Association of neonatal serum immunoglobulin G1 concentration with health and performance in beef calves

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Objective—To evaluate associations between neonatal serum IgG1 concentration and pre- and postweaning morbidity and mortality rates and average daily gains (ADGs) in beef calves and define a cutoff point for serum IgG1 concentration necessary for optimal health and performance of calves.

Design—Nonconcurrent cohort study.

Animals—1,568 crossbred beef calves.

Procedure—Single radial immunodiffusion was used to quantify IgG1 concentration in sera collected from calves between 24 and 72 hours after birth. Logistic regression, ANCOVA, and likelihood ratios were used to analyze data.

Results—In the preweaning period, lower perinatal IgG1 concentrations were significantly associated with higher morbidity rates, higher mortality rates, and lower ADGs. Calves with serum IgG1 concentration < 2,400 mg/dL were 1.6 times as likely to become ill before weaning and 2.7 times as likely to die before weaning as calves with higher serum IgG1 concentrations. Calves with serum IgG1 concentration of at least 2,700 mg/dL weighed an estimated 3.35 kg (7.38 lb) more at 205 days of age than calves with lower serum IgG1 concentration. No significant association of serum IgG1 concentration with feedlot morbidity, death, or ADG was identified.

Conclusions and Clinical Relevance—By use of likelihood ratios, the threshold of serum IgG1 concentration for optimal health and performance of calves was higher than values reported previously. Implementation and quantitation of IgG1 concentration necessary for optimal health and performance of calves, morbidity and mortality rates and ADGs in beef calves and, by use of likelihood ratios, define a cutoff point for serum IgG1 concentration necessary for optimal health and performance of beef calves.

Materials and Methods

Selection of cattle—A nonconcurrent cohort design was selected for this study. Calves from beef-breed dams that were 4 years of age or older and had been bred to purebred Charolais or Belgian Blue-cross bulls were eligible for inclusion in the study. Calves born with no or only minimal assistance of passive transfer of immunoglobulins from maternal to fetal circulation.1 This renders the newborn calf essentially agammaglobulinemic. Adequate and immediate intake of colostrum rich in immune factors and antibodies is essential to confer protective immunity to young calves.

The general positive influence of colostrum on calf health has been widely recognized.2-5 Although much has been discovered in the last century about colostral composition and the physiologic process of absorption from the gastrointestinal tract, relatively little has been done to quantify the effects of different concentrations of IgG1 absorption on subsequent health and performance, especially in beef calves. Many factors, in addition to intake of colostrum, such as pathogen challenge, environment, and herd management practices, play vital roles in calf health.6,8 Quantitative information regarding performance, health, and economic benefits is critical to appropriately integrate recommendations on colostral intake into an effective management program to optimize calf health and performance. The objectives of the study reported here were to evaluate and quantify associations between serum IgG1 concentration and pre- and postweaning morbidity and mortality rates and ADGs in beef calves and, by use of likelihood ratios, define a cutoff point for serum IgG1 concentration necessary for optimal health and performance of beef calves.

Bovine fetuses, like all ruminants, have a syndesmochorial type of placenta that does not permit direct communication between the fetal and maternal circulations.8 This renders the newborn calf essentially agammaglobulinemic. Adequate and immediate intake of colostrum rich in immune factors and antibodies is essential to confer protective immunity to young calves.

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tance on February 28 through May 20 in each of the years 1996, 1997, and 1998 at the Roman L. Hruska US Meat Animal Research Center were included. All calves were maintained with similar management practices and levels of intervention. Calves were excluded from the study if they were not sired by the prescribed set of bulls, were fostered away from their dams, or left the herd for unknown reasons; there were no available data regarding dam line; or a blood sample had not been obtained between 24 and 72 hours after birth. Within 24 hours of birth, each calf was individually identified with 2 ear tags. For each calf, the identification number, sire line, date of birth, sex, birth weight, dam's degree of difficulty during parturition (calving difficulty score assigned), calf's coat color, and type of birth (single or twin) were recorded.

Data pertaining to weather conditions during the 24-hour period in which each calf was born were obtained from the High Plains Regional Climate Center, Lincoln, Neb. The source of the measurements originated within 4 miles of the facility where the cattle resided, and data were recorded each day at the same time. Standards and guides from the National Weather Service were utilized in collection of data. From the facility where the cattle resided, and data were recorded each hour period in which each calf was born were obtained from the High Plains Regional Climate Center, Lincoln, Neb. The source of the measurements originated within 4 miles of the facility where the cattle resided, and data were recorded each day at the same time. Standards and guides from the National Weather Service were utilized in collection of data. From the facility where the cattle resided, and data were recorded each 24-hour period, the minimum temperature, mean temperature, amount of precipitation, minimum wind chill index, mean wind chill index, and relative humidity were obtained for use in the study.

