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Risk factors identified on arrival associated with morbidity and mortality at a grain-fed veal facility: A prospective, single-cohort study

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ABSTRACT

High levels of morbidity, mortality, and antimicrobial use are common in the veal industry. For the sustainability of the industry, it is important to address these challenges and determine factors that can be used to improve animal health and welfare. The objectives of this prospective observational cohort study were to describe the health status of calves on arrival at a grain-fed veal facility and determine characteristics that were associated with morbidity and mortality. On arrival, the calves were assessed for health abnormalities, weighed, measured for hip height and length from withers to lumbosacral junction, and had blood collected to determine serum total protein level. Body mass index (BMI) was calculated using weight on arrival divided by the sum of the calf's length from withers to lumbosacral junction and hip height. The calves were observed for 77 d after arrival, during which the producer was responsible for recording all antibiotic treatments and mortality. We built Cox proportional hazard models for morbidity and mortality variables. We created 2 morbidity models: 1 for calves that were treated <21 d after arrival at the facility, and 1 for calves that were treated during the 11 wk at the facility. From January to December 2017, 998 calves were evaluated on arrival at the veal rearing facility. A large proportion (68%) were treated with antibiotics in the first 21 d after arrival. The only explanatory variable in the final <21 d morbidity model was BMI: calves with a higher BMI had a lower hazard of being treated for disease in the first 21 d after arrival. A total of 872 calves (87%) were treated at least once over the 11-wk housing period. A calf arriving with a BMI >371.46 g/cm or a serum total protein between 5.8 and 6.2 g/dL had a lower level of morbidity during the observation period. Over the 11-wk housing period, 74 calves (7.5%) died. Calves that arrived at the facility with a fecal score of 2 or a rectal temperature between 38.9 and 39.1°C had a higher hazard of dying; calves that had a BMI of >371 g/cm were less likely to die than calves that had a BMI <330 g/cm. These results point to the importance of assessing calves on arrival at a veal facility as a measure of identifying those at high risk for morbidity and mortality.
Key words: veal, calf health, mortality, antimicrobial use

INTRODUCTION

Mortality and morbidity are significant challenges faced by veal producers. The risk of mortality varies considerably; however, recent studies conducted in Canada and other European countries have found that 3 to 8% of calves die during the veal production period (Bähler et al., 2012; Renaud et al., 2018a; Bokma et al., 2019). Disease is also common: Pardon et al. (2012a) reported that 25% of calves developed one or more diseases over the 6 to 8 mo from arrival to slaughter despite the fact that a blanket antimicrobial therapy was commonly provided on arrival. Such high levels of disease have led to the use of large quantities of antimicrobials in the veal calf sector (Bos et al., 2013), and this has contributed to the development of antimicrobial resistance in commensal and animal pathogens (Labio et al., 2007; Catry et al., 2016). Given these levels of morbidity, mortality, and antimicrobial use, it is important for the veal industry to address these challenges and determine factors that can be used to improve animal health and welfare.

A recent study demonstrated that calves at high risk for mortality can be identified on arrival at a milk-fed veal facility (Renaud et al., 2018a). Specifically, calves arriving with a low body weight; an umbilicus that was enlarged with heat, pain, moisture, or malodorous discharge; signs of clinical dehydration; multiple coughs when palpating the calf's trachea; a sunken flank; or from specific sources were associated with greater risk for mortality. If reliable identification of calves at high risk for mortality could be accomplished, it could pro-

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vide an opportunity to selectively treat with antibiotics or supportive therapy and reduce overall antibiotic use (Pardon et al., 2015). However, to date no large-scale epidemiological study has evaluated the effect of health status at arrival on morbidity through the growing period, although such a study could provide further evidence that selective therapy may be an area to explore. In addition, literature evaluating current levels of morbidity on Canadian veal farms is scarce: the last study evaluating morbidity on veal farms in Canada was conducted more than 2 decades ago (Sargeant et al., 1994).

The objectives of this study were to describe the health status of calves on arrival at a grain-fed veal facility and to associate characteristics of the arriving calf with morbidity and mortality. We hypothesized that the presence of health abnormalities on arrival would be associated with an increased level of mortality and morbidity.

MATERIALS AND METHODS

Experimental Design

We conducted a prospective cohort study from January 2017 to April 2018 at a veal rearing facility in southwestern Ontario, Canada. All calves entering the facility from January to December 2017 were eligible for enrollment. This study was conducted in accordance with University of Guelph Animal Care Committee requirements (Animal Use Protocol #3695). The veal facility was selected based on proximity to the University of Guelph, willingness to participate in the study, and ability to keep accurate records. The facility is a grain-fed veal rearing operation, where calves are fed milk replacer twice daily for 49 d and transitioned to a grain-based diet after weaning. Calves were housed in individual stalls with slatted rubber flooring for the first 21 d after arrival; after 21 d, the individual partitions were removed and calves were housed in groups of 5. All milk replacers contained decoquinate (30 mg/kg) and were formulated to contain 26% CP, 17% fat, 2.4% Lys, 0.8% Met, and 1.6% Thr; they were bucket-fed at a daily feeding rate of 520 g wk 1 to 2, 650 g wk 3, and 900 g wk 4 to 5 in a total of 4, 5, and 6 L of solution, respectively, with feedings split evenly between morning and afternoon. All calves were weaned over a 2-wk period by feeding 450 g once per day in wk 6 and 450 g every third feeding in wk 7. Calves were offered texturized calf starter (18% CP) from arrival until wk 3 and then transitioned to a corn and pellet ration with 2% straw (18.1% CP). Groups of calves arrived at the facility every 3 wk to fill a room of 80 calves. After 11 wk, the calves were transported to a larger group-housing facility and slaughtered after an additional 20 wk. Data were not captured beyond 11 wk, because the finishing facility did not have well-kept records.

Calves were transported from their dairy farm of origin or a local auction mart to the rearing facility. On arrival at the veal rearing facility, staff weighed the calves using a digital scale and administered an intranasal bacterin (Once PMH IN; Merck Animal Health, Kirkland, QC) and an intranasal viral vaccine (Bovilis IN; Merck Animal Health). In a subset of rooms, neomycin (NeoMed; Bimeda Inc., Terrace, IL) was provided orally in the milk. The use of group oral antimicrobials varied depending on whether a feed additive trial was being conducted. Heifer and beef cross calves were excluded from the data set due to low numbers. Season at arrival was categorized as winter (December to February), spring (March to May), summer (June to August), and fall (September to November).

