The Role of Colostrum in Managing Calf Health

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Passive immunity acquired by the newborn calf following ingestion of colostrum is a major determinant, but not the sole determinant, of health during the neonatal period. Colostral immunoglobulins provide both circulating antibody and antibody active at local surfaces such as the gut. There is a high prevalence of failure of passive transfer of colostral immunoglobulins in calves. The transfer of colostral immunoglobulins to the calf is influenced by factors such as age at first feeding, method of feeding, the volume of colostrum ingested and its immunoglobulin concentration, the feeding of single versus pooled colostrum, a possible effect from the presence of the dam, seasonal influences and individual calf variation in efficiency of absorption. In this paper the influence of each of these individual factors will be discussed, however, in most herds the occurence of failure of passive transfer results from an interplay between most of these influences.

Failure of Passive Transfer and Susceptibility to Disease

A relationship between failure of passive transfer of colostral immunoglobulins and subsequent susceptibility to neonatal disease has been shown for a number of different disease conditions.[1]

Septicemic colibacillosis. Failure of passive transfer is the major determinant for the occurrence of colisepticemia. Colisepticemia occurs only in calves that are agammaglobulinemic or markedly hypogammalobulinemic and this disease can be completely prevented by instituting management changes that prevent the occurrence of failure of passive transfer.

Calf Scours. There are four studies in the literature that show a relationship between the occurrences of diarrhea and serum immune globulin concentrations. In these studies calves with high circulating concentrations of serum immune globulins remained clinically healthy, calves with medium concentrations developed diarrhea but survived whereas calves with low serum concentrations developed diarrhea and died. These four studies are an exception as the majority of studies have not reported a relationship between the occurrence of diarrhea and serum immune globulin concentrations but have reported a relationship between low serum immune globulin concentrations and death from diarrhea. These findings suggest that the severity of diarrhea in enteric disease of neonatal calves is influenced by serum immune globulin concentrations and balance studies in groups of calves with diarrhea have demonstrated a significant negative relationship between fecal output and serum immune globulin concentrations. The majority of these studies have been concerned only with morbidity and mortality and there is little information on the relationship between failure of passive transfer and mortality from specific etiological causes of diarrhea.

Salmonellosis. There is a brief field report of a high prevalence of salmonellosis in calves with low concentrations of serum immune globulins and a negative relationship between serum immune globulin concentration, fecal output and death in neonatal salmonellosis is also recorded.

Pneumonia. There are four reports which establish a relationship between the occurrence of failure of passive transfer in calves and subsequent susceptibility to pneumonia.

Miscellaneous Conditions. Failure of passive transfer has been associated with the occurrence of navel ill and peritonitis in calves.

Growth Rate. As might be expected, calves with failure of passive transfer that develop clinical illness, but recover, will show a reduced rate of gain. However, a positive relationship between serum immune globulin concentrations and growth rate in healthy lambs and calves has been reported. In the case of beef calves the superior growth rate was only evident in the early part of life and was lost by six weeks of age.

Methods of Testing for Failure of Passive Transfer

Zinc Sulfate Turbidity Test

Immune globulins are selectively precipitated by specific concentrations of zinc sulfate. One hundred microliters of serum are added to six ml of a zinc sulfate solution containing 208 mg $ZnSO_47H_2O$ per liter and the test is allowed to incubate at room temperature for one hour. Serum from colostrum-deprived calves or calves with complete failure of passive transfer will show no turbidity. The development of turbidity is directly related to the serum immune globulin level. The test can be quantitated using an absorptionmeter.

Disadvantages of Test. Serum, not plasma, must be used for the test as fibrinogen will precipitate at this zinc sulfate concentration and give false-positive readings. The zinc sulfate solution must be freshly prepared using boiled distilled water as absorbed carbon dioxide will interfere with the accuracy of the test. Soda lime straws can be used to store made-up solutions. The equipment required for quantitation of the test is generally not available in practice laboratories, however, with practice, an assessment of the immune globulin status of the calf can be made visually as calves with severe failure of passive transfer will show no or negligible turbidity.