**Determination of neonatal IgG1 status**—A blood sample was collected from a jugular vein of each calf between 24 and 72 hours after birth. This time period for blood collection was selected to allow adequate time for calves to absorb a maximum amount of IgG1 from ingested colostrum. Clotted blood samples were centrifuged, and sera were collected and stored at −80°C until assayed. Single radial immunodiffusion was used to quantitate IgG1 concentration in each serum sample. One hundred thirty-six serum samples had IgG1 concentrations ≤ 412 mg/dL, which were beyond the range of the assay; therefore, the IgG1 concentration in those samples could not be precisely estimated. For statistical analysis, the IgG1 concentration of 801 to 1,600 mg/dL was considered as a continuous variable, and calves with marginal passive transfer (all calves with serum IgG1 concentration ≤ 800 mg/dL) were classified as a trivariate categorical variable with regard to the success of passive transfer (failure, marginal, or adequate). When serum IgG1 concentration was considered as a continuous variable and as a trivariate categorical variable with regard to the success of passive transfer (failure, marginal, or adequate). When serum IgG1 concentration was considered as a continuous variable, the serum samples that had < 412 mg of IgG1/dL were classified as < 412 mg/dL.

**Preweaning morbidity, death, and performance**—Trained personnel monitored calf health by performing daily herd checks and were not aware of the calves’ IgG1 status. Calves were observed for signs of illness, such as malaise, diarrhea, dyspnea or increased respiratory effort, trauma, physical deformities, mentation abnormalities, nasal discharge, and increased rumen fill (bloat). When signs were observed, an individual morbidity event record was created for that calf that included diagnosis, date of diagnosis, and prescribed treatment. All personnel identified illnesses and diagnosed diseases on the basis of standard guidelines, which included case definitions and prescribed treatment protocols. For example, a person examining a lame calf with swelling of joints and a swollen umbilicus would, based on the guidelines, assign a diagnosis of “joint ill” (septic arthritis and omphalitis) to the calf and proceed with the prescribed treatment protocol. The treatment assignments were made in accordance with a preestablished treatment protocol. Complete postmortem examinations by veterinarians or a qualified veterinary technician were conducted on all calves that died. Necropsy findings, supple-

mental tests, and diagnoses were recorded and subsequently entered into a database.

A preweaning morbidity event was defined as any recorded disease event during the period between birth and weaning for which a treatment was administered. Morbidity events associated with a traumatic cause were excluded from analyses. Classification of preweaning deaths was based on postmortem records. Deaths attributed to traumatic causes, including drowning and lightning strike, were excluded from analyses. Preweaning performance was determined by calculating individual ADG from birth to weaning. Calves were weaned at approximately 200 days of age, and actual weights at weaning were recorded. Adjusted weaning weights were also calculated for 200-day weights by use of the Beef Improvement Federation guidelines that adjusted for age of the dam and sex of the calf.

**Postweaning morbidity, death, and performance**—Postweaning morbidity rates were assessed in a 2-stage process. Calves were moved to a feedlot environment at weaning where experienced feedlot personnel monitored calves daily for indications of illness. Morbidity events included signs of depression, decreased rumen fill (anorexia), bloat, droopy ears, ocular discharge, head tilt, lameness, nasal discharge, increased respiratory effort, or dyspnea. Calves exhibiting ≥ 1 of these symptoms were sent to the feedlot hospital for further assessment, and preestablished protocols were used to make diagnoses and assign treatments. Diagnoses were established on the basis of 1 set of standard guidelines provided to all personnel. The assignment of a particular diagnosis to an ill calf was based on signalment and clinical signs. For example, a person examining a lame calf that had signs of infection between the digits with swelling, heat, or drainage from an open wound would, based on the guidelines, assign a diagnosis of foot rot (interdigital necrobacillosis) to the calf. When signs were observed, an individual morbidity event record was created for the calf that included diagnosis and prescribed treatment; date of diagnosis; and type, amount, and routes of administration for each drug. All calves that died at the feedlot underwent a postmortem evaluation. Deaths were classified by use of database records supplemented with original copies of postmortem examination records. Deaths resulting from trauma or other atypical events (such as anaphylactic shock) were excluded from further analyses. Final weights (feedlot-out weights) of calves were measured and recorded approximately 7 to 10 days before slaughter. Postweaning performance was measured by calculating individual ADG from weaning to feedlot-out weight.

**Statistical analysis**—Descriptive statistics were generated for pre- and postweaning health and performance outcomes. The primary risk factor of interest was the immunoglobulin status of perinatal calves. Serum IgG1 concentration was examined as a continuous variable and as a trivariate categorical variable with regard to the success of passive transfer (failure, marginal, or adequate). When serum IgG1 concentration was considered as a continuous variable, the serum samples that had < 412 mg of IgG1/dL were classified as < 412 mg/dL.

