Failure of Passive Transfer in Calves

Thomas E. Besser, *DVM, PhD*
Washington Animal Disease Diagnostic Laboratory
Department of Veterinary Microbiology and Pathology
Clive C. Gay, *DVM, MVSc, FACVSc*
Field Disease Investigation Unit
Department of Veterinary Clinical Sciences
College of Veterinary Medicine
Washington State University

Introduction

Acquisition and absorption of adequate amounts of colostral immunoglobulins are essential to the health of the newborn calf. Calves are born lacking any significant amount of circulating immunoglobulins and rely on antibodies acquired from colostrum for protection against common environmental pathogens. The major immunoglobulin in colostrum is IgG1, but there are also significant amounts of IgG2, IgM and IgA. Considerable amounts of these immunoglobulins in ingested colostrum are transferred across the epithelium of the small intestine during the first few hours of life and transported via the lymphatic system to the blood. Immunoglobulins in the blood then enter extravascular fluids and external body secretions, depending upon the immunoglobulin class. The absorbed immunoglobulins protect against systemic invasion by microorganisms (and therefore against bacterial septicemias) during the neonatal period. In addition, both unabsorbed immunoglobulins and immunoglobulins re-secreted back into the gut play important roles in protection against intestinal infections for several weeks following birth. Good passive immunity also reduces the occurrence of respiratory disease during the first months of life and may be a determinant of improved lifetime productivity.

Partial or complete failure of passive transfer of colostral immunoglobulins is a major determinant of susceptibility to neonatal disease and mortality in calves. Consequently, it is important that calves acquire adequate circulating concentrations of immunoglobulin from the colostral transfer process.

Monitoring Rates of Failure of Passive Transfer

Every herd should have a policy for feeding of colostrum and its efficacy should be periodically monitored as part of the routine health surveillance. The policy should be modified or changed if it does not result in high rates of adequate passive transfer. Health records should be kept for each calf. Cut points for adequate passive transfer will vary between farms according to calf management, housing and the infection pressure and can be determined from health records and serum IgG values.

Monitoring frequency and sample size depend on the herd size. Radial immunodiffusion is the gold standard for measurement of serum immunoglobulins, but is too expensive for routine monitoring. Our preference is for serum total protein estimated by refractometry, but zinc sulfate and sodium sulfite tests also are effective. Where stored colostrum is fed, the farm should keep records relating to feeding such as the date and time of birth and of feeding; the volume fed; the identity of the colostrum fed; and, if appropriate, the method of feeding. These should be initialed by the feeder. Stored colostrum should be identified with the date of collection, the identity of the source cow, the volume of colostrum from that milking and whether it is first-milking colostrum. This should be initialed by the person responsible for collection. These records will greatly facilitate investigating the cause of failure of passive transfer.

Factors that Influence Passive Transfer of Colostral Immunoglobulins

Age at First Feeding

It is commonly stated that the intestine is capable of absorbing immunoglobulins for 24-30 hours after birth. These limits have been established by physiologists interested in the duration of the absorptive period. However, the absorptive capacity already is markedly reduced by 8 hours after birth. A herd policy for colostral feeding that minimizes the time between birth and colostral feeding will reduce the percentage of calves with failure of passive transfer. Herd policy should be that all calves receive colostrum within 2 hours of birth, in order to emphasize the importance of early feeding. This also allows for a second colostrum feeding during the period of maximal absorption in those herds that do not practice large-volume colostrum feeding at first feeding.

Formation of Colostrum

There are 4 different immunoglobulin classes in bovine serum and colostrum, but immunoglobulin G_1 (IgG_1) is predominant. IgG_1 is concentrated in colostrum by an active, selective, receptor-mediated transfer of IgG_1 from the blood of the dam across the mammary gland secretory epithelium. This transfer to colostrum begins approximately 4-5 weeks before calving, and in most cows continues until the point of calving. This active transfer process results in colostral IgG_1 concentrations that may be 10 times higher than maternal serum IgG_1 concentrations, and ideally results in the transfer of several hundred grams of IgG_1 into the colostrum.

Provided colostrum is fed at an early age, the immunoglobulin mass ingested is a prime determinant of the subsequent serum immunoglobulin concentration. Early studies suggest that an immunoglobulin mass of between 80 and 100 grams must be ingested for successful passive transfer. Subsequent studies have suggested these values are minimal, and our studies with Washington state Holstein calves suggest that at least 150 grams of IgG_1 must be fed to avoid failure of passive transfer. This mass must be fed within the first 12 hours of life, but preferably is fed at the first feeding.

The mass of immunoglobulin ingested is a function of the volume of colostrum ingested and its immunoglobulin concentration. Failure of passive transfer can occur from an inadequacy in either component. Thus, cows may produce colostrum of high immunoglobulin concentration, but have an inadequate volume to provide sufficient mass for the calf. In the other situation, cows can produce large volumes of colostrum but its immunoglobulin concentration is low and the calf cannot ingest sufficient colostrum to achieve the required mass.