Refractometer Test

Absorbed immunoglobulins contribute considerably to the serum total protein concentration. The serum total protein concentration can be used as an indirect measure of immunoglobulin concentration in newborn calves. Either serum or plasma can be used and the tests can be run rapidly using a microhematocrit centrifuge. Total protein readings of less than 5.5 g/dl are indicative of failure of passive transfer and levels less than 5 g/dl are evidence of severe failure. Both the refractometer and a microhematocrit centrifuge are common in practice laboratories.

Disadvantages of Tests. The test is an indirect measure of serum immune globulin concentrations and can be influenced by anything that affects total protein concentrations. In particular dehydration associated with neonatal diarrhea can result in elevated readings. The test is not a good quantitative test.

Electrophoresis

Serum electrophoresis allows a more exact definition of total protein concentrations and individual serum component quantification. It has only moderate value for immunoglobulin quantification and is inferior to radial immunodiffusion.

Radial Immunodiffusion

This test allows accurate quantification of serum immunoglobulin and its subclasses. Forty-eight hour serum concentrations of less than 10 mg/ml, 0.8 mg/ml and 0.22 mg/ml are considered as evidence for failure of passive transfer for IgG, IgM and IgA respectively. IgG should be used as the reference immunoglobulin in studies determining the prevalence of passive transfer failure as it has a relatively long half life and so the time of blood sampling, within limits, has relatively little influence on the values obtained. In contrast IgM and IgA have short half lives and the time of blood sampling will markedly influence the values obtained.

Disadvantages of Test. This test is beyond most practice laboratories and is usually not conducted routinely by diagnostic laboratories. It takes a period of time to run this test and consequently the results are usually historical and not of value for individual calf monitoring studies. The test has considerable value for survey studies establishing the status of passive transfer of immune globulins in herds.

Other tests such as the gluteraldehyde and sodium sulfite tests have been described. In my opinion they offer no advantages over the tests described above.

Where a problem with passive transfer of immunoglobulins is suspected in a herd radial immunodiffusion or the zinc sulfate turbidity test can be used to examine a large number of serums to determine the magnitude of the problem. The refractometer test is the most rapid method of determining the immunoglobulin status of an individual calf but the zinc sulfate test can also be used for this purpose.

Age at First Feeding of Colostrum

The time after birth that colostrum is first fed is well recognized as a major influence on successful passive transfer of colostral immunoglobulins. The small intestine of the calf has the capability of absorbing and transfering colostral immunoglobulins into the intestinal lymph and subsequently to the circulation. This capacity exists for the first 24 to 36 hours after birth following which ingested immunoglobulins are not absorbed and are lost as far as the circulatory immune system is concerned, although they may still have considerable importance in intestinal lumenal activity. From feeding trials Scottish workers[2] postulated a linear fall in the absorptive capacity of the intestine between birth and closure and extrapolated closure times of 16, 22 and 27 hours for IgM and IgG respectively. In more extensive feeding trials Stott[3 4] at Arizona could not find any substantial difference between closure time for individual immunoglobulins but did demonstrate that closure was influenced by the time after birth of feeding. Thus, in calves initially fed colostrum at birth the average time of closure for all immunoglobulin classes occurred at 21 to 23 hours whereas if feeding was delayed until 24 hours-of-birth closure in some calves was extended to 31 to 33 hours after birth.

The determination of closure times is of importance in examining the phenomenon of colostral immunoglobulin absorption in calves but the bare statement of these times can be misleading for the individual calf and for considerations of this subject from the point of view of calf health. Although calves may absorb immunoglobulins from colostrum first fed as late as 12 to 24 hours after birth, the efficiency of absorption in many of these calves is very low and frequently insufficient amounts are absorbed to provide protection against neonatal disease. Also there is considerable individual variation in closure time and although some calves may absorb immunoglobulins for periods as long as 24 to 36 hours after birth others do not. It is apparent from the Arizona studies that some calves fed colostrum at 12 hours after birth failed to absorb any immunoglobulins and that the percentage of calves that failed to absorb any immunoglobulins increased with increasing delays of feeding (50% of calves fed at 24 hours.).