Standardized Health Scoring System

A single graduate student, trained by a veterinarian, evaluated all calves on arrival using a standardized health scoring system. An iPad (Apple Inc., Cupertino, CA) with the Calf Health Scorer app (University of Wisconsin-Madison, Madison, WI) and Qualtrics (www.qualtrics.com) was used to facilitate health scoring. The Calf Health Scorer app provided images and descriptions to evaluate the respiratory system (nose, eye, ear, cough; McGuirk and Peek, 2014), attitude, fecal consistency (McGuirk, 2008), navel inflammation (adapted from Fecteau et al., 1997), joint swelling, and rectal temperature. Fecal score was categorized into 3 levels: normal–semiformed; loose; and watery consistency. Navel score was also categorized into 3 levels: normal or slightly enlarged but not warm or painful; swelling with pain or heat; and swelling with severe pain, heat, and malodorous discharge. These variables were categorized to aid in eliminating misclassification between normal and slightly abnormal characteristics. A Qualtrics form was used to collect data on clinical dehydration (Wilson et al., 2000), BCS (Wilson et al., 2000), and the presence of a sunken flank (Bähler et al., 2012). The level of dehydration was scored based on skin tent retention, eye recession, and attitude. A calf was categorized as $\leq$5% dehydrated if the skin tent returned to normal in <2 s, eyes were not sunken, and the calf was bright and alert; if the skin tent returned to normal in 2 s and the eyes were not sunken, the calf was categorized as 6 to 8% dehydrated; a calf was >8% dehydrated if the skin tent returned to normal in >3 s, the eyes were sunken, or the calf was dull or depressed. Additional information collected using the Qualtrics survey included hip height (cm), length (cm)

from the withers to the lumbosacral junction, and navel diameter (mm) measured as the circumference at the base of the calf's umbilicus (Mastercraft, Vonore, TN). Body mass index (**BMI**) was calculated using weight on arrival (g) divided by the sum of the calf's length from the withers to the lumbosacral junction and the hip height (Mei et al., 2002). This allowed for a more objective score compared with the subjective BCS.

Blood Collection

Blood was collected from the jugular vein into a 10-mL sterile blood collection tube without an anticoagulant (BD Vacutainer; Becton Dickinson and Co., Franklin Lakes, NJ). Blood samples were allowed to clot and then centrifuged at 1,500 × g for 15 min at approximately 20°C. Serum was separated and serum total protein (**STP**) was evaluated using a digital refractometer (Palm Abbe #PA202x; Misco, Solon, OH). Failure of passive transfer of immunity was defined as <5.1 g/dL (Renaud et al., 2018b).

Outcome Assessment

Personnel on the farm were responsible for identifying and treating calves for disease using a protocol created in consultation with their veterinarian. A single observer was responsible for the majority of the treatments, but 2 additional staff members gave at least 1 treatment during the trial. Calves were treated with trimethoprim and sulfadoxine (Borgal 3 mL/45 kg i.m. once per day for 3 consecutive days, Merck Animal Health) along with meloxicam (Metacam 2.5 mL/100 kg s.c. once; Boehringer, Burlington, ON, Canada) if they had 3 consecutive days of watery diarrhea, had blood in loose or watery feces, or had loose or watery feces and were refusing milk for 2 consecutive feedings. All calves that had diarrhea were also treated with 2 L of electrolytes once daily. Calves were screened for respiratory disease by farm personnel, who evaluated for nasal and ocular discharge, abnormal respiration rate, and the presence of a cough, and measured rectal temperature. Calves with respiratory disease were treated with florfenicol (Nuflor 6 mL/45 kg s.c. once; Merck Animal Health) and meloxicam (Metacam 2.5 mL/100 kg s.c. once; Boehringer). Treatment and mortality records, including reason and date, were obtained from the producer and used for the analysis.

Sample Size Calculation

A proportion estimation sample size calculation was used to determine the required number of calves. Based on previous work by Pardon et al. (2015) and Renaud et al. (2018a), we estimated that calves identified with a health abnormality on arrival would have a morbidity risk of 26% and those without an abnormality would have a morbidity risk of 17%. Using a 95% CI and 80% power, a sample size of 916 calves was required.

Statistical Analysis

All statistical analyses were conducted using Stata 14 (StataCorp LP, College Station, TX). Data were imported from Excel (Microsoft Corp., Redmond, WA) into Stata 14 and checked for completeness. We created causal diagrams to illustrate the hypothesized relationship between dependent and independent variables and used these to guide the analyses (Figure 1). We generated descriptive statistics for all explanatory variables in the data set.

Cox proportional hazard models were built for morbidity and mortality variables, controlling for the room of the calves as a random effect. We created 2 morbidity models: one for calves that were treated <21 d following arrival at the facility, and one for calves that were treated at any time in the 11 wk at the facility. When observing overall morbidity in the subset, it appeared that morbidity had 2 peaks: the first occurred in the first 21 d of the calves' arrival at the facility, and the second occurred later in the growing period (Figure 2). Many studies (Bähler et al., 2012; Pardon et al., 2012a; Winder et al., 2016) have identified that the first 21 d after arrival is the period of greatest risk for disease; thus, we built a model to explore this critical phase. Morbidity was defined as a calf being treated for signs of respiratory disease or diarrhea. We built a single model to explore factors associated with mortality, because a small number of calves (n = 22) died in the first 21 d after arrival. Mortality was defined as a calf that died during the 11 wk under observation. The time series variable for both models was the number of days until the event.

