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## Disease Management of Dairy Calves and Heifers

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Besides stillbirths, disease is the most significant reason for mortality of dairy calves and heifers. Although reported mortality rates vary greatly by age, passive transfer status, type of operation, housing, season, management, country, region, and origin of the data set, enteritis and pneumonia emerge as the most common reasons for disease-related deaths among dairy calves and heifers [1–4]. Septicemia is an important cause of death in very young calves [5,6], diarrhea is the most important disease in calves less than 30 days of age [3,4,6], and pneumonia is the most important problem in replacement heifers over 30 days of age [3–5].

The economic impact of dairy heifer replacement disease and death is significant. The cost of raising heifers at \$1200 to \$1600 [7] or \$1.40 to \$1.88 per day is high [8,9] but is superseded by the cost of purchasing a springing heifer. Whether the goal is to maintain or expand herd size, disease management of dairy heifers is an appropriate focus for producers and their veterinarian. In many dairy calf raising operations, the veterinarian's role is limited to managing health problems, whereas most routine disease management, vaccinations, and treatment protocols are producer-driven. Although producer recognition of the common calf disease concerns when validated by postmortem examination is shown to be specific [1], the sensitivity of detection is poor at 58% and 56%, respectively, for enteritis and pneumonia. Early recognition and effective treatment of sick calves may reduce mortality and address the concern of 40% of dairies that report having insufficient number of replacement heifers to maintain herd size [3].

This article presents veterinarians with a systematic approach to calf disease investigations. Record analysis, colostrum and feeding protocols, housing and bedding management, protocol reviews, diagnostic testing, and data

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analysis are used to define problems, sources of infection, opportunities for improving resistance, disease detection, and prevention.

### Solving enteric disease problems of calves

The investigation of herd-based calf diarrhea begins with an accurate understanding of the age of onset, morbidity, and mortality data. For an endemic herd problem, it is optimal to review 12 months of retrospective data. The minimum database includes the total number of calves born; the number of heifer calves alive at 24 or 48 hours (depending on when they leave the calving pen); the number affected; primary age-group affected; treatment history; and the mortality rate. For calf enteritis outbreaks, it is useful to see at least 3 months of similar data. Calf records may not be kept or may provide minimal information but a review of the adult cow records can provide enough information to calculate calf mortality rate. Prospective record keeping may be necessary and forms that are simple and useful (Table 1) can be provided to the dairy before the investigation. A verbal clinical history is necessary and important but the scope, which is frequently dominated by the most recent cases, requires some validation from a minimum of 3 months of records. Other records of potential importance to the investigation are laboratory results from calf fecal specimens, blood cultures, tissue specimens, or postmortem examinations.

Most calf diarrhea problems are caused by a combination of factors, not all of which are infectious. The purpose of the herd investigation is to elucidate the potential enteric pathogens and to focus on the environment, calf immune status, nutrition, and management to define other contributing factors. Colostral immunity is an essential part of enteric disease management and is discussed elsewhere in this issue. Most calf diarrhea herd problems are caused by mixed infections [10] and the agents may change over time, depending on season of the year and population dynamics within the environmental site of exposure. By analyzing the fecal shedding patterns of calves in the affected age groups, potential pathogens can be identified. Knowledge of the agents can better define sources or sites of exposure,

Table 1  
Calf health records that elucidate age of onset, morbidity, and mortality

Calf ID	Calf birth date	Illness 0–48 hours (✓)	Illness 48 hours–5 days (✓)	Illness 5–14 days (✓)	Illness 14 days–weaning (✓)	Treated calf more than 1 episode of illness (✓)	Recovered (R) or died/culled (D)
3148				(✓)			R
3150				(✓)			D

can result in the development of more effective treatment plans, and can result in more specific preventive recommendations.