Individual weaning weights and ADG from birth to weaning and from weaning to feedlot-out weight were outcomes of interest. These variables served dual purposes because they were also covariates in the analysis of other outcomes. In our analyses, ADG was considered a continuous variable. Deaths and morbidity events were used as dichotomous variables. Other variables were included in the analysis to control for confounding and interaction and included characteristics of the dam and the calf itself and climatic factors at the time the calf was born.
Continuous predictor variables used in the analysis included serum IgG1 concentration, calf birth date, calf birth weight, weaning weight, adjusted weaning weight, and feedlot-out weight. Except for precipitation, all climatic variables were treated as continuous predictor variables in the analysis. Precipitation was analyzed as a continuous variable and also as a categorical variable. Precipitation was analyzed categorically by sorting all days (24-hour periods) in which a measurable amount of precipitation had occurred into 1 group and classifying days (24-hour periods) in which precipitation had not occurred into another group.

To control for dam line, this variable was broadly categorized and analyzed as a fixed effect. Categories of dam-breed influences included British (n = 341), Brahman (269), Boran (282), Tuli (301), Bourbon Blue (311), and Piedmontese (64). Dam morbidity was analyzed as a categorical predictor variable, and health records were obtained and examined for all dams of calves in the study population. Any recorded treatment associated with a morbidity event for the dam from 60 days before calving until it weaned its calf was noted.

Other categorical predictor variables included serum IgG1 concentration coded trivariately, dam line, sire line, sex of calf, type of birth (single or twin), preweaning treatments for illness, feedlot treatments for illness, and dam’s calving difficulty score. A calving difficulty score of 0 or 1 was assigned to each calf. All calves that were born without assistance received a calving difficulty score of 0, and calves of dams that had minimal levels of dystocia received a score of 1.

Logistic regression was used to examine the associations of serum IgG1 concentration with morbidity and death. Potential confounders were screened and included for consideration in multivariable modeling if their independent association with health yielded a value of $P < 0.05$. Dam and sire lines and year of birth were included in all models. Serum IgG1 concentration was forced into all models and its significance examined. The Wald $\chi^2$ statistic (Wald statistic $< 0.05$) was used to evaluate each possible experimental model. The best 5 models, ordered from highest to lowest likelihood ratio (LHR) value, were obtained. Possible models ranged from a 1-variable model to a maximum model size of 15 effects. The Hosmer-Lemeshow statistic was used to assess goodness-of-fit. The most parsimonious model that contained significant covariates (Wald statistic $< 0.05$) was selected, and ORs and their 95% CIs were determined.

Multiple regression analysis was used to assess pre- and postweaning gains. Serum IgG1 concentration was forced into all models and its significance examined. Independent variables were entered in a best $R^2$ selection method, and possible models were ranked according to $R^2$ value. This method works by identifying subsets of independent variables of various sizes. Members of each subset contain equal numbers of variables, and the models are sorted in decreasing order of magnitude of $R^2$ value. Although each subset contains equal numbers of variables, the variables may differ in size. Criteria for entering or leaving the model were set at $P < 0.05$. Once the best model for continuous variables was ascertained, an ANCOVA was used to allow inclusion of both quantitative and qualitative predictor variables. Effects of dam and sire lines and year of birth were included in every model as fixed effects. Criteria for entering or leaving the model remained at $P < 0.05$. Comparisons of the adjusted $R^2$ and $P$ value were used to distinguish the model most suitable for each outcome.

Likelihood ratios were generated by incremental classification of serum IgG1 concentrations and subsequent treatment of the upper limit of each IgG1 classification as a cutoff value. Groups of LHRs were generated by successively dichotomizing serum IgG1 values more than 412 mg/dL, more than or less than 500 mg/dL, and more or less than each 100 mg/dL level from 500 to 2,800 mg/dL. Positive and negative LHRs (LHR+ and LHR–) and their 95% CIs were calculated separately for each of the 6 health and performance outcomes of interest (pre- and postweaning morbidity, death, and ADG) at each cutoff point in the range of serum IgG1 concentrations. Pre- and postweaning morbidity and death were coded as qualitative dichotomous variables. Pre- and postweaning ADGs were also coded as dichotomous variables by calculating the overall means for pre- and postweaning ADG. Animals were then assigned to 1 of 2 groups: calves with ADG below the population mean for daily gain or calves with ADG equal to or greater than population mean for daily gain. For each serum IgG1 cutoff value, the frequencies of true-positive, false-positive, true-negative, and false-negative results were determined.

For purposes of this study, LHR+ (ie, LHR+ = sensitivity/(1 – specificity)) described how many times more likely a calf that had the outcome of interest would have a serum IgG1 concentration at or below the cutoff value than would a calf that did not have the outcome of interest. An LHR– (ie, LHR– = (1 – sensitivity)/specificity) described how many times more likely a calf that had the outcome of interest would have a serum IgG1 concentration above the cutoff value than would a calf that did not have the outcome of interest.