For each model, the functional form of the continuous explanatory variables was assessed by computing the Martingale residuals from a model without the continuous predictor of interest and plotting the residuals against the predictor. If the relationship was not linear, the variable was categorized into 2 categories. If a variable failed to meet the linearity assumption, the variable was categorized into quartiles. In the mortality model, rectal temperature on arrival and BMI were categorized; in the morbidity models, BMI and STP were categorized. We used Spearman rank coefficients to determine collinearity between the variables. If the correlation coefficient between 2 variables was ≥0.6, only 1 variable was retained, based on the lowest number of missing values, reliability of the measure-

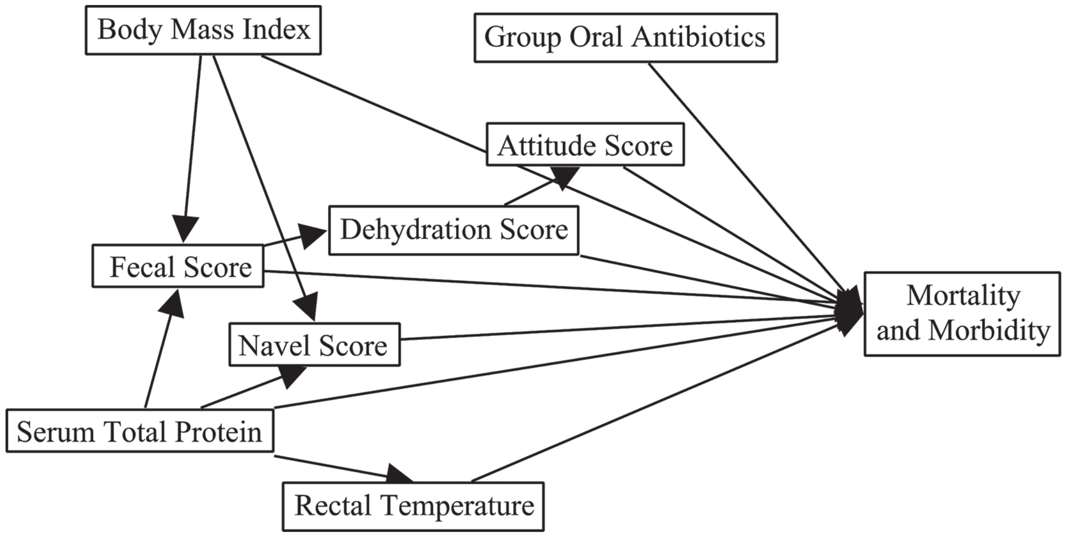

Figure 1. Causal diagram describing the relationship of measured variables to morbidity and mortality.

ment, and biological plausibility (Dohoo et al., 2010). Explanatory variables that were unconditionally associated (P-value <0.2) with the outcome in univariable Cox proportional hazard models were offered to a multivariable model through manual backward stepwise removal. For all variables of interest, we used a P-value ≤0.05 to assess significance. We assessed confounding before removing any predictors. If the difference in the coefficient of a significant variable between the reduced and full model was >20% and was not an intervening

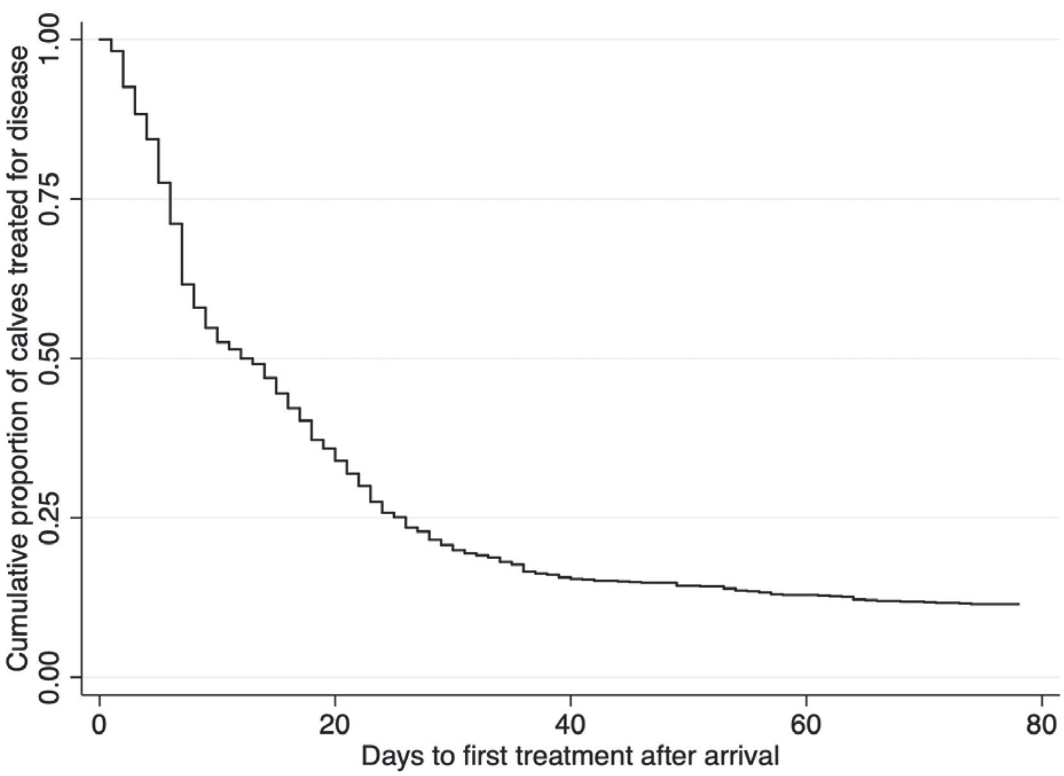

Figure 2. Kaplan-Meier survival estimate: days after arrival that treatment for disease occurred in 998 calves screened on arrival at a grain-fed veal facility.

variable identified in the causal diagram, the variable was considered to be a confounder and was kept in the model regardless of statistical significance. However, if the difference in the coefficient of a significant variable between the reduced and full model was <20%, it was removed. Two-way interactions were evaluated based on evidence from the literature and were kept in the models if significant. We assessed the fit of the models using the test of proportional hazards. If the test was significant ($P < 0.05$), we tested the proportionality of each predictor and stratified the model on the nonproportional predictor. Outliers were identified and evaluated using deviance residuals, as well as score residuals. If any covariate patterns were determined to be outliers or greatly affected the model, we investigated them further for appropriate interpretation, although they were ultimately kept in the model if the data were not erroneous. We calculated Harrell's C concordance statistic for each model to evaluate their overall predictive ability (Dohoo et al., 2010).

Cutpoints were generated by the Youden index (Youden, 1950) for individual predictors that were significant in the final models. The Youden index is a summary measure of the receiver operating characteristic curve, measuring the accuracy of a diagnostic marker and generating an optimal cutpoint to maximize both sensitivity and specificity (Fluss et al., 2005). Weight on arrival was also added to determine whether BMI had better predictive ability.

