of morbidity or mortality.

Colostrum management could be a key factor contributing to calf losses in male calf rearing (Godden,

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2008). Immunoglobulin G and total protein can both be used as markers for colostrum intake, with IgG being more specific in identifying failure of passive transfer (Weaver et al., 2000). Currently, the only tests that directly measure serum IgG are ELISA and radial immunodiffusion (Weaver et al., 2000). However, given the semiquantitative nature of the ELISA, radial immunodiffusion is the gold standard test (Fecteau et al., 2013). Failure of passive transfer is a common problem in male calves (Trotz-Williams et al., 2008; Pardon et al., 2015), and a strong association between serum IgG concentration and morbidity in male calves has been found (Pardon et al., 2015). However, a clear link between IgG status and mortality has not yet been established in the veal industry.

The acute phase response is a nonspecific reaction that occurs in response to tissue injury and leads to the production of acute phase proteins. Haptoglobin is an acute phase protein that increases in serum during bacterial and viral disease (Gånheim et al., 2007). It has been used to identify calves with pneumonia (Angen et al., 2009) and as a prognostic tool for calves with diarrhea (Hajimohammadi et al., 2011). Upon arrival of calves at a veal facility, the level of alpha-2 globulins—of which haptoglobin is a fraction—has been shown to affect neonatal calf diarrhea and average daily gain (Pardon et al., 2015). As the concentration of haptoglobin is low in healthy calves (Gånheim et al., 2003), it could be used as a screening tool to identify diseased calves soon after arrival at a veal facility.

Improved energy status protects against disease and supports immune function (Todd et al., 2017). It has been reported that 17% of surveyed Canadian dairy source farms providing inferior nutrition to male calves compared with female calves (Renaud et al., 2017), and this, combined with the energy expenditure and mobilization occurring during calf transport (Knowles et al., 1999), means that many male calves enter the veal industry with suboptimal energy status and low body fat cover (Wilson et al., 2000). Serum concentrations of BHB, nonesterified fatty acids (**NEFA**), cholesterol, glucose, and urea could all serve as markers of energy status in calves.

The objective of this study was to identify clinically measurable health and metabolic indicators associated with mortality occurring in the first 21 d following arrival at a veal facility.

MATERIALS AND METHODS

This observational case-control study was conducted in cooperation with a single milk-fed veal calf producer and in accordance with the University of Guelph Animal Care Committee (Animal Use Protocol: #3453). The producer had 5 barns in different geographical locations in southwestern Ontario, Canada. The diet provided to the calves did not differ by barn but there were several management differences. Barns 1, 2, and 4 fed calves manually, whereas barns 3 and 5 used automated calf feeders. Calves were housed individually in barns 1 and 4 and in groups of 60 calves in barns 3 and 5. Barn 2 housed calves in individual pens in early life, transitioning to groups of 8 calves at 5 to 6 wk following arrival.

Data Collection

When calves arrived at the receiving facility, they were immediately evaluated using a standardized health scoring system and weighed with a digital weighing scale (Cardinal Scale Manufacturing Co., Webb City, MO). The supplier of the calf and arrival date were also recorded. The suppliers were placed into 3 categories: local, drover, and auction. "Local" refers to dairy farmers who delivered calves directly to the veal facility. "Drover" refers to calves transported from multiple dairy farms to the veal facility and "auction" were calves derived from auction facilities. Calves were identified on arrival based on their Canadian Cattle Identification Agency ear tag using a handheld radiofrequency ID (RFID) reader. Mortalities occurring during the growing period were recorded using an electronic recording database (Trax-IT; Merit-Trax Technologies, Mount Royal, Quebec, Canada).