To determine the potential enteric pathogens to which calves have been exposed, fecal specimens are obtained from untreated calves within the affected age group. A good clinical history and calf health records provide the initial evidence for the age group of calves from which fecal specimens are obtained. The population at-risk can be confirmed by identifying the age of calves being treated for diarrhea on the day of the farm investigation. Unless, the age-of-onset of diarrhea is in calves less than 5 days of age, diagnostic tests for enterotoxigenic *Escherichia coli* are not performed. For calf diarrhea problems with age-of-onset between 5 and 14 days, the age group most commonly affected in most calf diarrhea investigations, samples are submitted for rotavirus, coronavirus, *Salmonella* spp, and *Cryptosporidium parvum*. Diarrhea problems in calves older than 14 days or in weaned heifers may include diagnostic tests for attaching and effacing *E coli*, *Salmonella* spp, *Eimeria* spp, and *Giardia* spp. Fecal samples are obtained from a minimum of six calves by inserting a gloved finger into the rectum carefully to extract feces that are present or by gently massaging the rectal lining. Most calves defecate with the stimulation and the feces can be collected into a 4-oz specimen cup. One should remove gloves before sampling the next calf, clean the outside surface, and seal the cap of the specimen cup. Four cotton swabs can be used to obtain a rectal smear from calves that do not produce manure. The calf identification, age or birth date, and fecal consistency score are recorded as shown in Table 2. Sample handling should follow the directions of the diagnostic laboratory receiving the samples, but within 30 minutes of collection it is best to place feces for *Salmonella* culture into transport or selective *Salmonella* media like tetrathionate, selenite, or both. We bring media to the farm and inoculate each with

Table 2

Fecal examination and analysis from a calf diarrhea investigation with typical day of onset at 9 days

Animal ID	Age or birth date (d)	Fecal score	EM for virus	Smear for <i>Cryptosporidium parvum</i>	<i>Salmonella</i> culture	Identified or treated (✓)
7200	10	2	Negative	Negative	Negative	
7202	9	0	Negative	Positive	Negative	
7203	9	2B	Coronavirus	Positive	Negative	
7204	9	2	Negative	Positive	<i>S Newport</i>	
7207	8	1	Negative	Positive	Negative	
7209	8	3	Rotavirus	Positive	Negative	✓
7210	7	1	Negative	Positive	Negative	

Where fecal score is 0 = normal consistency; 1 = semiformed or pasty; 2 = loose but enough consistency to remain on bedding; 3 = watery feces that sift through bedding material; B = blood is present.

a 1- to 2-g (pea-size) portion of fresh feces. *C parvum* and viral samples can be prepared according to the laboratory's specifications. For acid-fast stained smears, a dry cotton swab is dipped into the fecal specimen and then used to make a thin fecal smear on each of two glass slides that are appropriately labeled and submitted for *C parvum*. The remainder of the fecal sample is submitted for rotavirus and coronavirus testing.

From expected level of exposure to potential fecal pathogens in the environment [11–13], it is anticipated that up to 20% of the calves sampled may be shedding rotavirus, coronavirus, or *C parvum*. Fecal shedding of virus in orally vaccinated calves is uncommon [14], so when two or more of six calves sampled are positive for the enteric viruses or *C parvum* or if any calf is *Salmonella* spp positive, the exposure is considered abnormally high. Enteric pathogens revealed in fecal shedding profiles can be validated as the cause of herd diarrhea problems when intestinal microscopic lesions described in postmortem specimens are consistent with the pathogens present in the feces. As shown in Table 2, fecal shedding results show evidence of increased exposure to *C parvum* and *Salmonella newport* in a herd with calf diarrhea problems in 9-day-old calves. Previous postmortem examinations from the herd had demonstrated some intestinal villus blunting and clumping, consistent with *C parvum* infection, but the fibrino-purulent and necrotizing enteritis from three recently examined dead calves had not been linked to a *Salmonella* spp isolate. With abnormal fecal shedding patterns present, locating the source of infection is important and provides incentive to find solutions that bypass, dilute, or distance calves from that site.

Finding the sources of infection for a dairy herd with calf diarrhea must take into account the health status of the dam, routes of infection of the potential pathogens, the traffic pattern of the calves, incubation period of the potential pathogens, and the behavior of calves. Sick and bacteremic calving cows are more likely to have septicemic calves than calves with enteritis. *Salmonella dublin* carrier cows, whether or not they have clinical manifestations, are a high risk for colostrum transmission of the disease to their calves, in which clinical disease is most common between 2 weeks and 3 months [15] but can also occur at an earlier age. Most enteric pathogen transmission between the dam and calf, however, occurs by fecal-oral spread by colostrum or the environment. Even healthy cows have a large increase in fecal coliform bacterial counts during the periparturient period [16], putting the calves that commingle with cows in the calving environment at much higher risk for enteric infection. Fecal-oral transmission of enteric pathogens to calves can occur by contaminated bedding; commingled animals; pets; pests; colostrums; feeds; feeding utensils; esophageal feeders; or the hands, boots, or clothing of calf caregivers. Salivary secretions from sick calves that reach the mouth of susceptible calves can transmit *Salmonella* spp and other enteric pathogens, making the disposal of refused milk, water, and feed away from the calf environment an essential aspect of disease management. Esophageal feeders, balling guns, clothing, and hands can facilitate salivary-oral transmission in a dairy herd experiencing calf

diarrhea problems and must be cleaned and disinfected between successive calf uses.

