Effect of colostrum administration by use of oroesophageal intubation on serum IgG concentrations in Holstein bull calves

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Objective—To determine the amount of colostral IgG required for adequate passive transfer in calves administered colostrum by use of oroesophageal intubation and evaluate the impact of other factors on passive transfer of colostral immunoglobulins in calves.

Animals—120 Holstein bull calves.

Procedures—Calves were randomly assigned to specific treatment groups on the basis of volume of colostrum administered and age of calf at administration of colostrum. Colostrum was administered once by oroesophageal intubation. Equal numbers of calves received 1, 2, 3, or 4 L of colostrum, and equal numbers of calves received colostrum at 2, 6, 10, 14, 18, or 22 hours after birth. Serum samples were obtained from calves 48 hours after birth for IgG determination by radial immunodiffusion assay. Effects of factors affecting transfer of colostral immunoglobulins were determined by use of a stepwise multiple regression model and logistic regression models.

Results—A minimum of 153 g of colostral IgG was required for optimum colostral transfer of immunoglobulins when calves were fed 3 L of colostrum at 2 hours after birth. Substantially larger IgG intakes were required by calves fed colostrum > 2 hours after birth.

Conclusions and Clinical Relevance—Feeding 100 g of colostral IgG by oroesophageal intubation was insufficient for adequate passive transfer of colostral immunoglobulins. At least 150 to 200 g of colostral IgG was required for adequate passive transfer of colostral immunoglobulins. Use of an oroesophageal tube for administration of 3 L of colostrum to calves within 2 hours after birth is recommended. (Am J Vet Res 2008;69:1158–1163)

The importance of the ingestion and absorption of colostral immunoglobulins on morbidity, fatalities, growth, and future productivity of dairy calves has been described.1–6 Calves with inadequate passive transfer of colostral immunoglobulins have an increased risk of death during the first 3 months after birth.7,8 Additionally, a decreased rate of weight gain,9 less milk production,10 and a decreased survival rate until end of the first lactation1 have been reported in calves with FPT. Failure of passive transfer of colostral immunoglobulins is responsible for approximately half of calf deaths on US dairy farms.7

Colostrum administration practices that affect serum immunoglobulin concentrations in calves include the timing of colostrum administration,9,10 volume of colostrum fed, method of administration,1 timing of colostral collection,10 colostral IgG concentration,11 and dam parity.11,12 It has been recommended in other reports4,11,14 that calves should ingest at least 100 g of colostral IgG for adequate passive transfer of colostral immunoglobulins. However, that recommendation was made on the basis of anecdotal or clinical observations, rather than on the results of controlled studies.

Lower rates of FPT have been reported9 in calves fed colostrum by use of an oroesophageal tube, relative to calves fed colostrum via a bottle or calves allowed to suckle from their dams. Administration of 3 to 4 L of colostrum has been recommended to ensure sufficient IgG mass is delivered.9 Feeding calves by use of an oroesophageal tube is an attractive alternative to feeding by use of bottles on many large commercial dairies because calves can be fed colostrum in a rapid manner by experienced employees. Unfortunately, no prospective studies have critically examined the effects

Abbreviation
FPT Failure of passive transfer

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of volume of colostrum administered and the timing of colostrum administration on the serum IgG concentration in calves fed by use of an oroesophageal tube. 

Despite the accumulated information of the factors that affect passive transfer and the recognized importance of passive transfer of colostral immunoglobulins in dairy calves, approximately 35% to 40% of US dairy calves have inadequate passive transfer of colostral immunoglobulins. On the basis of this high prevalence of FPT in calves, we hypothesized that current recommendations regarding colostrum feeding practices are inadequate. Thus, the total immunoglobulin mass being fed to each calf is inadequate or colostrum administration practices require more concerted efforts than are performed by most caretakers. The first objective of the study reported here was to determine the amount of colostral IgG required for adequate passive transfer of colostral immunoglobulins in calves fed colostrum by oroesophageal intubation. The second objective was to evaluate the impact of calf age at time of colostrum administration, volume of colostrum administered, colostrum IgG concentration, dam parity, weight of colostrum produced by the dam, calf birth weight, and their interactions on transfer of colostral immunoglobulins in dairy calves.