For each outcome, magnitude of LHR and limits of the 95% CIs were examined. Further investigation ensued if the LHR+ was > 1.0 and 1.0 was not contained within the surrounding confidence limits. If these conditions were met, modeling of the outcome with the appropriate covariates and the selected IgG1 cutoff value was performed to determine significance ($P < 0.05$). When comparing cutoff values, the magnitude of LHR+– Wald $P$ values ($< 0.05$) was considered, and those associated with higher $R^2$ values were considered optimal.

Results

In the present study, 798 calves were sired by Charolais bulls and 770 calves were sired by Belgian Blue-cross bulls. Most calves (1,558/1,568 [99.4%]) were single births. The mean birth weight for calves in the study was 39.9 kg (88 lb), and weights ranged from 20.9 to 66.2 kg (46 to 146 lb). Of the 1,568 calves included in the study, 796 (51%) were heifers and 772 (49%) were bull calves. In the study group, 1,529 calves were born without assistance (calving difficulty score of 0). Only 2% (39/1,568) of calves were assigned a calving difficulty score of 1 because their dams required assistance during parturition. Of the 1,568 dams, 28 were treated because of a morbidity event that had occurred within the period of 60 days prior to parturition until weaning. On the day the calves were born, minimum recorded temperatures ranged from –26.16°C to 14.17°C (–15.1°F to 57.5°F). Mean temperatures ranged from –18.78°C to 18.78°C (–1.8°F to 65.8°F). Mean wind chill factors ranged from –20.8°F to 58.6°F, whereas mean wind chill factors ranged from –36.5°F to 51.0°F. Mean temperatures ranged from 0.0 to 0.85 inches, and 303 of the study calves were born on days that had a measurable amount of precipitation.

Preweaning morbidity among beef calves—After excluding 12 traumas and atypical morbidity events, 1,556 calves were entered in the preweaning morbidity analysis. At least 1 morbidity event prior to weaning was recorded for 12.0% (187/1,556) of the study population. Morbidity events and deaths were often associated with a serum IgG1 concentration above the cutoff value than would a calf that did not have the outcome of interest.
cido with disease of the respiratory or gastrointestinal tract. For example, diagnoses of pneumonia (73/187 calves) or scour (25/187) accounted for more than 50% (98/187) of the recorded preweaning morbidity events. Calves with serum IgG1 concentrations ≤ 800 mg/dL had a preweaning morbidity rate of 21.7% (48/221), compared with a rate of only 13.4% (18/134) for calves with serum IgG1 concentrations from 801 to 1,600 mg/dL. A preweaning morbidity event was diagnosed in only 10.1% (121/1,201) of the calves that had serum IgG1 concentrations > 1,600 mg/dL. Dam line, calf’s year of birth, and sire line were included a priori in the preweaning morbidity logistic regression model. Sex of the calf and calving difficulty score were considered as covariates on the basis of univariate screening; however, calving difficulty was not included in the final model. Thus, the final model included calf sex and serum IgG1 concentration as independent variables. Adequate goodness-of-fit was determined by use of the Hosmer-Lemeshow goodness-of-fit test ($P > 0.50$), and the model accounted for 10.6% of the variability associated with preweaning morbidity. Calves classified as having failure of passive transfer (serum IgG1 concentration ≤ 800 mg/dL) were 2.24 (95% CI, 1.52 to 3.29) times as likely to have a preweaning morbidity event, compared with calves classified as having adequate passive transfer (serum IgG1 concentration > 1,600 mg/dL). Calves classified as having marginal passive transfer (serum IgG1 concentration of 801 to 1,600 mg/dL) were not (OR = 1.38; 95% CI = 0.80 to 2.39) more likely to have a preweaning morbidity event, compared with calves classified as having adequate passive transfer.

When considering a serum IgG1 cutoff value for preweaning morbidity based on LHR+ > 1.0 with 1.0 not contained within the surrounding CI, 2 possible cutoff values were identified: 2,400 and 2,500 mg/dL. Covariates included in the logistic regression model were identical to those used in the final model for preweaning morbidity. Model convergence and the goodness-of-fit criteria were satisfied for each model. Serum IgG1 concentration was significantly negatively associated with preweaning morbidity when calves were classified by dichotomizing serum IgG1 concentration at 2,500 or 2,400 mg/dL. When compared with 2,500 mg/dL, the threshold of 2,400 mg/dL resulted in a slightly higher OR (1.65 vs 1.5). Calves with serum IgG1 concentrations ≤ 2,400 mg/dL were 1.6 (95% CI, 1.19 to 2.28) times as likely to develop illness before weaning as calves with IgG1 concentrations > 2,400 mg/dL. This model accounted for 9.4% of the variability associated with preweaning morbidity rate.