As the newborn calf moves from the birthing pen to its final preweaning home, every place of short-term occupancy is regarded as a potential source of infection. From the maternity pen to the warming or drying area, to the transport vehicle or temporary hutch, all of the environments should be evaluated for enteric pathogens. Considering the percentage of time that calves most at risk for enteric infections spend lying [17], the most likely environmental source of an enteric infection is the bedding. Qualitative assessments of bedding cleanliness are subjective, unreliable, difficult to communicate, and easy to dismiss. Objective data that can be reported and compared with appropriate benchmarks provide motivation for change. The concept of quantifying bedding bacteria as a risk assessment tool for mastitis [18,19] is well established, whereas the interest in identifying specific bacteria like multidrug-resistant *Salmonella* in bedding material is more recent [20] but is useful for locating an environmental site of infection. An evaluation of different calf bedding materials [17] also demonstrates the use of this approach to assessing disease risks in the environment where calves spend most of their time.

For herd problems of enteric disease in calves, bedding materials from each environment that has housed calves are submitted both for bacterial counts (University of Minnesota Laboratory for Udder Health, Minnesota Veterinary Diagnostic Laboratory, St. Paul, MN) and *Salmonella* spp culture. Samples are taken with gloved hands from the perimeter of the pen in each of the four quadrants and from the center of the pen, specifically avoiding sampling fecal material. Samples for bacterial count are collected in a sealable storage bag and stored in the refrigerator overnight before shipment to the laboratory. Bedding samples for *Salmonella* culture are placed in room temperature buffered peptone water pre-enrichment media, which is sealed tightly and shipped overnight to the laboratory in biohazard bag containers. Bedding sample results from a dairy with diarrhea that starts in 5-day old calves is shown in Table 3. On that dairy, calves leave the maternity pen, move to a currently unoccupied maternity pen hutch, from which location they are taken by truck to a second farm, where they are placed in a clean hutch. Because of a 1- to 2-day incubation period for the fecal pathogens identified in the calves, bedding from a 3-day occupied hutch is also sampled. From the data in Table 2, the bedding from the unoccupied hutch in the maternity pen and the truck are the most likely sources of infection for the calves on that dairy.

For the enteric pathogens of most concern to calves, the incubation periods range from 12 hours to 5 days. When a herd diarrhea problem affects calves within the first 5 days of life, the source of infection is usually encountered before the calf reaches its final preweaning pen. Alternatively, the source of infection for diarrhea that begins after 7 days of age is usually found in the calf housing area. The optimal bedding material for calves

Table 3  
Bedding sample results from a dairy with diarrhea in 5-day-old calves

Sample source	Coliforms (colonies/mL)	Total colonies (colonies/mL)	<i>Salmonella</i> culture
Maternity pen	1000	576,000	Negative
Empty maternity hutch	35,000	36,875	Negative
Clean hutch	750	11,500	Negative
3-day occupied hutch	1500	577,500	Negative
Truck	6,900,000	6,921,750	<i>S muenster</i>
Goal for clean pen	< 1000	< 5000	Negative
Goal for occupied pen	< 500,000	< 2,000,000	Negative

depends on age of the calf, temperature, cost, bedding, season, and management. When granite fines, sand, rice hulls, long wheat straw, and wood shavings were compared [17], performance indices were similar under the moderate temperatures of the study period but calves on sand and granite fines had more scours. Adding clean, dry bedding to maintain a minimum of 3 in between the calf and the base of the pen and the removal of all feed refusals from the calf housing area are two very effective ways to dilute and distance calves from potential enteric pathogens. Continuous occupancy of calf raising facilities is a major risk factor that increases both the number and survival time of enteric pathogens in the environment. A goal of having 10% more calf pens than calves at maximum occupancy [21] provides time for cleaning, sanitizing, and resting pens between successive occupants. Strategic filling of calf raising facilities to empty large areas of the barn, rather than a single row at a time, can reduce endemic enteric disease of calves. Disinfection protocols are useful if prior cleaning of facilities and pens has removed all organic debris; if the disinfectant is effective for the agents encountered in that facility; and if contact application, time, and surface are as specified. Safe, broad-spectrum disinfectants that can be used in housing facilities, have penetration into soil or porous surfaces, can be cross-protective for boots, and can be applied in novel ways lead to greater compliance and improved calf disease management [22–24].