**Materials and Methods**

**Animals**—Holstein bull calves (n = 120) from the University of Missouri Foremost Teaching and Research Dairy were used in the study. Only calves whose births were observed were included in the study. Assistance during parturition was recorded. Twin calves were excluded; thus, only singleton calves were included in the study. After parturition, each calf was immediately separated from the dam, weighed, and assigned a unique identification number. The study was approved by the University of Missouri, Columbia, Animal Care and Use Committee.

**Procedures**—Cows were milked by use of a portable milking machine within 2 hours after parturition. Each calf was provided colostrum obtained only from its dam. Calves from cows that did not produce sufficient colostrum were administered colostrum obtained from 1 other cow.

Calves were randomly assigned to specific treatment groups on the basis of volume of colostrum administered and age of calf at time of colostrum administration. Equal numbers of calves received 1, 2, 3, or 4 L of their dam’s colostrum, and equal numbers of calves received colostrum at 2, 6, 10, 14, 18, or 22 hours after birth. Thus, 5 calves received colostrum at each volume and each time point after birth. Therefore, 30 calves received each volume of colostrum (5 calves for each volume X 6 time points), and 20 calves received colostrum at each time point (5 calves for each time point X 4 volumes). Calves with missing values during data collection were removed from the study and replaced with calves that were assigned to the same treatment groups.

A single feeding of the assigned volume of fresh colostrum was administered once by oroesophageal intubation to each calf at the assigned time after birth. Thereafter, all calves were fed 2 L of a commercial milk replacer every 12 hours. All calves enrolled survived until at least 48 hours after birth. Blood samples were collected from calves at 48 hours after birth. Serum was harvested, and samples were stored at –20°C until processed for serum immunoglobulin determinations.

**Determination of serum and colostral IgG concentrations**—Colostral and total serum IgG concentrations were determined by use of a radial immunodiffusion technique reported elsewhere, with slight adaptations. Briefly, radial immunodiffusion plates for measurement of IgG were prepared by dissolving 1% agarose in a sodium barbital buffer containing 0.1% sodium azide. Rabbit-anti-bovine IgG (1%) was added to the agarose solution. Eleven milliliters of agarose solution was then added to 10-cm Petri dishes. After the agarose solidified, wells (3 mm in diameter) were cut in the agar. Serum and colostrum samples were diluted 1:20 and 1:120, respectively, by use of barbital buffer; 5 µL of diluted sample was inoculated into each well. Wells were incubated for 72 hours at 23°C, and the diameter of the zone of precipitation was then recorded. Sample IgG concentrations were determined by comparing the diameters of the zones of precipitation with values for a standard curve generated by use of serial dilutions of a bovine IgG standard. The regression equation generated in this manner accurately predicted (R² = 0.98) the inoculum IgG concentration.