Standard Health Scoring System

An iPad (Apple Inc., Cupertino, CA) with the Calf Health Scorer app (University of Wisconsin-Madison, Madison, WI) and Qualtrics software (http://www.qualtrics.com/) was used to facilitate the health scoring. The Calf Health Scorer app provided images and descriptions to evaluate the respiratory system (nose, eye, ear, cough; McGuirk and Peek, 2014), fecal consistency (McGuirk, 2008), navel inflammation (adapted from Fecteau et al., 1997), joint swelling, and rectal temperature. A Qualtrics form was used to collect data on the evaluation of dehydration (Wilson et al., 2000), BCS (Wilson et al., 2000), and sunken flank (Bähler et al., 2012; Table 1). All calves were examined by 1 of 3 observers; however, all case and control triads were evaluated by the same observer.

Blood Collection and Processing

Following the health examination, approximately 10 mL of whole blood was collected from the jugular vein into a sterile blood collection tube without an antico-

Table 1. Description of health variables scored on arrival to the milk-fed veal facility

	Score				
Variable	0	1	2	3	4
Nose score	Normal serous discharge	Small amount of unilateral discharge	Bilateral, cloudy or excessive discharge	Copious, bilateral mucopurulent discharge	
Eye score	Normal	Small amount of ocular discharge	Moderate amount of bilateral discharge	Heavy ocular discharge	
Ear score	Normal	Ear flicking	Slight unilateral droop	Head tilt or bilateral droop	
Cough score	No cough	Induced single cough	Induced repeated coughs or occasional spontaneous cough	Repeated spontaneous cough	
Fecal score	Normal	Semi-formed, pasty	Loose, stays on top of bedding	Watery, sifts through bedding	
Navel score	Normal	Slightly enlarged, not warm or painful	Slightly enlarged with slight pain or moisture	Enlarged with heat, pain or malodorous discharge	
Joint score	Normal	Slight swelling, not warm or painful	Swelling with pain or heat, slight lameness	Swelling with severe pain, heat and lameness	
Dehydration score	Skin tent returns to normal <2 s, bright alert, strong suckle (≤5% dehydrated)	Skin tent returns to normal in 2 s, eyes not sunken, good suckle (6 to 8% dehydrated)	Good suckle, eyes slightly sunken, skin tent returns to normal in 2–4 s (8 to 10% dehydrated)	Mild depression, sternal recumbency, moderately sunken eyes, skin tent returns to normal in 4–8 s, tacky mucus membranes with poor suckle (10 to 12% dehydrated)	Profound depression, absent suckle, lateral recumbency, eyes deeply sunken, skin tent returns to normal in >8–10 s. Dry mucous membranes (>12% dehydrated)
BCS	Subcutaneous fat covering bony prominences	Thin covering of subcutaneous fat over bony prominences	Bony prominences are easily palpated	No subcutaneous fat covering frame	Emaciated with little muscle or fat present and clearly defined bone structure
Sunken flank	No	Yes			

agulant (BD Vacutainer, Becton, Dickinson and Co., Franklin Lakes, NJ). Blood was transported on ice to the laboratory, where it was allowed to clot and then centrifuged at 1,500 × g for 15 min at approximately 20°C. The approximate time from blood collection until centrifugation of the blood was 3 h. Serum was separated and stored at −20°C until submission to the Animal Health Laboratory (Guelph, ON, Canada) and Saskatoon Colostrum Company (Saskatoon, SK, Canada) for further analysis. Serum from cases and controls was analyzed for NEFA, BHB, glucose, cholesterol, urea, haptoglobin, and IgG. The biochemistry testing was done on the Roche Cobas 6000 c501 automated chemistry analyzer (Roche Canada, Laval, QC, Canada). Concentrations of NEFA and BHB were measured using Randox NEFA and Randox BHBA kits (Randox Laboratories Canada Ltd., Mississauga, ON, Canada). Glucose concentration was determined using the Roche GLU3 kit (Roche Canada) whereas cholesterol concentration was determined using the Roche CHOL2 kit (Roche Canada). The Roche UREAL kit (Roche Canada) was used to measure urea concentrations. Haptoglobin concentrations were measured by determining the hemoglobin binding capacity of serum, which was quantified against a standard sample (Skinner et al., 1991). Serum IgG was determined by radial immunodiffusion as described by Chelack et al. (1993).