Preweaning death among beef calves—Nine calves were excluded from this analysis because their deaths were a result of trauma or an extraordinary event. After these exceptions were removed, 1,559 calves were entered in the analysis of deaths. Of the 1,559 calves, 42 (2.7%) died before weaning (Table 1). Two hundred twenty-one calves were classified as having failure of passive transfer (serum IgG1 concentration ≤ 800 mg/dL), and of these, 19 (8.6%) died before weaning. In the group of calves classified as having marginal passive transfer (serum IgG1 concentration of 801 to 1,600 mg/dL; n = 135), there were only 3 (2.2%) preweaning deaths. Of the 1,203 calves classified as having adequate passive transfer (serum IgG1 concentration > 1,600 mg/dL), 20 died before weaning; this group had the lowest rate of mortality (1.7%) among the 3 groups. Dam and sire lines and calf’s year of birth were included a priori in the preweaning death logistic regression model. Lowest recorded temperature on the day the calf was born and serum IgG1 concentration were included in the final model. Model convergence criteria were satisfied in the final model, and the Hosmer-Lemeshow goodness-of-fit test had a $P$ value of 0.93. The final model accounted for 11% of the variability in preweaning mortality rate. Calves that were classified as having failure of passive transfer were 4.9 (95% CI, 2.48 to 9.52) times as likely to die before weaning than calves classified as having adequate passive transfer. Compared with calves that had adequate passive transfer, calves with marginal passive transfer were not (OR, 1.20; 95% CI, 0.35 to 4.14) more likely to die before weaning. When the marginal passive transfer category was combined with the failure of passive transfer category and compared with the adequate passive transfer category, the OR was reduced to 3.4 (95% CI, 1.79 to 6.45).

After LHRs were generated and examined for values with an associated LHR > 1.0 with 1.0 not contained within the surrounding CI, two possible cutoff values were identified: 2,400 and 2,500 mg/dL. Covariates included in the logistic regression model were identical to those used in the final model for preweaning morbidity. Model convergence and the goodness-of-fit criteria were satisfied for each model. Serum IgG1 concentration was significantly negatively associated with preweaning morbidity when calves were classified by dichotomizing serum IgG1 concentration at 2,500 or 2,400 mg/dL. When compared with 2,500 mg/dL, the

<table>
<thead>
<tr>
<th>Serum IgG1 concentration (mg/dL)</th>
<th>No. of calves (%) that had ≥ 1 preweaning morbidity event</th>
<th>No. of calves (%) that died before weaning</th>
<th>No. of calves (%) that had ≥ 1 morbidity event at the feedlot*</th>
<th>No. of calves (%) that died at the feedlot*</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 800</td>
<td>48/221 (21.7)</td>
<td>19/221 (8.6)</td>
<td>20/202 (9.9)</td>
<td>2/202 (1.0)</td>
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<td>≤ 1,200</td>
<td>57/274 (20.8)</td>
<td>21/276 (7.6)</td>
<td>25/254 (9.8)</td>
<td>2/254 (0.8)</td>
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<tr>
<td>≤ 1,600</td>
<td>66/305 (18.8)</td>
<td>22/356 (6.2)</td>
<td>36/333 (10.8)</td>
<td>3/333 (0.9)</td>
</tr>
<tr>
<td>≤ 2,000</td>
<td>78/461 (16.9)</td>
<td>23/463 (5.0)</td>
<td>40/437 (11.2)</td>
<td>3/437 (0.7)</td>
</tr>
<tr>
<td>≤ 2,400</td>
<td>92/631 (14.6)</td>
<td>28/635 (4.4)</td>
<td>40/627 (11.1)</td>
<td>4/627 (0.8)</td>
</tr>
<tr>
<td>≤ 2,800</td>
<td>113/638 (17.5)</td>
<td>31/634 (4.9)</td>
<td>67/606 (11.1)</td>
<td>5/606 (0.8)</td>
</tr>
<tr>
<td>≤ 3,200</td>
<td>130/1,050 (12.3)</td>
<td>32/1,013 (3.2)</td>
<td>95/855 (11.5)</td>
<td>5/855 (0.6)</td>
</tr>
<tr>
<td>Total No. of calves (%)</td>
<td>187/1,566 (12.0)</td>
<td>42/1,559 (2.7)</td>
<td>175/1,513 (11.6)</td>
<td>6/1,517 (0.4)</td>
</tr>
</tbody>
</table>

*Period from weaning until removal of calf from the feedlot.

Table 1—Number of beef calves with various serum concentrations of IgG1 after ingestion of colostrum that had at least 1 morbidity event or died before weaning or during the interval after weaning until removal from the feedlot.
tained within the surrounding CI. 4 potential cutoff values were selected for further evaluation: 2,400, 2,500, 2,600, and 2,700 mg/dL. When these cutoff values were analyzed, covariates incorporated in the model were identical to those used in the final preweaning death model with the more conventional cutoff value (serum IgG1 concentration ≤ 800 mg/dL) and also included sex of the calf and the recorded minimum temperature on the day of the calf’s birth. Dam and sire lines and calf’s year of birth were included as a priori in the model. When serum IgG1 cutoff values of 2,600 and 2,700 mg/dL were analyzed, P values were < 0.05 but the lower CI value was very marginal at 1.02. Analysis of serum IgG1 concentration cutoff values of 2,400 or 2,500 mg/dL resulted in P values indicating significance (ie, values < 0.05) and more reliable CIs surrounding the ORs. When serum IgG1 concentration of 2,400 mg/dL was used as a cutoff value, calves with serum IgG1 concentrations < 2,400 mg/dL were 2.7 times (95% CI, 1.34 to 5.36) as likely to die before weaning, compared with calves with higher concentrations.