In addition to bedding contamination, other sources of enteric disease pathogens for calves are feeds, feeding equipment, pathogens on the skin, and the pen itself. Colostrum bacterial contamination is discussed elsewhere in this issue. Milk replacer and pasteurized milk have a low risk for bacterial contamination, especially fecal coliform bacteria, when there is proper mixing, storage, delivery, and feeding with clean equipment. Unpasteurized whole milk can present a high risk for enteric infection when it is nonsaleable milk that, if not fed immediately, has not chilled. To determine the level of risk coming from the liquid feed, a bulk tank milk culture can be performed. Of most interest in reviewing the culture results is the total bacterial count and the lactose-positive (fecal) coliform count. Table 4 shows goals and the ranges in milk and milk replacer bacterial numbers from bucket

Table 4

Bulk tank milk culture results from unpasteurized milk and milk replacer samples from dairies with calf diarrhea problems

	Range (cfu/mL)	Goal (cfu/mL)
Total count	1500-> 15,000,000	< 10,000
Fecal coliforms	0-> 15,000,000	0
Other gram-negative bacteria	0-> 15,000,000	< 5000
<i>Streptococcus non-agalactia</i>	0-80,000	< 5000
Coagulase-negative <i>Staphylococcus</i>	0-95,000	< 5000
<i>Staphylococcus aureus</i>	0-40,000	0
Other bacteria	0-50,000 (with probiotics)	< 5000 if no probiotics are added

or bottle samples obtained just before calf consumption in herds with calf diarrhea problems (McGuirk, unpublished data, 2006). Culture swabs are used to assess cleanliness of feeding equipment, esophageal feeders, nipples, feeding bottles, and buckets for potential enteric pathogens. Only lactose-positive coliform growth is reported as evidence of inadequate sanitizing procedures.

Self-grooming, a normal behavior of calves, can introduce enteric pathogens from the skin of calves. Although this is not considered a major risk factor for transmission of enteric disease, commingled calves, calves with contact across open pen dividers, or calves housed in barns that are power-washed while still occupied may be at risk. Aerosolized bacterial spread of enteric pathogens, although possible [25], is rarely the primary source of enteric disease in calves.

A review of current vaccination, routine health management, and treatment protocols is an important part of enteric disease management in calves. Colostrum management, as discussed elsewhere in this issue, is the most effective way to transfer immunity to the specific enteric pathogens, enterotoxigenic *E coli*, coronavirus, rotavirus, and *Clostridium perfringens* types C and D from vaccinated cows to newborn calves. Similarly, vaccinated cows may transfer the benefit of gram-negative core antigen vaccine and siderophore receptor porin *S newport* vaccine immunity to calves. Because most calf diarrhea problems occur within the first 3 weeks of life, immune colostrum may be the only way effectively to protect young calves. The vaccines labeled for administration to the young calf to aid in preventing diarrheal diseases are limited and, with one exception (Entervene-d, Fort Dodge, Fort Dodge, Iowa), are administered at birth. Although many extra-label protocols attempt to improve the immunity of colostrum-deprived or susceptible calves against diarrheal diseases, there is little scientific basis for safety, efficacy, or disease protection. Where the veterinarian investigating calf diarrhea problems can be influential is in eliminating practices that have potential to do harm or that make calves more susceptible to disease. Avoid gram-negative bacterial vaccines not labeled for young calves. Do not



vaccinate calves during times of stress or disease susceptibility, and be cautious about the use of multiple or frequent small vaccine doses. The focus should be moved from vaccinating young calves to other means of reducing susceptibility or improving their immune status.

Routine medications, feed additives, and well calf treatments should be reviewed closely in calf herds with enteric disease problems. Individually, feed additives like immunoglobulins, mannan oligosaccharides, coccidiostats, antibiotics, direct-fed microbials, immune modulators, charcoal, amino acids, and other ingredients may benefit calves, but unrestrained combinations, concentrations, and packaged remedies may change intestinal flora, transport time, digestibility, absorption, and intestinal health of calves. Simplicity and consistency is a good starting point for most calf health programs.