RESULTS

Descriptive Statistics

Of 14 groups of calves, we assessed a total of 998 calves from January to December 2017. We did not receive information about calves' age on arrival, but estimated that most calves were between 1 and 7 d of age. Most calves arrived in the spring (39.7%); the smallest number arrived in the winter (17.2%). In the summer and fall, 22.6 and 20.6% of the calves arrived at the facility, respectively. Many calves had health challenges on arrival: 32% were clinically dehydrated, 19.9% had an abnormal navel, 13.5% had diarrhea, and 8% were dull or depressed. Very few calves had an abnormal respiratory score on arrival. The mean [± standard deviation (SD)] arrival weight of the calves was 46.9 ± 4.8 kg (range 34–68 kg). The mean (± SD) length of the withers to the lumbar sacral junction was 46.8 ± 2.9 cm, and mean (± SD) hip height was 86.7 cm ± 3.4 cm. The calculated mean (± SD) BMI was 349.6 ± 32.1 g/cm (range 240–485 g/cm). Calves arrived with a mean (± SD) STP of 5.8 ± 0.7 g/dL, and the incidence of failure of passive transfer of immunity was 13.1%. The mean (± SD) rectal temperature measured on arrival was 38.9 ± 0.6°C. The mean (± SD) diameter at the base of the calf's umbilicus was 23.66 ± 8.99 mm. Descriptive statistics of the health parameters measured on arrival can be found in Table 1.

Table 1. Frequency and prevalence of categorical variables measured on arrival at a grain-fed veal facility

Variable	Description	Numerical score	Frequency (no.)	Prevalence (%)
Attitude	Bright, alert, and responsive	0	918	92.0
	Dull	1	73	7.3
	Depressed	2	7	0.7
Nasal discharge	Normal, serous discharge	0	996	99.8
	Small amount of unilateral, cloudy discharge	1	2	0.2
Ear position	Normal	0	956	95.8
	Ear flicking	1	39	3.9
	Slight unilateral ear drop	2	3	0.3
Ocular discharge	Normal	0	940	94.2
	Mild ocular discharge	1	55	5.5
	Moderate bilateral ocular discharge	2	2	0.2
	Heavy ocular discharge	3	1	0.1
Cough score	No cough	0	906	90.8
	Induced single cough	1	92	9.2
Fecal score	Normal and semiformed, pasty	0	863	86.5
	Loose	1	75	7.5
	Watery consistency	2	60	6.0
Navel score	Normal and slightly enlarged, not warm or painful	0	799	80.1
	Slightly enlarged with slight pain or moisture	1	170	17.0
	Enlarged with pain, heat, or malodorous discharge	2	29	2.9
Dehydration	≤5% dehydrated	0	682	68.3
	6–8% dehydrated	1	265	26.6
	>8% dehydrated	2	51	5.1
Group treatment on arrival	No	0	645	64.9
	Yes	1	348	35.1

Table 2. Results of final Cox proportional hazards model evaluating the association between morbidity and risk factors measured on arrival in 992 calves at a grain-fed veal facility

Variable	Description	Hazard ratio	*P*-value	95% CI	n
Body mass index (g/cm)	<330.20	Referent			248
	330.20–348.93	0.90	0.28	0.74–1.09	245
	348.94–371.45	0.86	0.13	0.71–1.04	251
	>371.46	0.74	0.003	0.61–0.91	248
Serum total protein (g/dL)	≤5.2	Referent			209
	5.3–5.7	0.94	0.51	0.78–1.13	295
	5.8–6.2	0.82	0.05	0.67–0.99	240
	≥6.3	0.86	0.17	0.70–1.06	202

Morbidity

In the first 21 d after arrival, 676 calves (68.3%) were treated at least once; 420 calves (42.0%) and 501 calves (50.2%) were treated for diarrhea and pneumonia, respectively. Morbidity in the first 21 d of calves' arrival at the facility was used as the dependent variable. The median days to first treatment was 8, but ranged from 1 to 21 d after arrival.

For the early morbidity model, level of dehydration, use of group antibiotic treatment, and BMI were associated in univariable analysis with treatment of disease in the first 21 d after arrival. The sole variable associated with early morbidity in the final model was BMI. A calf with a BMI of 348.94 to 371.45 g/cm [hazard ratio (**HR**) 0.73; 95% CI: 0.59–0.91; $P = 0.004$] or >371.46 g/cm (HR 0.65; 95% CI: 0.52–0.81; $P < 0.001$) had a reduced hazard of being treated for disease in the first 21 d after arrival compared to a calf with a BMI of <330.20 g/cm.

A total of 872 (87%) calves were treated at least once over the 11-wk housing period. Of those, 425 (43%) were treated for diarrhea, and 820 (83%) were treated for respiratory disease. The median days to first treatment was 9, but ranged from 1 to 74 d after arrival (Figure 2). The Harrell's C concordance statistic was 0.55, meaning 55% of the time the model correctly ordered survival times for pairs of calves, suggesting that the predictive ability of the model was limited.

For the morbidity model, STP, navel score, level of dehydration, use of group antibiotic treatment, and BMI were associated with the outcome in univariable analysis. After manual backward selection, BMI and STP remained as the predictor variables in the final model (Table 2). A calf with a BMI of >371.46 g/cm was associated with a 26% reduction in the hazard of being treated for disease in the 77 d under observation compared with a calf with a BMI of <330.20 g/cm (Figure 3). A calf with an STP of 5.8 to 6.2 g/dL was associated with an 18% reduction in the hazard of being treated compared with a calf with an STP of ≤5.2 g/dL (Figure 4). The predictive ability of the model was again limited, only correctly ordering survival times for pairs of calves 54% of the time (Harrell's C concordance statistic 0.54).

Based on the Youden index, the optimal cutpoint for BMI when looking at morbidity over the entire period was 351.85 g/cm [Sensitivity (**Se**) 0.46; specificity (**Sp**) 0.56; area under the curve (**AUC**) 0.51]. The cutpoint for BW on arrival was 46.04 kg (Se 0.54; Sp 0.47; AUC 0.51), and for STP, was 5.75 g/dL (Se 0.41; Sp 0.54; AUC 0.48).