All studies suggest that the absorptive capacity of the intestine for colostral immunoglobulins falls at a linear rate following birth and with pregressive delays in feeding of colostrum increasingly lower concentrations of serum immunoglobulins will be achieved. For the average calf, with a normal closure time and a good absorptive efficiency during the first few hours of life, adequate absorption of immunoglobulins will be achieved if colostrum is fed within the first 6 to 8 hours of life; however, all calves are not average and this time frame of feeding will not be suitable for the smaller number of calves with earlier closure periods and a more rapid loss of intestinal absorptive capacity in the first few hours after birth. In order to minimize the occurrence of passive transfer failure in this group of calves it is essential that all calves be fed colostrum at an early age. A recommendation can be made that all calves should be fed their first feeding of colostrum within the first 2 hours of life. Although the feeding of colostrum within this time period may be managementally difficult this recommendation emphasizes the importance of early feeding and will optimize the efficiency of absorption in all calves as well as providing early local intestinal protection against enteric acting and enteric invading microorganisms.

Mass of Immunoglobulin Ingested

The mass of immunoglobulin ingested is a prime determinant of the subsequent serum immune globulin concentration. There is a linear relationship between these two parameters and two separate studies[5 6] have estimated that 50% and 68%, respectively, of the variation in calf serum immune globulin concentrations can be attributed to differences in the amount of immunoglobulin mass consumed per unit of body weight. The mass of immunoglobulin ingested is a product of the volume of colostrum ingested and its immunoglobulin concentration. In practical feeding situations the volume of colostrum fed can be manipulated, however, immunoglobulin concentration has probably the greatest significance to the occurrence of failure of passive transfer and calf health.

Volume of Colostrum

The volume of colostrum produced by the cow and available to the calf for sucking or artificial feeding is not a limiting factor for successful passive transfer in most instances. The possible exception is a limited colostral volume produced by some heifers. Radostits[7] has reported that beef heifers in range situations may have critically low volumes of colostrum. Critically low volumes of colostrum have also been reported in beef cattle subjected to severe nutritional deprivation during pregnancy.

In general the yield of colostrum at the start of the first lactation is lower than that at subsequent lactations in all breeds. Breed differences in yields of colostrum are recorded[8], however, they are unlikely to be of significance as a major cause of failure of passive transfer.

The volume of colostrum ingested by natural sucking has been recorded at 2.4±0.18 kg for the first 24 hours of life in American Holstein calves[9], 2.55±0.18 kg for Dutch Friesian calves[10], 2.75±0.28 for Belgium Blue White calves[10] and 3.3±0.5 kg for Ayrshire calves.[11] These naturally ingested volumes are not too different from the common recommendation that artificially fed calves should be fed 2 quarts or 2 liters of colostrum at the first feed. However, in view of the proportion of colostrum with low immunoglobulin concentrations this volume may be insufficient.

Immunoglobulin Concentration in Colostrum

Studies on the immunoglobulin concentrations in colostrum have been reviewed by Roesti and Fey[12] and by Fleenor and Stott.[13] The latter authors point out that falsely high values will be achieved using the radial immunodiffusion analytical technique when colostral whey rather than whole colostrum is analyzed. Stott has recorded the following immunoglobulin concentrations for first milking colostrums; IgG 73.4±42 mg/ml, IgM 12±3.3 mg/ml, and IgA 17.8±10.7 mg/ml. Using similar analytical methodology we have found the following IgG concentrations in first-milking colostrums from 3 different Holstein herds, 50.9±27.3 mg/ml, 65.6±26.6 mg/ml, and 62.0±29.9 mg/ml. These analyses were on colostrums as fed in these herds. It is apparent that there is a substantial variation between cows in the immunoglobulin concentration of first-milking colostrums and that many first-milking colostrums contain concentrations of immune globulins that are too low to provide sufficient immunoglobulin mass for successful passive transfer to the calf—especially when limited amounts of colostrum are fed by artificial feeding methods. Using the data above we have estimated that from 17 to 42 percent of colostrum in the 3 herds contained insufficient immunoglobulins for successful passive transfer if 2 liters of colostrum were the volume fed to calves.