**Preweaning performance parameters**—Individual calf preweaning ADGs were calculated for calves that survived from birth to weaning. Gains ranged from 0.42 to 1.26 kg/d (0.93 to 2.77 lb/d). The mean ADG for all calves from birth to weaning was 0.92 kg/d (2.03 lb/d). Overall, 1,511 animals were included in this analysis.

Dam and sire lines and calf’s year of birth were included in the multivariable logistic models. Calf’s birth weight, sex, and calving difficulty score were also significantly associated with gain in some of the models. Serum IgG1 concentration was analyzed as a continuous variable and as a categorical variable but was not significantly associated with ADG from birth to weaning in any of the models.

After screening potential serum IgG1 concentration cutoff values for LHR+ > 1.0 with 1.0 not contained in the surrounding CI, values from 2,200 to 3,200 mg/dL were selected for further evaluation. Covariates were identical to those used in the final model for preweaning ADG with the more conventional cutoff values and included dam and sire lines; calf’s year of birth, birth weight, and sex; and calving difficulty score. In contrast to the analysis that involved conventional serum IgG1 cutoff values, results derived from examination of LHR uncovered significant effects of serum IgG1 concentration on gain (Table 2). The R² values were similar among models and accounted for 29.0% to 29.2% of the variability in preweaning ADG. Analysis of all nonconventional serum IgG1 concentration cutoff values indicated that there was significant association between lower serum IgG1 concentration and lower ADG with similar point estimates of –0.014 to –0.018 kg/d (–0.03 to –0.04 lb/d).

**Postweaning morbidity among beef calves**—After excluding atypical morbidity events, 1,513 heifers and steers were included in the postweaning morbidity analysis. Overall, 175 (11.6%) calves of that population were treated at least once while in the feedlot. Of the 202 calves classified as having failure of passive transfer, 20 (9.9%) had at least 1 morbidity event in the feedlot (Table 1). Among 131 calves categorized as having marginal passive transfer (serum IgG1 concentration of 801 to 1,600 mg/dL), 6 had a morbidity event; the rate of morbidity in these calves was higher (12.2%) than the rate (9.9%) in calves classified as having failure of passive transfer (serum IgG1 concentration ≤ 800 mg/dL). The morbidity rate for calves with adequate passive transfer (serum IgG1 concentration > 1,600 mg/dL) was intermediate at 10.5% (139/1,319 calves).

Use of logistic regression satisfied the convergence criterion, and after adjusting for effects of dam and sire lines and calf’s year of birth, the only significant factor in the model was the calving difficulty score. No significant effects of serum IgG1 concentration on feedlot morbidity rate were evident in any of the models. In addition, some models identified slightly lower risk for groups with higher serum IgG1 concentration, whereas other models identified slightly higher risks in those groups. There were no significant differences among serum IgG1 concentrations and no significant association of ity rate with increasing serum IgG1 concentration. No additional serum IgG1 concentration cutoff values were identified or evaluated because no values satisfied both criteria (LHR+ and lower limit of the CI > 1.0) for further screening.

**Postweaning death among beef calves**—Only 0.4% (6/1,517) of the calves died while in the feedlot. Less than 1% (2/202) of calves classified as having failure of passive transfer (serum IgG1 concentration ≤ 800 mg/dL) died while in the feedlot. Of the 132 calves with marginal passive transfer (serum IgG1 concentration of 801 to 1,600 mg/dL), only 1 died (Table 1). Of the 1,183 calves with adequate passive transfer (serum IgG1 concentration > 1,600 mg/dL), only 3 (0.2%) died while in the feedlot. This low number of cases prevented use of regression modeling of postweaning death, and no association with serum IgG1 concentration was detected.

**Postweaning performance parameters**—Individual animal ADG ranged from 0.5 to 1.9 kg/d (1.1 to 4.2 lb/d). When all values were averaged, the mean ADG from weaning to feedlot-out weight was 1.1 kg/d (2.5 lb/d). Feedlot-out weights ranged from 320 to 730 kg

<table>
<thead>
<tr>
<th>Serum IgG1 concentration (mg/dL)</th>
<th>Point estimate of ADG (lb/d) if serum IgG1 concentration ≤ cutoff value</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 2,200</td>
<td>-0.33336</td>
<td>0.2916</td>
</tr>
<tr>
<td>≤ 2,300</td>
<td>-0.3344</td>
<td>0.2917</td>
</tr>
<tr>
<td>≤ 2,400</td>
<td>-0.3440</td>
<td>0.2916</td>
</tr>
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<td>≤ 2,500</td>
<td>-0.3160</td>
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<tr>
<td>≤ 2,600</td>
<td>-0.3461</td>
<td>0.2921</td>
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<tr>
<td>≤ 2,700</td>
<td>-0.3690</td>
<td>0.2934</td>
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<tr>
<td>≤ 2,800</td>
<td>-0.3194</td>
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<tr>
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(704 to 1,605 lb; mean feedlot-out weight, 535 kg [1,176 lb]). Mean age of cattle at time of shipment to slaughter was 16 months (480 days; age range, 13 to 19 months [384 to 569 days]).