Mortality

The outcome variable was calves that died in the 11 wk at this facility. A total of 74 calves (7.5%) died during the period of observation. The mean days to mortality was 42, and ranged from 1 to 77 d after arrival (Figure 5). Navel score, fecal score, rectal temperature, BMI, STP, and use of group antibiotic treatment were associated with mortality in univariable analysis. After manual backward selection, the final model included fecal score, BMI, and rectal temperature (Table 3). We found no interaction terms or outliers. If a calf arrived at the facility with a fecal score of 2, it had a 2 times greater hazard of dying than a calf with a fecal score of 0 or 1 (Figure 6). Again, BMI was an important predictor: a calf with a BMI of >348.94 g/cm had a reduced hazard of dying compared to a calf with a BMI <330.20 g/cm (Figure 7). Finally, a calf with a rectal temperature of 38.9 to 39.1°C had a higher hazard of dying than a calf with a temperature of <38.7°C (Figure 8). The Harrell's C concordance statistic was 0.66, indicating the model could correctly order survival times for pairs of calves 66% of the time based on fecal score, BMI, and rectal temperature.

For the mortality model, the optimal cutpoints were 336.81 g/cm for BMI (Se 0.56; Sp 0.32; AUC 0.44), 44.22 kg for BW on arrival (Se 0.62; Sp 0.29; AUC 0.45), and 38.95°C for rectal temperature (Se 0.59; Sp 0.51; AUC 0.55).

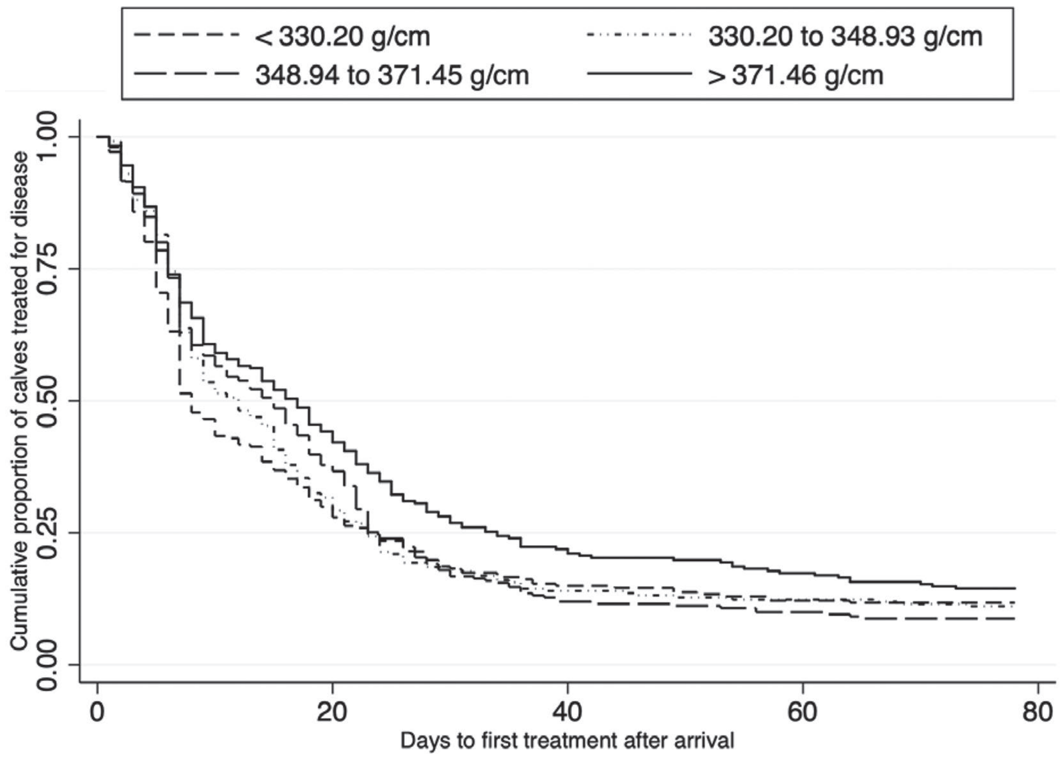

Figure 3. Kaplan-Meier survival estimate: days after arrival that treatment for disease occurred in 998 calves screened on arrival at a grain-fed veal facility, differentiated by body mass index.

DISCUSSION

Parameters measured upon arrival at the veal facility in this study were associated with morbidity and mortality. Fecal score, BMI, and rectal temperature measured on arrival were associated with mortality, and BMI and STP were associated with morbidity. For those producers that are able, evaluating calves' fecal consistency and BMI could be done on the farm of origin to avoid purchasing high-risk calves. Making contracts with surrounding dairies to provide healthy calves that can thrive at the veal facility would also be beneficial for the dairy farm of origin and the veal producer.

A potential limitation to consider is that the producer was very selective about which calves they brought into the facility. They would commonly leave calves that were visually less healthy on the dairy farm of origin. This may have introduced selection bias and could limit the external validity of the study, because few veal producers in Canada have a high level of control of the calves they purchase. This could explain some of the differences found compared with a similar study conducted at an Ontario milk-fed veal facility, where navel score, level of dehydration, and the presence of a sunken flank were associated with mortality (Renaud et al., 2018a). The inability to control for the source of the calves in the analysis is another limitation to consider. Previous studies have found that the source of the arriving calves is important to consider when purchasing calves (Renaud et al., 2018a), but because the facility in this study did not record the source of origin, it could not be included in the analysis. Providing oral antibiotics to some calves on arrival may have lessened the effect of some health characteristics on mortality and morbidity. This could have affected some of the associations found in this study and should be considered when interpreting the study results. A final limitation to consider is that we did not evaluate intra-rater reliability, although low agreement with some of the measures evaluated was found in a similar study (Renaud et al., 2018a).

We identified a high level of morbidity in this study: almost 87% of calves were treated over the observation period. Other studies that did not use blanket antimicrobial therapy identified that 15 to 60% of calves were treated for respiratory disease and diarrhea over the first 3 to 6 mo of life (Waltner-Toews et al., 1986; McGuirk, 2011; Windeyer et al., 2014; Pardon et al., 2015), suggesting that the number of calves treated in

this study was high. Producer diagnosis is not always consistent and effective (Virtala et al., 1996); in the present study, reliance on producer diagnosis and treatment may have led to the high proportion of calves being treated for disease. The mortality rate was similar to previously reported mortality, which ranged from 4 to 10% (Winder et al., 2016; Renaud et al., 2018a). Because this measure is much more objective than morbidity, more weight should be placed on the associations made with mortality.