**Data analysis**—Mean ± SEM colostral IgG concentrations for cows in their first, second, and third or greater lactation were calculated. Mean ± SEM calf birth weight and weight of the colostrum produced by the dam also were calculated. The cutoff point to define adequacy of passive transfer in calves at 48 hours after birth was a serum IgG concentration ≥ 1,340 mg/dL, as determined by results of other studies. Effects of calf age at time of colostrum administration, volume of colostrum administered, colostrum IgG concentration, dam parity (ie, lactation number), weight of colostrum produced by the dam, and calf birth weight on serum IgG concentration at 48 hours after birth were determined by use of a stepwise multiple regression model. Calf birth weight, weight of colostrum produced by the dam, call age at time of colostral administration, and colostral IgG concentration were treated as continuous independent variables. Colostrum volume fed to a calf (1, 2, 3, or 4 L) was treated as a categorical independent variable because of nonlinear effects identified during preliminary regression model diagnostics. Dam parity (first, second, and third or greater) and assistance during parturition (assistance or no assistance) were treated as categorical variables. First-parity cows and administration of 1 L of colostrum were considered referent categories for parity and colostral volume administered, respectively. Second-order interactions between volume of colostrum administered and colostral IgG concentration were evaluated. Additionally, interactions between volume of colostrum administered and calf age at time of colostrum administration were evaluated. Variables
were considered for inclusion in a stepwise logistic regression model when the value to enter was \( P < 0.01 \). The variable (or variables) or interaction with the lowest value of \( P \) to enter the model was added to the model at each step until no variable had a value to enter of \( P < 0.1 \).d At each step, all variables included in the model were evaluated to determine whether they remained significant (\( P < 0.1 \)) after addition of any new variables or interactions.d The mean value for total colostral IgG intake required for adequate passive transfer of colostral immunoglobulins was calculated by solving the final regression model prediction of serum IgG for colostral IgG concentration and then multiplying this IgG concentration by the volume administered.

A logistic regression model that predicted the probability of a calf having FPT at 48 hours after birth was developed as a function of calf birth weight, calf age at time of colostrum administration, volume of colostrum fed, dam parity, assistance during parturition, weight of colostrum produced by the dam, and colostral IgG concentration.\(^5\) Second-order interactions between volume of colostrum administered and colostral IgG concentration were evaluated. Interactions between volume of colostrum fed and calf age at time of feeding colostrum also were evaluated. The variable (or variables) or interaction with the lowest value of \( P \) to enter the model was added to the model at each step until no variable had a value to enter of \( P < 0.1 \).d The goodness of fit of the final model was estimated by use of the Pearson \( \chi^2 \) statistic.\(^e\)

### Results

In the study, 44, 33, and 43 calves from cows of the first, second, and third or greater lactation, respectively, were enrolled. Mean ± SEM colostral IgG concentrations for all cows and cows of the first, second, and third or greater lactation were 67.2 ± 2.8 g/L, 68.1 ± 2.7 g/L, 65.0 ± 3.0 g/L, and 68.0 ± 2.7 g/L, respectively. Mean weight of colostrum produced by the dam was 8.8 ± 0.5 kg, and mean calf birth weight was 40.9 ± 0.6 kg. Mean serum IgG concentration was 1,136 ± 50.8 mg/dL.

Results were obtained for the multiple regression model that predicted serum IgG concentration at 48 hours after birth as a function of calf weight, time of colostrum administration, volume of colostrum administered to a calf, and colostrum IgG concentration (Table 1). Dam parity, calf birth weight, weight of colostrum produced by the dam, and whether parturition was assisted were not significantly (\( P > 0.1 \)) associated with serum IgG concentration. Interactions between colostral IgG concentration and volume of colostrum administered, age of calf at time of colostrum administration, and volume of colostrum administered were not significant (\( P > 0.1 \)) independent variables for the serum IgG concentration at 48 hours after birth. Colostral IgG concentration and volume of colostrum administered to a calf were positively correlated with the serum IgG concentration at 48 hours after birth. Age of calf at time of colostrum administration was negatively correlated with the serum IgG concentration at 48 hours after birth.

By use of the regression model, the mean total colostral IgG concentration required to achieve a serum IgG concentration of 1,340 mg/dL was calculated for all possible permutations of volume of colostrum administered, calf age at time of colostrum administration, and various colostral IgG concentrations (25, 50, 75, 100, and 125 g/L). For example,
the mean total IgG concentration for a calf receiving 3 L of colostrum at 2 hours after birth was calculated by use of the following equation:

\[
1,340 \text{ mg/dL} = 509.049 + (5.795 \times \text{colostral IgG concentration}) + (464.357 \times V_2) + (633.756 \times V_3) + (623.670 \times V_4) - (20.058 \times \text{calf age at time of colostrum administration})
\]