Selection of Cases and Controls

A calf was selected as a case if it died ≤21 d after arriving at the facility. The 21-d cutpoint was selected based on previous work that demonstrated that a significant proportion of mortality occurred in the first 3 wk after arrival at veal calf facilities (Bähler et al., 2012; Pardon et al., 2012a; Winder et al., 2016). Two controls for each case were randomly selected from calves that survived >21 d, arrived on the same day, and were housed in the same barn as the cases. Two controls were used to improve the precision of the association estimates (Dohoo et al., 2010a). All calves selected were male.

Statistical Analysis

All statistical analyses were completed using Stata 14 (StataCorp LP, College Station, TX). Data were imported from Excel (Microsoft Corp., Redmond, WA) into Stata 14 and checked for completeness. Calves with missing data were deleted from analysis (complete-case analysis; Pigott, 2001). A causal diagram was created to evaluate the relationship between mortality and the measured variables (Figure 1). Descriptive statistics were generated for all explanatory variables in the data set.

Blood measures of cases and controls were summarized to describe characteristics of both groups. A Student's t-test was used to identify significant ($P \leq 0.05$) differences between cases and controls for normally distributed parameters and a Kolmogorov-Smirnov test was used for non-normally distributed parameters. All blood parameters had normal distributions except BHB, haptoglobin, and urea.

A single conditional logistic regression model was built to explore associations with mortality ≤21 d following arrival. The assumption of linearity of continuous predictor variables was assessed by plotting the logarithmic odds of the outcome against the variable. If a variable failed to meet the linearity assumption, the variable was categorized into 2 categories. Concentrations of

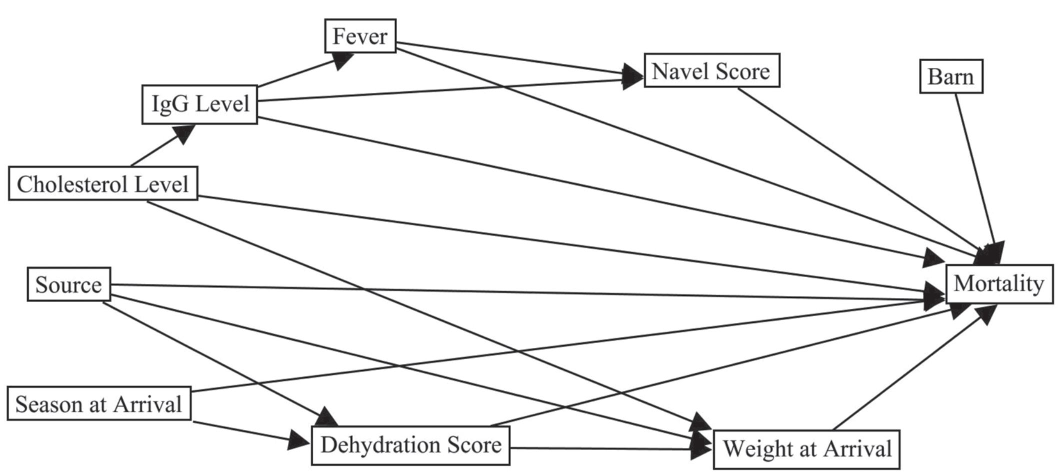

Figure 1. Causal diagram describing the hypothesized relationship of measured variables to mortality occurring during the first 21 d of the growing period at a milk-fed veal calf facility in Ontario.