Body mass index on arrival was associated with morbidity and mortality. Solely evaluating the weight of calves on arrival does not take into account variations in calves' body condition, height, and length. Therefore, we developed a BMI as a composite measure of weight, height, and length so that the entire calf could be evaluated, rather than focusing solely on weight. Mei et al. (2002) used a similar scale to the one used in this study and found that a BMI scale was the most accurate at detecting the condition of infants. In this study, BMI had a lower Akaike information criterion than BW on arrival in all models, but the performance of these parameters was similar in terms of overall sensitivity, specificity, and AUC. Hence, from a practical perspective and ease of evaluation, body weight on arrival could be a screening tool as part of risk assessment for producers. The association of BMI with health is comparable to other studies, in which lower weight or height was associated with a higher risk of morbidity and mortality (Virtala et al., 1996; Brscic et al., 2012; Winder et al., 2016). Because underweight calves were in a more proinflammatory state following transport to a veal facility, this could explain increased disease susceptibility, where excessive inflammation contributes to a reduced disease protection (Masmeijer et al., 2019). As well, BMI could be a reflection of the nutritional status of the calf before arrival, the size of the calf at birth, and the age of the arriving calf (Winder et al., 2016). Previous disease has also been shown to reduce ADG (Virtala et al., 1996; Windeyer et al., 2014), affect body weight (Stanton et al., 2010), and may reduce BMI. Due to the importance of this measure, future studies should focus on determining ways to increase the BMI of arriving calves.

Neonatal calf diarrhea is one of the most important diseases in calves under 30 d of age (Virtala et al., 1996; McGuirk, 2008). An interesting finding in this study was that a fecal score of 3 was not associated with mortality, whereas a fecal score of 2 was associated a greater risk of mortality. The reason for this finding is

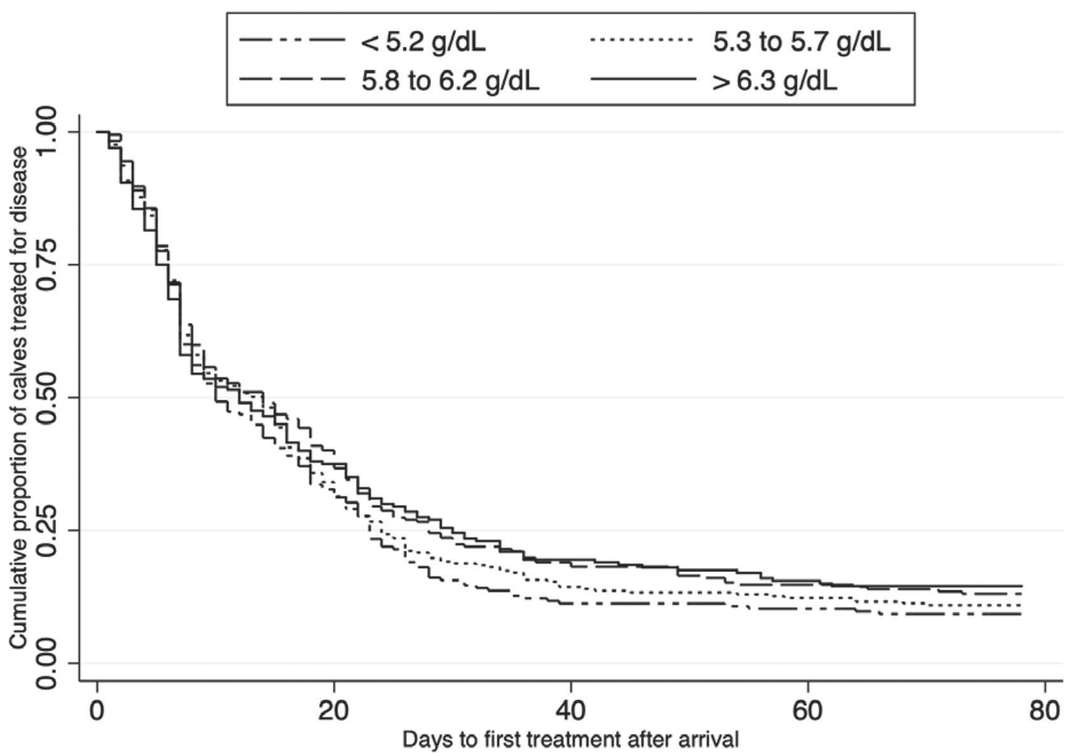

Figure 4. Kaplan-Meier survival estimate: days after arrival that treatment for disease occurred in 998 calves screened on arrival at a grain-fed veal facility, differentiated by serum total protein.

Table 3. Results of final Cox proportional hazards model evaluating the association between mortality and risk factors measured on arrival in 992 calves at a grain-fed veal facility

Variable	Description	Hazard ratio	*P*-value	95% CI	n
Fecal score	0 and 1	Referent			863
	2	2.11	0.03	1.08–4.16	75
	3	0.28	0.21	0.04–2.03	60
Body mass index (g/cm)	<330.20	Referent			248
	330.20–348.93	0.90	0.28	0.74–1.09	245
	348.94–371.45	0.51	0.04	0.27–0.98	251
	>371.46	0.34	0.006	0.16–0.74	248
Rectal temperature (°C)	<38.7	Referent			258
	38.7–38.8	1.37	0.47	0.59–3.19	156
	38.9–39.1	2.20	0.03	1.09–4.44	257
	≥39.2	1.36	0.41	0.66–2.81	327

unclear, but calves that have loose but not solely liquid feces could already be dehydrated and be unable to pass any more fluid for a more liquid fecal consistency. This was a particularly interesting finding and should be explored further.

Failure of passive transfer of immunity has been related to increased morbidity and mortality in calves (Donovan et al., 1998; Renaud et al., 2018a). In this study, we determined that an STP of 5.8 to 6.2 g/dL was protective against morbidity, suggesting that a higher cutpoint may be necessary when evaluating the effect of STP on disease. Because we found discrepancies between this cutpoint and the historical cutpoints used, and considering that many of the historical thresholds were determined using healthy, well-hydrated calves, further research may be necessary to determine the cutpoints to be used when evaluating IgG and STP in veal calves.