Dairy cows almost invariably produce large volumes of colostrum, with production of between 10 and 20 lbs. is common in Holsteins. In the dairy breeds there is not a problem in the volume of colostrum available for ingestion, but there can be a problem in immunoglobulin concentration.

Table 1 shows the distribution of IgG_1 concentrations in over 1,200 first-milking colostrums from Washington Holsteins. From this table, it is obvious there is considerable variation in colostral immunoglobulin concentration—a major determinant of the occurrence of failure of passive transfer of immunoglobulins in Washington Holsteins. For example, colostral feeding systems which routinely feed 2 quarts (approximately 2 liters) of colostrum will fail to provide an immunoglobulin mass of 100 grams in approximately 58% of the feedings. The desired mass of 150 grams will not be achieved in over 80% of the feedings. Although feeding a 150-gram mass may be the ideal, feeding of a 100-gram mass is currently our target, as it is more realistically achieved given the distribution of colostral immunoglobulin concentrations.

Table 1. Distribution of colostrum by immunoglobulin concentration, based on data from Washington state Holstein cattle.

IgG_1 Concentration (mg/ml)	Percent of Colostrums	Cumulative Percentage
0-20	4.94	4.94
20-30	13.51	18.45
30-40	21.17	39.62
40-50	18.78	58.40
50-60	14.99	73.39
60-70	9.88	83.28
70-80	6.34	89.62
80-90	3.46	93.08
90-100	2.47	95.55
100+	4.44	100

We have examined the following influences on colostral immunoglobulin concentrations:

Length of dry period. As mentioned above, immunoglobulins are selectively transferred into the udder for 4-5 weeks prior to calving. Consequently, the length of the dry period might be expected to influence immunoglobulin concentrations. We have found no practical influence on immunoglobulin concentration, providing the dry period is longer than 30 days.

Calving to milking time. Immunoglobulin secretion into the udder ceases prior to, or at the point of, calving, and immunoglobulin concentrations fall dramatically with subsequent milkings. Although we found a significant fall in immunoglobulin concentration with increasing calving-to-first-milking time, the fall in concentration was not of practical significance providing that interval did not exceed 8 hours.

Lactation Number. Colostral immunoglobulin concentrations are reported to increase with increasing lactation number. We observed this trend in colostrums from cows of lactation 2 onward. However, the immunoglobulin concentration of colostrum from first-calf heifers was equivalent to that of lactation 3+ cows. Many herds to do not feed colostrum from heifers on the basis of reported low immunoglobulin concentrations. This would not be justified by our findings. It is possible the colostrum from first-calf heifers contains a poorer spectrum of immunity when compared with that from older cows, but it also is possible that young heifers' colostrums contain more antibodies directed towards pathogens of young animals. No feeding trials have shown that colostral immunoglobulin from first-calf heifers is less protective than an equivalent mass of immunoglobulin from older cattle. In general, lactation number cannot be used to pick colostrums with higher immunoglobulin concentration as the within-lactation number variation is far greater than the between-lactation number variation.

Colostral Volume. There is a fall in colostral immunoglobulin concentration with increasing colostrum volume, and if possible high-volume colostrums should not be used for first feedings. Stored colostrums contain a disproportionate number of low IgG concentration members due to this effect.

Colostrum Pools. There can be problems with feeding from colostrum pools. In theory, the pooling of colostrums should avoid extreme variation in colostral immunoglobulin concentrations and should reflect the antigenic experience of the herd. In practice, most colostrum pools have low IgG concentrations due to the diluting effect of high-volume, low-IgG concentration colostrums. Therefore, if colostrum pooling is practiced, we recommend that only a fixed volume be added from each individual colostrum. An additional problem with colostrum pools is the increased probability of contamination and proliferation of bacterial pathogens such as *Salmonella* spp.

Specific Gravity. Some selection for colostral quality can be made by measuring specific gravity. The commercially available colostrometer has cut points that are appropriate for a 2-quart feeding of colostrum. With these cut points and this volume of feeding, it will select against approximately 50% of low-IgG concentration colostrums, but will "pass" as suitable for the remaining low IgG concentration colostrums. Thus, approximately 50% of low-immunoglobulin-concentration colostrums will test satisfactory on the colostrometer. Proper use of the colostrometer should include a standard waiting period of at least 2 hours in a moderate-temperature environment to allow air entrained during milking to escape. This also allows equilibration to even out temperature differences that have a direct effect on specific gravity. In general, the higher the specific gravity, the higher the immunoglobulin content, so using a cut point above the yellow-green (~50 mg/ml) threshold will select for better colostrum quality.

Storage and Freezing. Colostrum can be stored at refrigerator temperature for 7 days and kept at -4°F (-20°C) deep frozen indefinitely. Excessive heat should be avoided in thawing frozen colostrum. To assist in thawing, colostrum is best frozen in flat plastic zip-lock bags.

Feeding Systems to Optimize Ingestion of Adequate Immunoglobulin by the Calf

Natural sucking is the desired method of intake of colostrum and is the most efficient, but it is influenced by the sucking drive and vigor of the calf at birth. Natural sucking of dairy calves is commonly associated with a high rate of passive transfer failure. In part, this results from a problem of neonatal vigor and delayed sucking. Failure of 25%-34% of calves to suckle by 6-8 hours of age and 18% of calves to suckle by 18 hours of age has been observed. These delays result in greatly impaired immunoglobulin absorption by calves.