NEFA, haptoglobin, and BHB were categorized based on cutpoints generated by the Youden Index (Youden, 1950). The Youden Index is a summary measure of the receiver operator characteristic (ROC) curve, measuring the accuracy of a diagnostic marker and generating an optimal cutpoint for the marker (Fluss et al., 2005). Collinearity among the explanatory variables was tested using Spearman rank coefficients. If the correlation coefficient between 2 variables was ≥ 0.6, only 1 variable was retained based on fewest missing values, reliability of measurement, or biological plausibility. Univariable logistic regression models were constructed to identify variables that were unconditionally associated with the outcome using a P-value of 0.2. Risk factors that had univariate associations ($P < 0.2$) were subsequently offered to a multivariable model through a manual backward stepwise process. Variables were retained in the multivariable models if $P < 0.05$. Evaluating the effect of the removed variables on the coefficients of the remaining variables was used to assess confounding. A variable was deemed a confounder if it was not an intervening variable based on the causal diagram (Figure 1), and the log odds of a significant variable in the model changed by at least 20%. Two-way interactions were evaluated between variables suspected to interact based on evidence from the literature and remained in the final model if significant ($P < 0.05$) (Dohoo et al., 2010b). Outliers were identified and evaluated using Pearson residuals and deviance residuals as well as delta-betas, case-control group delta-betas, delta-χ^2, and case-control group delta-χ^2 (Dohoo et al., 2010c). If outliers were found, they were explored to determine the characteristics of the observations that made them outliers. The outliers were retained in the analysis unless the magnitude and direction of the coefficients in the final model were altered by the removal of the data points or if the data were found to be erroneous.

For continuous metabolic indicators in blood that were significant in the final multivariable model and linearly associated with logarithmic odds of the outcome, a Youden's Index (Youden, 1950) was used to determine cutpoints.

RESULTS

Descriptive Statistics

In total, 4,825 calves were evaluated from November 2015 to September 2016; 135 cases died $\leq$21 d following arrival, representing a mortality risk of 2.8% and encompassing 38% (135/357) of the overall mortality occurring in the facility. A total of 270 controls were randomly selected using the criteria previously described. The majority (43%) of case and control calves arrived at the facility in the summer months (June to August) with 26, 25, and 6% arriving in the spring (March to May), winter (December to February), and fall (September to November), respectively. The calves were assigned to the 5 barns based on the availability of rooms within the barn. Barns 1, 2, 3, 4, and 5 housed 27, 28, 35, 7, and 4% of the calves, respectively. The calves were derived from 120 sources, which were categorized into 3 main groups. Local, drover, and auction-derived calves represented 21, 66, and 13% of the overall population, respectively.

Health Parameters

Table 2 describes the proportion of cases and controls with specific health attributes. A χ^2 value was calculated for each health attribute to identify statistically significant differences between the case and control groups (Table 2). Dehydration and emaciation were present in 50 and 54% of calves at arrival, respectively. Approximately a quarter of calves entered the facility with an abnormal navel score or fecal score. A calf seldom entered the facility with an abnormality in the respiratory or joint parameters. Rectal temperature (Table 3) did not differ numerically between cases and controls. Three observers evaluated all the calves upon arrival, with observers 1, 2, and 3 examining 40, 45, and 15% of the case-control groups, respectively.

Blood Parameters

We detected significant differences between cases and controls in weight at arrival, and serum BHB, glucose, cholesterol, and IgG (Table 3). A total of 14 (10%) cases and 6 (2%) controls were hypoglycemic (<3.3 mmol/L; Smith, 2009). Based on the Youden Index, haptoglobin was cut at 0.18 g/L (sensitivity: 0.67; specificity: 0.39; area under the curve: 0.51); NEFA was cut at 0.35 mmol/L (sensitivity: 0.67; specificity: 0.39; area under the curve: 0.53); and BHB was cut at 60.50 μmol/L (sensitivity: 0.34; specificity: 0.55; area under the curve: 0.45).

Early Mortality Model

The variables unconditionally associated with early mortality are given in Table 4. In the final multivariable model, 6 variables were significant (Table 5). A navel score of 2 and dehydration scores of 4 and 5 were associated with higher odds of mortality. Drover-derived calves, greater weight at arrival, and a greater concentration of IgG or cholesterol were associated with lower odds of mortality. No interactions were identified in the final model. A single match group outlier

Table 2. Frequency distribution (%) of calf health attributes scored on arrival at a milk-fed veal facility for 135 calves that died ≤21 d following arrival to a milk-fed veal facility (case) and 270 calves that survived >21 d following arrival to a milk-fed veal facility (control)