The provision of oral antimicrobials for the first week after arrival was not associated with morbidity or mortality. Over the 14 lots, 348 calves (35%) were group-treated. It is not uncommon for producers to

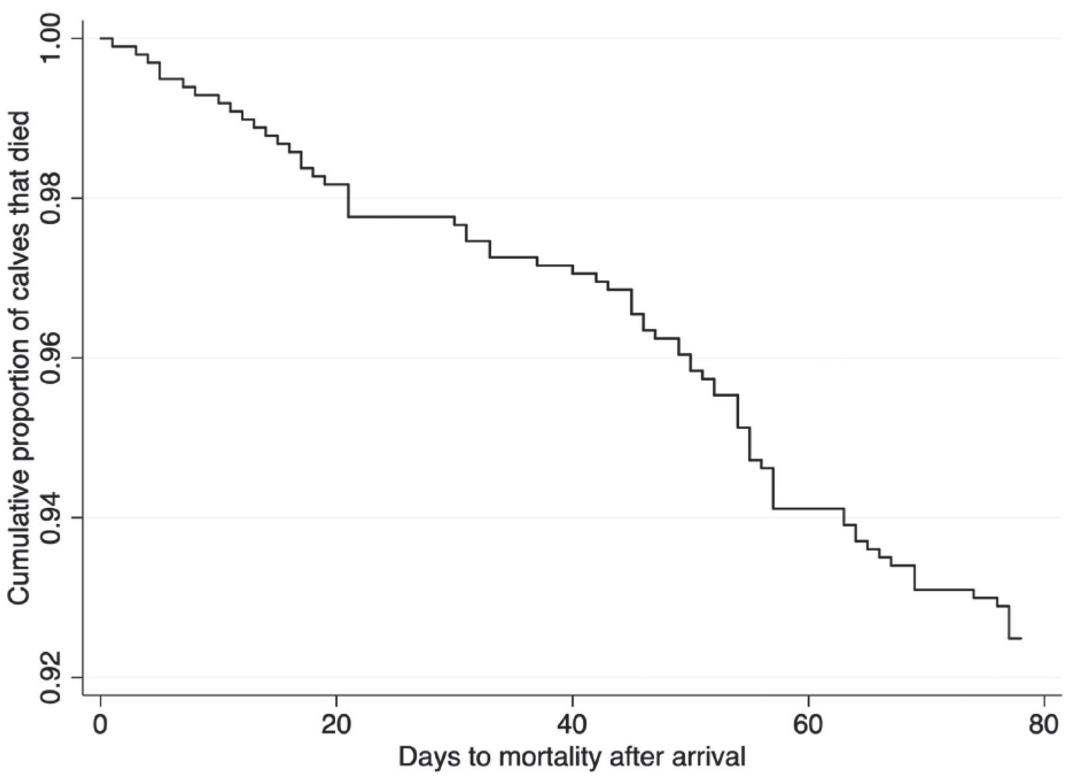

Figure 5. Kaplan-Meier survival estimate: days after arrival that death occurred in 998 calves screened on arrival at a grain-fed veal facility.

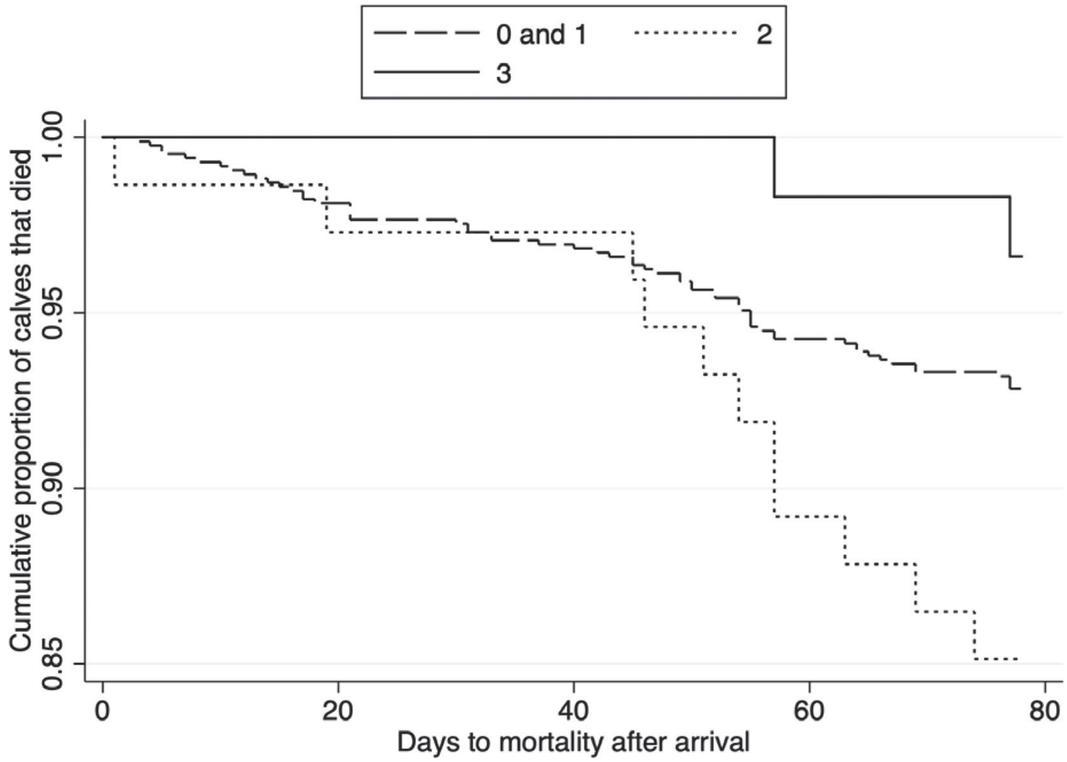

Figure 6. Kaplan-Meier survival estimate: days after arrival that death occurred in 998 calves screened on arrival at a grain-fed veal facility, differentiated by fecal score.