Factors that lead to variation in the immune globulin concentration in colostrum and that can be manipulated in field situations to avoid feeding colostrums with low immune globulin concentrations are not well delineated. Colostral immunoglobulins are at their lowest concentrations at the first lactation and it is probable that colostrum from heifers should not be used for first-feeding colostrum for calves. The increase in immunoglobulin concentration with lactation number occurs predominantly with IgG which increases to the third or fourth lactation.[8 14 15] IgM increases over the first two lactations whereas IgA remains relatively constant in concentration regardless of lactation number. Breed differences in colostral immunoglobulin concentrations are recorded[16 17] and there is evidence of repeatability of colostral immunoglobulin concentration in the same cow from year to year.[18] Dietary restrictions during pregnancy have not been shown to have an effect on colostral immunoglobulin concentration, however, udder health may have an influence. The rapid fall in colostral immunoglobulin concentration following calving and associated with milking is well recognized and emphasizes the importance of the use of first-milking colostrums for colostrum feeding and the importance of obtaining these colostrums shortly after calving.

Arizona workers studied the value of measuring the specific gravity of colostrum to predict colostral immunoglobulin concentration and found a good correlation. This method of analysis is now marketed commercially and the instrument is called a colostrometer. In our hands this instrument will discard 50% of low immune globulin concentration colostrums and will predict high immune globulin concentration colostrum. Machine milked colostrums should not be tested immediately following milking. The instrument has considerable value in field situations and can be used to eliminate from first feedings a substantial proportion of colostrum with low immunoglobulin concentrations.

Colostrum Pools

The mixing together of colostrums and feeding from this pool is frequently advocated. In theory the mixing together of colostrum should result in a pool of good average immunoglobulin concentration and should circumvent the problem of low immunoglobulin concentration colostrums being fed. However, in practice this does not occur. From feeding trials we have established that calves fed from colostrum pools frequently acquire substantially lower serum immune globulin concentrations than calves that are fed equivalent volumes of homologous colostrum from their own dam. A critical examination of the literature reporting serum immune globulin concentrations following the feeding of colostrum pools also shows this trend. We have studied the efficiency of absorption of immunoglobulin from colostrum pools and homologous colostrum and found no difference.[20] However, colostrum pools, as made by us from first-milking colostrums, and as reported in the literature, almost invariably have a low immunoglobulin concentration. It would appear that this phenomenon results from the fact that high volume colostrums are likely to have low immunoglobulin concentration. The influence of these high volume, low immunoglobulin concentration colostrums on the final immunoglobulin concentration of the colostrum pool is considerable and many pools have low concentrations which are critical where small volumes are fed. The colostrometer can be used to select high immunoglobulin concentration colostrums for the formation of colostrum pools. Low concentration colostrums should be used only for second feedings or for general calf milk feeding.

In summary there is little doubt that the mass of immunoglobulin ingested by the calf from colostrum is a prime determinant of the subsequent serum immune globulin concentration. Most studies have shown a linear relationship between these values and between 50 and 68 percent of the variation in serum immune globulin concentrations can probably be attributed to differences in the amount immunoglobulin consumed per unit of weight. The use of a colostrometer will eliminate a significant proportion of low concentration colostrums. Even so the concentration of immunoglobulins in the colostrum of American Holsteins is such that 2 liters is too small a volume to feed and where possible greater volumes should be given. The ability to do this will depend upon the method of feeding.