Variable	Calf	Score 0	1	2	3	4	χ^2 (*P*-value)
Nasal score	Case	76	23	0	0	—	0.88
	Control	76	24	0	0	—	
Eye score	Case	70	27	2	0	—	0.49
	Control	65	33	2	0	—	
Cough score	Case	90	7	3	0	—	0.02
	Control	94	6	0	0	—	
Fecal score	Case	61	19	13	7	—	0.18
	Control	68	21	8	3	—	
Navel score	Case	19	47	23	11	—	0.17
	Control	21	55	17	6	—	
Joint score	Case	98	1	0	2	—	0.05
	Control	100	0	0	0	—	
BCS	Case	1	7	41	35	16	0.78
	Control	2	8	34	39	17	
Dehydration score	Case	41	39	15	5	0	0.01
	Control	55	31	12	1	0	
Sunken flank	Case	73	27	—	—	—	0.30
	Control	77	23	—	—	—	

was identified; however, it was not determined to be a recording error and was retained in the final model as the magnitude and direction of the coefficients did not change. Cutpoints generated by Youden's Index for continuous variables that were significant in the final model and linearly associated with logarithmic odds of the outcome are presented in Table 6.

DISCUSSION

This study demonstrated that serum IgG and cholesterol concentrations were associated with increased risk for mortality in the first 21 d following arrival at a veal facility. To our knowledge, this is the first study to identify cholesterol as a marker for mortality in calves arriving at a veal facility. However, creating cutpoints for IgG and cholesterol yielded poor estimates of sensitivity and specificity, suggesting that, as standalone tests, both parameters are poor at identifying calves at high risk for early mortality and it may not be economical to use these tests practically. Health status at arrival, specifically navel score and degree of dehydration, were predictors of mortality occurring in the first 21 d following arrival. Source of the calves and weight on arrival were associated with early mortality. A limitation to this study was the length of time from blood

Table 3. Weight, rectal temperature, and metabolic parameters for 135 calves that died ≤21 d following arrival to a milk-fed veal facility (case) and 270 calves that survived >21 d following arrival to a milk-fed veal facility (control)

Variable	Group	Mean	SD	Minimum	Maximum	*P*-value
Weight (kg)	Case	45.29 (99.84 lb)	4.74 (10.44 lb)	36.29 (80 lb)	58.51 (129 lb)	0.02
	Control	46.55 (102.62 lb)	5.11 (11.27 lb)	34.01 (75 lb)	68.49 (151 lb)	
Rectal temperature (°C)	Case	39.16	0.55	37.7	41.7	1.00
	Control	39.16	0.49	37.9	40.7	
BHB (umol/L)	Case	62.24	54.72	0.0	299.0	0.003
	Control	77.58	75.54	2.0	661.0	
Cholesterol (mmol/L)	Case	1.44	0.49	0.2	2.7	<0.001
	Control	1.79	0.61	0.6	4.2	
Glucose (mmol/L)	Case	4.95	1.15	2.1	7.5	0.009
	Control	5.24	0.99	1.8	8.1	
Haptoglobin (g/L)	Case	0.29	0.38	0.1	2.5	0.50
	Control	0.23	0.29	0.1	3.3	
Nonesterified fatty acids (mmol/L)	Case	0.41	0.16	0.1	0.9	0.28
	Control	0.43	0.18	0.1	1.0	
Urea (mmol/L)	Case	3.91	2.52	1.0	17.6	0.36
	Control	3.59	2.24	0.8	25.0	
IgG (g/L)	Case	13.6	9.89	0.4	46.1	<0.001
	Control	19.76	11.07	0.7	72.3	

Table 4. Results of univariable conditional logistic regression model of associations of variables assessed at arrival and mortality ≤21 d after arrival at a milk-fed veal facility using data from 135 case calves and 270 control calves