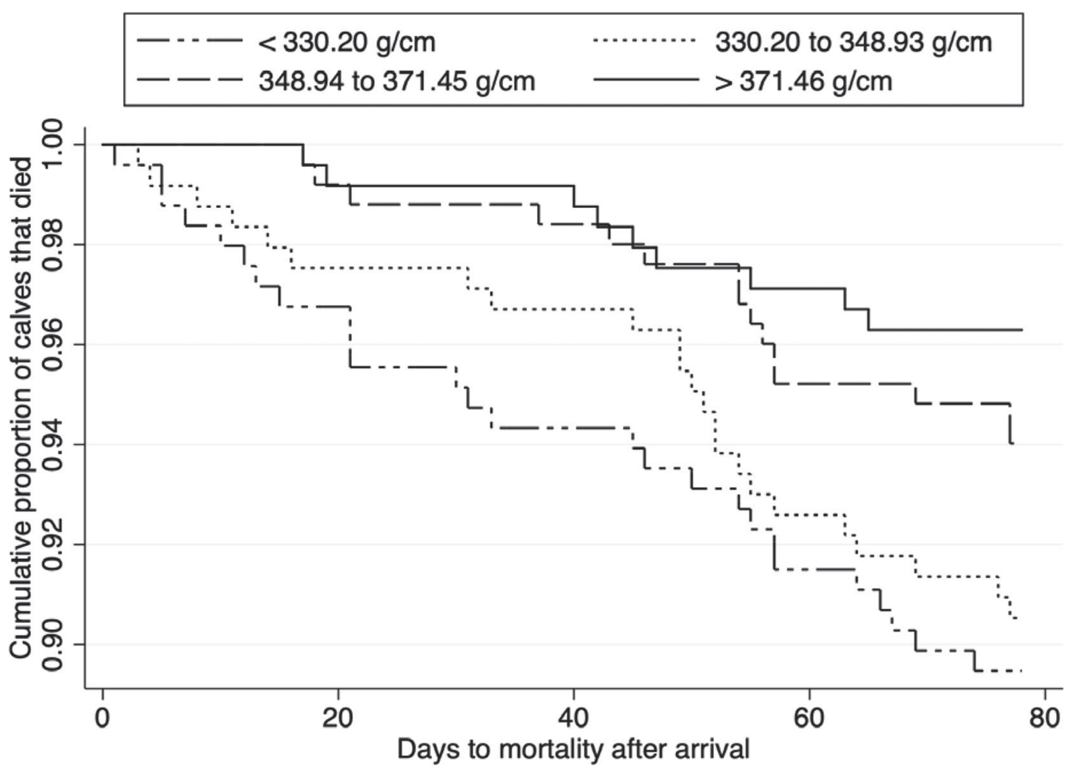

Figure 7. Kaplan-Meier survival estimate: days after arrival that death occurred in 998 calves screened on arrival at a grain-fed veal facility, differentiated by body mass index.

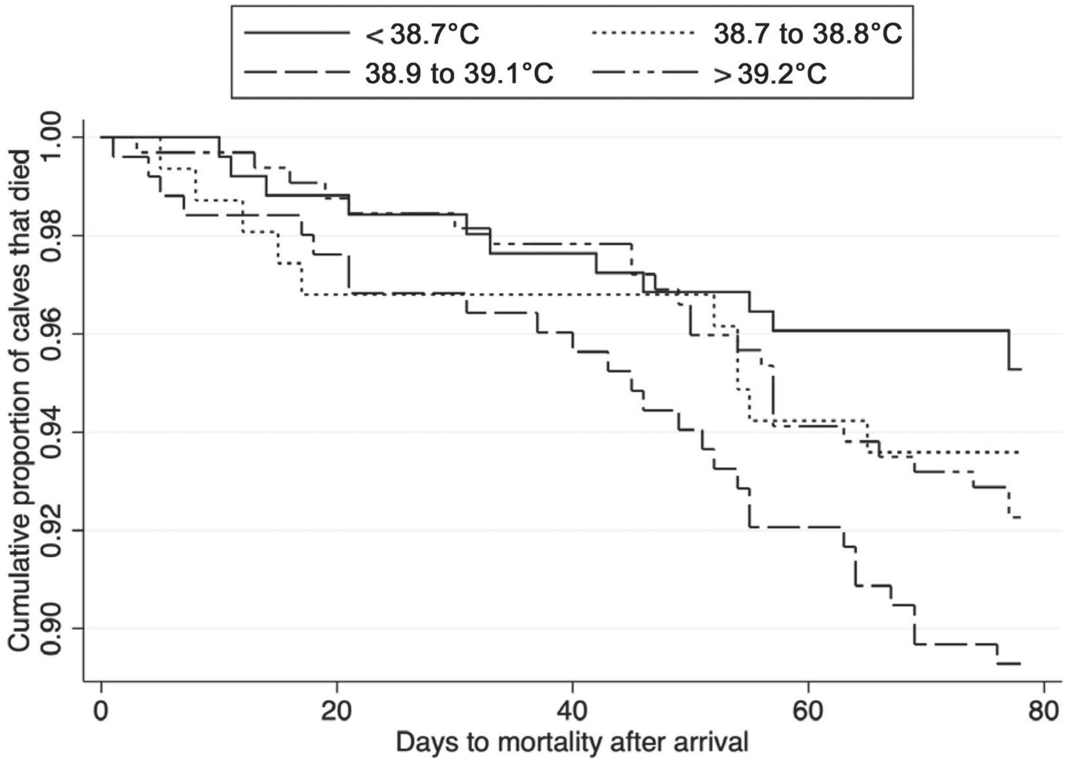

Figure 8. Kaplan-Meier survival estimate: days after arrival that death occurred in 998 calves screened on arrival at a grain-fed veal facility, differentiated by rectal temperature.

treat prophylactically to prevent disease outbreaks and metaphylactically to control pathogens once they have invaded the facility. However, Jarrige et al. (2017) stated that it would be helpful to the industry to explore the necessity and effectiveness of this strategy, because it represents the majority of antimicrobial consumption (Pardon et al., 2012b; Lava et al., 2016; Jarrige et al., 2017). Future research should focus on trying to eliminate this practice through selective therapy to reduce the incidence of morbidity and mortality.

CONCLUSIONS

Based on the results of this study, measuring the health status of calves on arrival at a veal facility can aid in early detection of disease. Specifically, BMI, STP, diarrhea, and rectal temperature measured on arrival were associated with mortality and morbidity. The reduction of morbidity and mortality at veal production facilities may be possible through early interventions on arrival. Because the prevalence of these health abnormalities is high on arrival, future studies should explore how to prevent these conditions from occurring before arrival through improved management of transport and early life on the dairy farms of origin.

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