where \( V_2, V_3, \) and \( V_4 \) represent administration of 2, 3, and 4 L of colostrum, respectively. Thus, the equation for the aforementioned example becomes 1,340 mg/dL = 509.049 + (5.795 \times \text{colostral IgG concentration}) + (464.357 \times 0) + (633.756 \times 1) + (623.670 \times 0) - (20.058 \times 2). Solving the equation yields a colostral IgG concentration of 40.951 g/L. Hence, administration of 3 L of colostrum to a calf 2 hours after birth would require a mean of 40.951 g/L \( \times 3 \) L = 122.85 g of colostral IgG for adequate passive transfer of colostral immunoglobulins. Total mean colostral IgG contents required for adequate passive transfer of colostral immunoglobulins when calves were fed 1, 2, 3, and 4 L of colostrum at various time points after birth were summarized (Table 2).

The logistic regression model to predict the probability of a calf having FPT on the basis of the IgG concentration at 48 hours after birth was determined (Table 3). Dam parity, calf birth weight, whether parturition was assisted, and weight of colostrum produced by the dam were not significant (\( P > 0.1 \)) predictors of serum IgG concentration at 48 hours after birth. Interactions between colostral IgG concentration and volume of colostrum administered, age of calf at time of administration, and volume of colostrum administered were not significant (\( P > 0.1 \)) independent variables of serum IgG concentration at 48 hours after birth. The probability of a calf having FPT was calculated by use of the following equation:

\[
\text{Probability of FPT} = 1/(1 + \exp\{0.3543 + (0.0283 \times \text{colostral IgG concentration}) + (0.1052 \times \text{age of calf during colostrum administration}) - (3.815 \times \text{colostral IgG concentration})\})
\]

Table 3—Results of a logistic regression model that predicted the probability of a calf having FPT (defined as a serum IgG concentration < 1,340 mg/dL) on the basis of serum IgG concentrations at 48 hours after birth in 120 Holstein bull calves.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient ( (95% \text{ CI}) )</th>
<th>( P \text{ value} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.3543 ((-4.0188 \text{ to } 3.3101))</td>
<td>0.850</td>
</tr>
<tr>
<td>Colostral IgG concentration</td>
<td>-0.0283 ((-0.0459 \text{ to } -0.0106))</td>
<td>0.002</td>
</tr>
<tr>
<td>Age of calf (ie, hours after birth) at colostrum administration</td>
<td>0.1052 ((0.0296 \text{ to } 0.1809))</td>
<td>0.019</td>
</tr>
<tr>
<td>Administration of 1 L of colostrum</td>
<td>3.8115 ((1.5561 \text{ to } 6.0669))</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

\( 95\% \text{ CI} = 95\% \text{ Confidence interval.} \)

Table 4—Probability that a calf provided colostrum by use of an oroesophageal tube would have FPT (defined as a serum IgG concentration < 1,340 mg/dL) as a function of colostral IgG concentration, volume of colostrum administered, and age of calf at time of colostrum administration in 120 Holstein bull calves.

<table>
<thead>
<tr>
<th>Volume of colostrum administered (L)</th>
<th>Age of calf at colostrum administration (hours after birth)</th>
<th>Colostral IgG concentration (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>1</td>
<td>0.95</td>
<td>0.90</td>
</tr>
<tr>
<td>6</td>
<td>0.97</td>
<td>0.94</td>
</tr>
<tr>
<td>10</td>
<td>0.98</td>
<td>0.96</td>
</tr>
<tr>
<td>14</td>
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<td>0.97</td>
</tr>
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<td>18</td>
<td>0.99</td>
<td>0.98</td>
</tr>
<tr>
<td>22</td>
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<td>0.99</td>
</tr>
<tr>
<td>2, 3, or 4</td>
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<td>0.17</td>
</tr>
<tr>
<td>6</td>
<td>0.38</td>
<td>0.24</td>
</tr>
<tr>
<td>10</td>
<td>0.50</td>
<td>0.32</td>
</tr>
<tr>
<td>14</td>
<td>0.60</td>
<td>0.43</td>
</tr>
<tr>
<td>18</td>
<td>0.70</td>
<td>0.53</td>
</tr>
<tr>
<td>22</td>
<td>0.76</td>
<td>0.63</td>
</tr>
</tbody>
</table>