Method of Feeding of Colostrum

Numerous studies have shown that in dairy breeds natural suckling can be associated with a significant rate of failure of passive transfer which can approach 40% of calves. Failure of passive transfer in natural sucking feeding systems occurs from a variety of causes. The poor sucking drive in many dairy calves can result in a substantial delay in intake of colostrum. A substantial proportion of calves fail to suck before 6 to 8 hours which is significant in view of the importance of age after birth of first intake of colostrum on the absorptive capacity of the intestine. The immunoglobulin mass ingested by naturally sucking calves may also be low as the result of the ingestion of inadequate volumes of colostrum or the ingestion of colostrum with a low immunoglobulin concentration. We have monitored naturally sucking herds which purport to encourage early sucking and frequent sucking by calves and have found high rates of failure of passive transfer. I can see no immediate practical solution to this problem as it is breed associated. However, efforts toward the longterm solution of the problem of failure of passive transfer in dairy breeds need to be directed in this area.

Artificial feeding systems can markedly increase it. In artificial feeding systems the calf may be fed colostrum milked from its own dam or colostrum that has been stored from previous calvings. When the calf is fed colostrum from its own dam there is commonly a delay in feeding as the colostrum is usually collected from the cow by machine milking at the end of the next milking shift after calving. This can result in delays in feeding of up to 12 hours, and occasionally more, and can be a significant factor influencing the prevalence of failure of passive transfer. Calves that are fed fresh-stored first-milking colostrum from cows that have calved previously do not experience delays in feeding associated with this factor.

The method of feeding can considerably influence the prevalence of failure of passive transfer. Calves do not readily adapt to bucket feeding or to nipple pail feeding and when this training is associated with the first feeding of colostrum considerable patience is required to be sure of an adequate and early intake of colostrum to avoid failure of passive transfer. Similarly, considerable patience is required to ensure an adequate intake of colostrum from a nipple bottle. Since a lack of sucking drive and of vigor is a major problem in dairy breeds all 3 methods of feeding can be associated with inadequate intakes of colostrum. The success of these methods of feeding depends somewhat upon the size of the enterprise. On small family farms, calves are likely to be fed by interested family members and, in general, the volumes of colostrum intake are likely to be higher, reflecting the interest and patience of these feeders. However, on large commercial enterprises these methods of feeding are less likely to be successful. In our own feeding trials we have found that the time required to feed a calf approximately 2.5 liters of colostrum via nipple bottle can vary from a few minutes up to 1 hour. The time constraints imposed by other mandatory farm activities on the availability of labor for calf feeding at a time dictated by a cow's calving obviously will limit the success of these methods of artificial feeding in large commercial enterprises.

The use of an esophogeal feeder allows the rapid administration of large volumes of colostrum and can allow intakes of colostrum far in excess of those achieved by natural sucking or by artificial methods of feeding that rely on sucking. The esophageal groove does not operate with this method of feeding and the vast majority of colostrum is deposited into the immature rumen. Radiographic studies have shown that material fed by this method rapidly enters the abomasum and small intestine, however, a considerable residium remains within the rumen for a period after feeding.[21] When large volumes of colostrum are fed this residual capacity of the rumen probably is of little importance to the amount of immunoglobulin presented to the small intestine for absorption. However, this may not be true when small volumes of colostrum are fed. It is apparent that adequate serum concentrations of immune globulins can be achieved when adequate volumes of colostrum are fed by an esophageal feeder, however, there is evidence to suggest that the efficiency of absorption of immune globulins fed by this method is less than that following feeding methods associated with sucking activity.[22]

There have been several studies that have examined the efficiency of passive transfer with varying feeding and husbandry practices, however, there have been several varia-bles in each of these studies and in my opinion, with the possible exception of the esophageal feeder, there is no intrinsic advantage or disadvantage of one method of feeding to another. Consequently one must advocate a feeding system that ensures an early and adequate intake of colostrum and one that is compatible with the managerial capabilities of the farm under consideration. This latter point is probably the most critical.

Mothering Effect

Scottish workers have reported an apparent effect of the presence of the dam on the efficiency of immunoglobulin absorption.[23] In this study calves left with their dams achieved significantly higher concentrations of serum immune globulins than calves fed identical amounts of the same colostrum but removed and kept separate from the dam following birth. The significance of the occurrence of such a mothering effect is obvious to farms that take the calf from the dam at birth and feed colostrum in calf houses removed from the dam. The presence of this mothering effect was not confirmed in studies on calves at Arizona[24] and we have not been able to show its presence for lambs. Nevertheless, until the status of the presence of a mothering effect is fully defined calves fed colostrum by artificial means should be left with the dam for as long a period as is managementally practical.