By use of multiple logistic regression, all point estimates for serum IgG1 concentration were not significant ($P > 0.05$), and no further analysis was pursued. Significant covariates included sex of calf and birth and weaning weights.

**Discussion**

The association between preweaning morbidity and death in calves with low serum IgG1 concentrations was consistent with other reports in the literature. In the present study, we extended evaluation of the effects of serum IgG1 concentration after colostrum ingestion to examine whether additional benefits for calf health were accrued at values greater than the traditional serum IgG1 concentration cutoff values of 800 and 1,600 mg/dL. Calves with serum IgG1 concentrations < 2,400 mg/dL were almost 3 times as likely to die, compared with calves with greater IgG1 concentrations. The detection of continuing negative effects of low serum IgG1 concentrations on preweaning morbidity and mortality rates, even in calves with 2,400 mg of IgG1/dL, of serum, suggests that negative effects of inadequate passive transfer may still occur at serum concentrations of IgG1 that are higher than those examined in other studies. This may provide added impetus to intercede and provide supplemental care to promote calf health.

The level of passive immunity neither guaranteed nor completely prevented preweaning morbidity or death among beef calves. Most calves that had been classified as having failure of passive transfer as calves with higher serum IgG1 concentrations. The risk for developing an illness in calves with serum IgG1 concentration < 800 mg/dL or marginal (801 to 1,600 mg/dL) passive transfer survived (333/355 [93.8%] calves) and remained healthy (289/355 [81.4%] calves) until weaning. In our study, 121 of 1,201 (10%) calves classified as having adequate passive transfer had at least 1 recorded preweaning morbidity event. Twenty of the 1,203 (1.7%) calves classified as having adequate passive transfer died before weaning, illustrating that adequate passive transfer (serum IgG1 concentration after ingestion of colostrum > 1,600 mg/dL) is not fail-safe protection against death before weaning among beef calves.

The risk for developing an illness in calves with low serum IgG1 concentrations was not as great as those in the study by Perino et al. In that study, beef calves categorized as having failure of passive transfer (serum IgG1 concentration < 800 mg/dL) were 9.4 times as likely to become ill in the preweaning period as calves with higher serum IgG1 concentrations. However, that study group was composed of first-born calves from crossbred beef cows, among which there was a high rate of twins (43%). Twins have been found to be at greater risk of death within the first 21 days of life than single-born calves. This remained true even when the 12 animals that had died but had been excluded from analysis of preweaning death were included in another calculation of overall mortality rate. Several factors may have contributed to the low overall mortality rate in our study population. The calves of the present study were maintained by knowledgeable personnel and provided with high-quality management and regular veterinary care. In addition, all dams were multiparous and calves were at least 24 hours of age before inclusion in the study. Overall mortality rates were likely decreased by the exclusions of atypical preweaning deaths and calves born to heifers.

In addition to the importance of serum IgG concentration, other key covariates were identified in the analysis of preweaning deaths. The maternal genetic description (dam line) and the recorded minimum temperature on the day the calf was born were factors that were significantly associated with death before weaning. To our knowledge, no other studies to investigate the combination of these variables and their effects on preweaning death have been reported. In addition to adjusting estimates of the effects of serum IgG1 concentration for these important factors, our data have provided new insights regarding combinations of factors that may be managed to reduce the frequency of preweaning death among beef calves.

One shortcoming of the present study was that some calves may have had morbidity events that were unnoticed during herd checks. Because morbidity events were defined as those calves needing treatment, some calves may have had undetected morbidity events or subclinical morbidity events that did not require treatment. However, all herd health checks and observations for morbidity events were conducted by trained and experienced personnel. Because 136 serum samples in which IgG1 concentration was < 412 mg/dL could not be accurately assayed, they were simply classified as < 412 mg of IgG1/dL for categorical analysis and as 411 mg of IgG1/dL for the analysis of serum IgG1 concentration in a continuous manner. In the continuous analysis of serum IgG1 concentration, this categorization likely underestimated the effect of serum IgG1 concentration on health and performance of beef calves.