Discussion

The threshold value for a serum IgG concentration that defines FPT in dairy calves varies. Serum IgG concentrations < 1,000 mg/dL have been used as an indication of FPT.\(^6,17\) In other studies,\(^2,18\) the number of fatalities was increased in calves with serum IgG concentrations < 1,200 mg/dL and < 1,500 mg/dL, respectively. Calves with serum IgG concentrations ≤ 1,200 mg/dL reportedly have higher odds (2 times higher) of developing pneumonia, compared with the likelihood for pneumonia in calves with a serum IgG concentration > 1,200 mg/dL.\(^6\) In another report,\(^19\) investigators suggested that a serum IgG concentration > 1,600 mg/dL indicates adequate passive transfer of colostral immunoglobulins. A field-based study\(^5\) in which investigators examined deaths in 3,479 dairy heifers revealed that...
calves with a serum protein IgG concentration ≥ 5.0 g/dL and < 5.5 g/dL had a relative risk of dying of 1.3, compared with the risk for calves with a serum protein concentration ≥ 5.5 g/dL (which is equivalent to a serum IgG concentration of 1,340 mg/dL). On the basis of that study, a serum IgG concentration of 1,340 mg/dL was chosen as the threshold that would define optimal passive transfer of colostral immunoglobulins. This cutoff point, although appropriate to guarantee optimal calf health, is probably an excessively rigorous goal for most commercial dairies. On these farms, rates of FPT as high as 10% probably are indicative of good practices regarding colostrum administration, and lower rates of FPT are probably unreasonable and unattainable goals. Hence, less rigorous cutoff points (ie, serum total protein concentration of 5.2 g/dL or serum IgG concentration of 1,000 mg/dL) are probably appropriate for routine monitoring.

The regression model that predicted serum IgG concentration deserves careful consideration (Table 1). The intercept of 509.049 mg/dL does not imply that a calf that receives no colostrum will have a serum IgG concentration of 509.049 mg/dL. The serum IgG concentration at 48 hours after birth for a 22-hour-old calf administered 0 L of colostrum that had a colostral IgG concentration of 0 g/L can be estimated as 509.049 + (22 hours × −20.058) = 67.773 mg/dL, which confirmed that calves will have an extremely low serum IgG concentration at birth. Hence, the model described here is consistent with those in other studies20,21 and is intuitively logical.

It should be mentioned that the results of the study reported here are applicable only to calves to which colostrum is administered once by oroesophageal intubation between 2 and 22 hours after birth. Smaller amounts of IgG may be adequate when calves receive a second colostral feeding during the neonatal period. Substantially larger IgG intakes are required by calves provided colostrum > 2 hours after birth. For calves provided colostrum at 6 hours after birth, the required mean IgG intake varied from 164 to 226 g. For calves provided colostrum at 12 hours after birth, the required mean IgG intake varied from 189 to 309 g. Thus, results of this study suggested that, in general, a minimum of 123 g of colostral IgG is required for adequate passive transfer when calves are fed 3 L of colostrum by use of an oroesophageal tube at 2 hours after birth. The information reported here contradicts results of other reports4 in which investigators recommended that calves should receive ≥ 100 g of colostral IgG to ensure adequate transfer of colostral immunoglobulins. It should be mentioned that multiple regression models in our study only predicted the mean colostral IgG concentration required for adequate passive transfer of colostral immunoglobulins. Thus, we anticipate that half of the calves fed 123 g of colostral IgG at 2 hours after birth would have FPT and the other half would have adequate passive transfer of colostral immunoglobulins.