Seasonal Variation in Immunoglobulin Absorption

There is a seasonal variation in the concentration of serum immune globulins acquired by calves from colostrum and in the prevalence of failure of passive transfer.[25] There is a higher prevalence of failure of passive transfer in the winter months and this may reflect seasonal variation in calf morbidity and mortality. Scottish studies associated this phenomenon with differences in management between summer born and winter born calves, where summer born calves were born at pasture and suckled their dams with the inherent mothering effect whereas winter born calves were removed from the dam at birth and fed colostrum by artificial means, frequently at late time after birth and with limited amounts. We have observed seasonal variation in calf serum immunoglobulin concentrations where there has been no seasonal variation in the colostrum feeding practices. This variation appears to be associated with a seasonal variation in absorptive efficiency of colostral immunoglobulins, however, the cause of this is undetermined. For the present a greater immunoglobulin mass should be fed during the winter months if seasonal variation in mortality or the results of IgG monitoring studies indicate that this variation in absorption is of significance in a herd. There is some evidence to suggest that cold stressed calves may acquire lower serum immune globulin concentrations from colostrum fed. Heat stress has also been associated with the acquisition of low concentrations of immune globulins.[24]

Genetic and Breed Effects

There are published breed differences in colostral immunoglobulin concentrations and published and recognized breed differences in calf vigor and sucking drive. In colostral feeding trials in dairy calves that standardize for all of the known influences on colostral immunoglobulin absorption, such as age at first feeding, immunoglobulin mass fed, method of feeding, season and the presence of the dam, there is still a substantial variation in the efficiency of immunoglobulin absorption which in a single trial may vary from 10 to 68 percent. It is possible that this variation may be genetic. The evidence for this is indirect. There has been no selection pressures for dairy calf survival which would be an indirect selection pressure for successful passive transfer. In beef calves and in sheep, where there has been such selection pressure, the prevalence of passive transfer failure is substantially less than that in dairy calves and serum immune globulin concentrations of these animals following colostrum feeding show a normal distribution with very little skew to the area of passive transfer failure. In contrast, the distribution of serum immune globulin concentrations in groups of neonatal dairy calves is almost invariably abnormal with a very marked skew to the passive transfer failure area.

Summary

Age at first feeding and immunoglobulin mass fed are the prime determinants for successful passive transfer of colostral immunoglobulins in calves.

Calves should receive their first feeding of colostrum within 2 hours of birth and a second feeding 12 hours later.

Field monitoring studies suggest that a single feed of 3 quarts of first-milking colostrum will result in satisfactory serum IgG concentrations during the summer months. However, this feeding will be inadequate during the winter months and a second feeding of 3 quarts of first colostrum must be fed again at 12 hours. For this reason a blanket recommendation is made that calves be fed 3 liters of first-milking colostrum before 2 hours of age and again at 12 hours of age to ensure adequate serum immunoglobulin concentrations throughout the year.

Colostral immunoglobulins are also important in local enteric protection. For this reason colostrum should also be fed on the second day. For this third and fourth feeding second-milking colostrum will suffice.

Colostrum should be milked as soon as possible from the dam after calving.

Colostrum from heifers should only be used for second day feeding.

A colostrometer should be used for detecting high immunoglobulin concentration colostrums for first day feedings.

Where colostrum pools are fed a colostrometer must be used for selection of colostrums to be used for first feeding pools.

Colostrum should be fed by nipple bottle where managerial expertise, time and patience can ensure the above parameters. Calves that do not ingest the full amount should be fed the remainder by esophageal feeder. Where managemental factors preclude the adequate feeding of calves by nipple bottle all calves should be fed by an esophageal feeder to ensure an adequate and timed intake of colostrum.

In natural sucking herds with calf health problems the immunoglobulin status of calves should be monitored despite assurances that calves are managed to ensure adequate colostral intake.

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