When modeling preweaning gain with traditional cutoff values for serum IgG1 concentration after ingestion of colostrum, IgG1 concentration did not significantly influence ADG from birth to weaning. Further investigation and modeling of other serum IgG1 concentration cutoff values selected after examination of LHRs revealed a significant relationship between serum IgG1 concentration and preweaning gain. When the point estimate of –0.02 kg/d (–0.036 lb/d) was multiplied by 205 days, the mean weight of calves with serum IgG1 concentration ≥ 2,700 mg/dL would be expected to be 3.4 kg (7.4 lb) more at 205 days of age than the weight of calves with serum IgG1 concentration < 2,700 mg/dL. Kyuma et al, Robison et al, Odde, and Fiems et al have also reported significant correlations between serum immunoglobulin concentration and subsequent weight gains. To our knowledge, our study is the only investigation involving beef cattle raised in an environment typical for North American cattle that has established a significant effect of serum IgG1 concentration on preweaning gain. It is possible that other studies that
did not determine that serum IgG1 concentration was significantly associated with preweaning gain would reveal significance if higher serum IgG1 concentration cutoff values were explored.

The improved ADG associated with higher serum IgG1 concentrations may have been related to a decreased rate of morbidity. In addition to improved gain, calves with high serum IgG1 concentrations also developed less illness. Wittum et al. reported that calves that had a preweaning morbidity event weighed less at weaning than calves that did not become ill. Dollars lost as a result of reduced weight gain attributed to low serum IgG1 concentration and subsequent preweaning morbidity in beef calves may be recovered through effective management and intervention strategies designed to optimize acquisition of passive immunity in a timely manner.

In our study, there was no significant effect of serum IgG1 concentration on feedlot health or performance parameters. Although the study of this report represents what we believe to be the largest investigation to date that was designed to measure the association of serum IgG1 concentration with feedlot morbidity and death and ADG, the mortality and morbidity rates were low. Competing risks may also have contributed to the lack of effect of serum IgG1 concentration on feedlot health and productivity. Calves that would have been at higher risk in the feedlot may have already died during the preweaning period. Calves that continued from the preweaning phase into the feedlot component of our study would be those that had managed to mount a competent active immune response to infectious challenges.

Lack of power in our study may also have contributed to the lack of significance between serum IgG1 concentration and postweaning morbidity, postweaning death, and ADG. For the threshold of 1,600 mg of IgG/L of serum, the analysis of feedlot morbidity events had only 5.5% power. To obtain 83% power, diagnoses of 25 additional morbidity events (total of 61 cases) in the low serum IgG1 concentration category would be necessary. This would be true if the proportion of morbidity events did not change for the other groups. The analysis of death had only 43% power. To increase this power to 79% (a = 0.05), 5 additional deaths (total of 11 cases) in the low serum IgG1 concentration category would have been necessary.

The lack of associations between serum IgG1 concentration and postweaning morbidity, postweaning death, and ADG is in contrast to findings of a study by Wittum and Perino, which is the only other published study with more typical morbidity rates. To our knowledge, this method of analysis has not been previously applied to define a cutoff value for serum IgG1 concentration after ingestion of colostrum in beef calves. Our data expand the body of evidence supporting the importance of timely acquisition of an adequate mass of colostral immunoglobulins for optimizing preweaning health and performance parameters in beef calves. Early detection and treatment of calves at risk for failure of passive transfer is likely to result in improved preweaning health and increased performance parameters within herds.

References

Selected abstract for JAVMA readers from the American Journal of Veterinary Research

Cardiovascular effects of desflurane in mechanically ventilated calves

Robert D. Keegan et al

Objective—To determine cardiovascular effects of desflurane in mechanically ventilated calves.

Animals—8 healthy male calves.

Procedure—Calves were anesthetized by face mask administration of desflurane to permit instrumentation. Administration of desflurane was temporarily discontinued until mean arterial blood pressure increased to ≥100 mm Hg, at which time baseline cardiovascular values, pulmonary arterial temperature, end-tidal CO₂ tension, and end-tidal desflurane concentration were recorded. Cardiac index and systemic and pulmonary vascular resistances were calculated. Arterial blood gas variables were measured and calculated. Mean end-tidal concentration of desflurane at this time was 3.4%. After collection of baseline values, administration of 10% end-tidal concentration of desflurane was resumed and calves were connected to a mechanical ventilator. Cardiovascular data were collected at 5, 10, 15, 30, and 45 minutes, whereas arterial blood gas data were collected at 15 and 45 minutes after collection of baseline data.

Results—Mean ± SD duration from beginning desflurane administration to intubation of the trachea was 151 ± 32.8 seconds. Relative to baseline, desflurane anesthesia was associated with a maximal decrease in arterial blood pressure of 35% and a decrease in systemic vascular resistance of 34%. Pulmonary arterial blood temperature was decreased from 15 through 45 minutes, compared with baseline values. There were no significant changes in other measured variables. All calves recovered from anesthesia without complications.

Conclusions and Clinical Relevance—Administration of desflurane for induction and maintenance of general anesthesia in calves was smooth, safe, and effective. Cardiopulmonary variables remained in reference ranges throughout the study period. (Am J Vet Res 2006;228:387–391)