Variable	Description	n	Odds ratio	95% CI	*P*-value
Rectal temperature	<40°C	377	Referent		
	≥40°C	25	1.85	0.84 to 4.05	0.13
Fecal score	0 and 1	345	Referent		
	2	39	1.85	0.90 to 3.83	0.09
	3	19	2.44	0.94 to 6.30	0.07
Navel score	0 and 1	296	Referent		
	2	78	1.61	0.93 to 2.77	0.09
	3	31	2.21	1.04 to 4.70	0.04
Dehydration score	0	201	Referent		
	1	137	1.88	1.13 to 3.12	0.01
	2	53	2.04	1.00 to 4.19	0.05
	3 and 4	11	5.83	1.58 to 21.41	<0.01
Sunken flank	Yes	98	Referent		
	No	305	0.65	0.36 to 1.18	0.16
Source	Local	85	Referent		
	Drover	269	0.59	0.36 to 0.98	0.04
	Auction	51	0.66	0.30 to 1.48	0.31
BW	Every 1 kg increase		0.92	0.87 to 0.98	<0.01
IgG	Every 1 g/L increase		0.94	0.91 to 0.96	<0.01
Glucose	Every 1 mmol/L increase		0.77	0.62 to 0.94	0.01
Cholesterol	Every 1 mmol/L increase		0.23	0.13 to 0.39	<0.01

collection until serum separation, which would lead to an underestimation of glucose levels due to the utilization of glucose by red blood cells.

The association of navel score with mortality is not a surprising finding because navel infection has been previously shown to affect mortality and overall health of calves (Donovan et al., 1998; Mee, 2008). The high prevalence of calves arriving with abnormal navel score is similar to that in the literature (Wilson et al., 2000) and demonstrates a need to further explore preventative measures for this condition. Calves that were >10% dehydrated at arrival were at increased risk of mortality. Dehydration is also a common issue found in the veal industry (Wilson et al., 2000) and could reflect the time in transit from the source dairy farm (Knowles et al., 1997). Weight at arrival has previously been demonstrated to affect both morbidity (Brscic et al., 2012) and mortality (Winder et al., 2016) in the veal industry. It is unclear whether weight is a reflection of age or nutritional status at the source dairy farm, but it needs to be explored as a mechanism to reduce the risk of mortality. Locally derived calves had increased risk of mortality compared with drover-derived calves. As drovers were more likely to be economically penalized by the veal facility for calves in poor health, they may have implemented a screening process to select healthier calves before transportation. For a more thorough discussion on the effect of health status, weight, and source of the calves on mortality, see Renaud et al. (2018).

Table 5. Final multivariable conditional logistic regression model describing the associations among significant independent variables and the outcome early mortality (≤21 d after arrival at a milk-fed veal facility) using data from 135 case calves and 270 control calves

Variable	Description	Odds ratio	95% CI	*P*-value
Navel score	0 and 1	Referent		
	2	2.22	1.10 to 4.50	0.03
	3	2.51	0.98 to 6.41	0.06
Dehydration score	1	Referent		
	2	1.36	0.74 to 2.48	0.32
	3	1.16	0.48 to 2.78	0.74
	4 and 5	6.10	1.12 to 33.19	0.04
IgG	Every 1 g/L increase	0.94	0.91 to 0.97	<0.01
BW	Every 1 kg increase	0.93	0.86 to 1.00	0.04
Cholesterol	Every 1 mmol/L increase	0.28	0.16 to 0.50	<0.01
Source	Local	Referent		
	Drover	0.48	0.25 to 0.93	0.03
	Auction	0.61	0.20 to 1.86	0.39

Table 6. Cutpoints calculated by Youden's Index[1] for IgG, BW, and cholesterol from blood samples collected from 135 cases and 270 controls at arrival to a milk-fed veal calf facility

Variable	Cutpoint	Se (%)	Sp (%)	AUC
IgG (g/L)	≥16.7	34	49	0.45
BW (kg)	≥46.49	36	54	0.41
Cholesterol (mmol/L)	≥1.6	36	40	0.38

[1]Se (sensitivity) was defined as the proportion of cases (died ≤21 d after arrival) having a test result above the cutpoint; Sp (specificity) was defined as the proportion of controls (survived >21 d after arrival) having a test result below the cutpoint; AUC (area under the curve) was the probability that a randomly selected case had a greater score than a randomly selected control.