Feeding 3 to 4 L of colostrum by artificial methods has been recommended.4 In the study reported here, administration of 4 L of colostrum once was not beneficial, compared with the benefits of administering 3 L of colostrum once, as determined on the basis of the colostral IgG concentration required to achieve adequate passive transfer (Table 1). In another study,23 no significant increase in serum IgG concentrations was detected at 24 or 48 hours after birth when 4 L of colostrum with a low IgG concentration was fed within 3 hours after birth, compared with serum IgG concentrations in calves fed 2 L of colostrum.

Results of the logistic regression in our study revealed no differences in the probability of a calf having FPT when fed 2, 3, or 4 L of colostrum with various IgG concentrations at various time points after birth (Table 3). A possible explanation for this result is the difference in the measured endpoints (a continuous dependent variable [serum IgG concentration] in the multiple regression models, compared with a binomial variable [adequate or inadequate serum IgG concentration] in the logistic regression). Calves provided 2, 3, or 4 L of colostrum by use of an oroesophageal tube by 2 hours after birth will have an FPT rate of < 9% when administered colostrum with an IgG concentration of > 75 g/L, whereas an FPT rate of 17% would be expected in calves provided 2, 3, or 4 L of colostrum with an IgG concentration of > 50 g/L. The volume of colostrum administered and the colostral IgG concentration were summarized (Table 4). For example, administering 1 L of colostrum with a colostral IgG concentration of 100 g/L at 2 hours after birth resulted in a probability for FPT of 0.68, whereas administering 2 L of colostrum with a colostral IgG concentration of 50 g/L resulted in a probability for FPT of 0.17.

Only bull calves were enrolled in the study because the study design was anticipated to create a substantial risk for FPT and, consequently, an increase in mortality and fatalities. In the study reported here, calf birth weight did not influence serum IgG concentrations at 24 or 48 hours after birth, which is consistent with results of other studies.2,8,23 Assistance during parturition did not affect serum IgG concentrations at 48 hours after birth in our study. In other studies,11,12 investigators detected no significant differences in colostral IgG concentration between cows in their first or second lactation; however, cows in their third or greater lactation had significantly higher colostral IgG concentrations. In the study reported here, there was no significant difference in the mean colostral IgG concentration for cows in the first, second, or third or greater lactation, and parity was not a significant predictor of serum IgG concentrations in calves at 48 hours after birth. Thus, the quality of colostrum (on the basis of the concentration of IgG) from first-parity cows was equivalent to that of older cows. Discarding colostrum from first-lactation cows because of a perception of a lower IgG concentration is strongly discouraged. However, it should be mentioned that these conclusions on differences in colostral IgG concentration attributable to parity of the dam were made on the basis of studies performed in a single herd. Geographic and nutritional factors may potentially influence colostral IgG concentration.

The endpoints chosen to define adequacy of passive transfer in the study reported here are for optimal colostral transfer of colostral immunoglobulins. The mean time after birth at which calves receive colostrum on all dairy operations in the United States is 3.3
hours. Thus, on most dairy farms in the United States, a minimum of 137 g (95% confidence interval, 106 to 167 g/dL) of IgG is typically required for adequate passive transfer when calves are fed 3 L of colostrum. Because ingestion of 123 g of colostral IgG will achieve adequate passive transfer in half of the calves, the results of our study suggested a minimum of 153 g of colostral IgG (upper limit of the confidence interval for administration of 3 L of colostrum at 2 hours after birth) is required for adequate passive transfer. Administration of 100 g of colostral IgG by oroesophageal intubation is inadequate to achieve passive transfer of colostral immunoglobulins. At least 150 to 200 g of colostral IgG is required for adequate passive transfer of colostral immunoglobulins. We recommend that calves provided colostrum by use of an oroesophageal tube receive 3 L of colostrum within 2 hours after birth.

**References**


**Correction: Antimicrobial susceptibility of enteric bacteria recovered from feedlot cattle administered chlortetracycline in feed**