Pendulous udders and large, bulbous teats also can limit colostral ingestion by calves. However, the major cause of failure of passive transfer in naturally sucking dairy calves lies with the ingestion of colostrum with inadequate immunoglobulin concentration. There is considerable variation in colostral intake by naturally sucking calves, but the average intake is approximately 2.5 liters. At this average intake, the colostral immunoglobulin concentration needs to be 40 mg/ml of IgG_1 in order to achieve a mass intake of 100 grams of this immunoglobulin. As can be seen from Table 1, a significant proportion of colostrums do not contain this concentration, and mass intakes will be even further reduced in calves that ingest below-average volumes. Experimental studies show that passive transfer failure can be minimized in natural sucking situations by assisting the calf to the udder early in its life and ensuring a long sucking period. However, in our experience most dairy farms that purport to do this can manage to assist only a proportion of calves, and consequently still suffer a high failure rate.

Systems of artificial feeding of colostrum to dairy calves can promote the intake of a high-immunoglobulin mass, providing they utilize selected colostrums and ensure a high-volume intake by the calf. The volume of colostrum that is fed on many farms (2 quarts) is too low to ensure adequate passive transfer. A degree of selection for colostrums with high immunoglobulin concentrations can be made by measurement of specific gravity. Feeding colostrum by nipple bottle can ensure a reasonable intake providing the feeder has patience. However, the volume of colostrum that can be administered by nipple bottle feeding is limited and, in one of our studies, it took an average of 20 minutes to bottle feed 1-hour-old calves 2.5 liters of colostrum. Nearly one-third of calves that were fed failed to drink 2.5 liters in a 1-hour period.

Nipple bottle feeding can be effective if the feeder has patience and time. Calves should be fed to satiation at birth and again at 12 hours of life, but with a minimum intake of 2.5 quarts at each feeding. Nipple bottle feeding will be associated with high rates of failure of passive transfer where calf feeding labor is inferior and where there are significant time constraints imposed on the labor by other tasks.

Larger volumes of colostrum can be fed by an esophageal feeder. Advantages are the volume that can be fed and the speed with which it can be administered. This method is particularly advantageous where time constraints of other farm activities limit the time available for calf feeding. However, colostrum administered by this method is less efficiently absorbed, probably due to retention of some colostrum in the immature forestomachs for several hours. For this reason large volumes (a minimum of 3 quarts and preferably 4 quarts to a Holstein calf) should be fed. If small volumes (1-2 quarts) are fed by an esophageal feeder, the absorption of immunoglobulins is usually sub-optimal and yet the calf will feel satiated and not inclined to naturally suckle for the next few hours. Feeding colostrum by an esophageal feeder is an effective method for avoidance of passive transfer failure in dairy cattle.

Colostrum Substitutes. There are a number of colostrum substitutes or supplements available. They contain varying amounts of immunoglobulins, and calf serum immunoglobulin values consequently vary following feeding, according to the producer.

Research is continuing on the cause of low immunoglobulin concentration in Holstein colostrum. Cows with high-concentration colostrum at one lactation tend to have high concentrations at subsequent lactations. It is possible that this reflects between-cow differences in the number and/or affinity of immunoglobulin receptors in the mammary gland.

References

1. Besser TE, Gay CC, Pritchett L: Comparison of three methods of feeding colostrum to dairy calves. J Am Vet Med Assoc198:419-422, 1991.
2. Fleenor WA, Stott GH Hydrometer test for estimation of immunoglobulin concentration in bovine colostrum. J Dairy Sci 63:973-977, 1980.
3. Oyeniyi OO, Hunter AG: Colostral constituents including immunoglobulins in the first three milkings postpartum. J Dairy Sci 61:44-48, 1978.
4. Petrie L, Acres SD, McCartney DH: The yield of colostrum and colostral gammaglobulins in beef cows and the absorption of colostral gammaglobulins by beef calves. Can Vet J 25:273-279, 1984.
5. Pritchett L, Gay CC, Besser TE, Hancock DD: Management and production factors influencing immunoglobulin G1 concentration in colostrum from Holstein cows. J Dairy Sci 74:2336-2341, 1991.
6. Stott GH, Fellah A (1983) Colostral immunoglobulin absorption linearly related to concentration for calves. J Dairy Sci 66:1319-1328, 1983.
7. Stott GH, Marx DB, Menefee BE, Nightengale GT: Colostral immunoglobulin transfer in calves. I. Period of absorption. J Dairy Sci 62:1632-1638, 1979
8. Stott GH, Marx DB, Menefee, BE Nightengale GT: Colostral immunoglobulin transfer in calves. III. Amount of absorption. J Dairy Sci 62:1902-1907, 1979
9. Stott GH, Marx DB, Menefee BE, Nightengale GT: Colostral immunoglobulin transfer in calves. IV. Effect of suckling. J Dairy Sci 62:1908-1913, 1979.