Calves depend almost entirely on the absorption of maternal immunoglobulins from colostrum after birth to protect against common pathogens until their own immune system reaches functional maturity (Godden, 2008). Thus, it is expected that the higher the concentration of IgG, the lower the risk of mortality. One of the major challenges with veal production is that veal producers rely on dairy producers to provide the necessary care of these calves on the dairy farm of origin before departure. As a minority (9%) of Canadian dairy producers did not always feed colostrum to male calves (Renaud et al., 2017), this is an area that needs to be addressed to improve the health and welfare of male calves.

Hypoglycemia is a common metabolic derangement occurring in neonatal calves (Smith, 2009). It can occur due to generalized infection (Lofstedt et al., 1999), diarrhea (Santos et al., 2002), or the withdrawal of milk (Smith, 2009). In this study, the prevalence of hypoglycemia was higher in cases than in controls, and glucose concentrations were associated with mortality in the unconditional analysis. However, the relationship between hypoglycemia and mortality did not remain in the final regression model, suggesting that other factors were more important for predicting mortality in this study. These findings regarding glucose need to be considered in light of the serum not being separated immediately.

The association of serum cholesterol with early mortality could have multiple explanations. Cholesterol deficiency haplotype (CDH), which results in low levels of cholesterol (Otter and Hately, 2017), causes emaciation, growth retardation, and diarrhea, leading to increased levels of mortality (Kipp et al., 2016). With the lineage of this deficiency tracing back to a prominent sire in Canada (Maughlin Storm; Kipp et al., 2016), this haplotype may be common in Canada. Cholesterol could also be used as a marker of colostrum intake. The cholesterol concentration is much higher in colostrum than in milk, and concentrations in the first days of life are proportional to the amounts of ingested colostrum (Ontsouka et al., 2016). Cholesterol in colostrum plays a critical role in mediating postnatal growth and development by influencing intestinal signaling and promotion of intestinal lactase activity, which may affect mortality and morbidity in calves (Ontsouka et al., 2016). Cholesterol concentrations in serum also increase with age (Piccione et al., 2010). As calves transported at older ages had lower mortality after transportation (Knowles, 1995), low cholesterol concentrations may represent younger calves. As multiple factors could influence cholesterol concentrations, greater understanding of the mechanisms surrounding cholesterol's influence on mortality is needed.

Concentrations of NEFA, BHB, and urea, which were used as markers of energy status, were not associated with mortality. Knowles et al. (1999) had previously found differences in long-distance transport of calves with respect to these parameters. However, in this study, it is unlikely that calves were transported or held off feed for more than 10 h, and these effects may only have been present in calves transported for longer durations.

Haptoglobin was not a good indicator of early mortality when evaluated upon arrival. Acute phase proteins increase rapidly with the onset of clinical signs or subclinical inflammation; therefore, haptoglobin may not identify calves during a disease incubation period (Svensson et al., 2007). Haptoglobin also increases in response to stress of transportation (Lomborg et al., 2008), which may result in elevated haptoglobin concentrations. These factors could explain the poor performance of haptoglobin in identifying individual calves at increased risk for disease or death. Similar conclusions were made by Svensson et al. (2007) and Murray et al. (2014), in which haptoglobin had a poor discriminative ability to identify individual calves with or at risk for disease.

CONCLUSIONS

Assessing health and metabolic factors upon arrival at a veal facility can identify calves at risk for mortality in the first 21 d after arrival. Calves with low levels of cholesterol and IgG at arrival are at greater risk for early mortality. Navel score, dehydration level, source, and weight should also be evaluated to identify high-risk calves. Screening of calves upon arrival at a veal facility may allow for detection and intervention on high-risk calves to improve survival rates; however, emphasis should be placed on preventative measures, such as improved colostrum management and navel care, before arrival at the veal facility.

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