The treatment protocol for calf diarrhea is based on early and effective detection followed by appropriate intervention. Calves with diarrhea (fecal score 2 or 3, with or without blood as described in [Table 2](#)) should be identified and currently on a treatment protocol. As part of a calf diarrhea investigation, determine the disease detection rate by dividing the number of calves currently being treated for diarrhea by the number of calves with fecal scores 2 (loose but enough consistency to remain on bedding) and 3 (watery feces that sift through bedding material). The goal of an 85% or greater detection rate can be achieved by twice weekly fecal scoring of all calves 2 weeks of age or less. In [Table 2](#), the detection of one of four calves with diarrhea is below expectations.

Diarrhea treatment protocols for farm use must be straightforward and trainable. It should penalize neither the calf nor the person administering treatments. For compliance, it must be effective, frequently monitored, and updated. The most important component of the treatment protocol is rehydration, and intravenous and oral fluid and electrolyte therapy of calves have been reviewed [26,27]. Feeding calves through the course of diarrhea maintains caloric intake and adds fluid volume and electrolytes to supplemental fluid administration. Continued feeding may facilitate the induction of digestive enzymes but may not be beneficial if force-feeding is required [28]. Therapeutic antibiotics are recommended for calves with diarrhea that have signs of systemic illness [29,30]. For the herd calf diarrhea protocol, criteria for treatment is clearly established as any calf with a fecal score 2 or 3 as described in [Table 2](#). If the examination of the calf reveals blood in the feces, a temperature greater than or equal to 103°F, or the calf is dull, depressed, or off feed a 3-day course of antibiotics is started. If the diarrheic calf has no signs of systemic illness, fluid therapy is the basis of the treatment protocol.

To encourage voluntary suckling, dividing the normal feeding volume into three or four smaller volume feedings may be better tolerated by sick calves. Milk or milk replacer is not given to diarrheic calves with a distended abdomen or to one that is down and cannot be assisted to maintain

sternal recumbency. Either a veterinarian is called or the recumbent calf is given intravenous fluid therapy. In addition to feeding milk, calves with diarrhea need 2 (diarrhea score 2) or 4 qt (diarrhea score 3) of warm electrolyte solution each day. The electrolyte solution can be fed immediately after (but not mixed in) the milk replacer or it can be fed at a time different than the milk replacer feeding. The approach I prefer is feeding four times per day: 1 qt milk followed by 1 qt oral electrolyte solution at the regular morning feeding, at noon, again at the regular afternoon feeding, and last thing in evening. Alternatively, the four-time-a-day feeding schedule can provide two feedings for milk and two feedings for oral electrolyte solution for calves with a fecal score of 3. Oral electrolyte solution (always mixed in water, not milk replacer) is fed until the diarrhea score returns to 1 or 0. As the fecal consistency improves, the 2-qt electrolyte solution feeding can be placed between the two milk feedings. Fresh warm water should be available to all calves but especially to diarrheic calves. Water is either fed at pleasure or within 20 to 30 minutes of a milk feeding so that calves drink before they leave the buckets to lie down.

The selection of a therapeutic antibiotic is based on the fecal culture results or its gram-negative bacterial spectrum [29,31]. Once started, an antibiotic protocol is not changed before the 3-day treatment is completed. The antibiotic recommendation may look like one of the three extralabel protocols shown next.

1. Tribissen (trimethoprim-sulfa tablets)

Dose: 20 mg/kg = 1 tablet (960-mg size) for a 100-lb calf twice daily.

Give two pills on the first dose.

Route: Oral, crushed and added to milk, crushed and dissolved in water–karo syrup combination, or bolus administered by balling gun used slowly and gently.

Frequency:

1. Calves <2 weeks: two times daily for 3 days

2. Calves 2–3 weeks: three times per day

2. Naxcel/excnel (Ceftiofur)

Dose: 5 mg/kg = 4.5 mL for a 100-lb calf. This dose is 2.5 times the dose for respiratory disease and is specific for *Salmonella*.

Route: In the muscle

Frequency: two times daily for 3 days

3. Nuflo (Florfenicol)

Dose: 20 mg/kg = 3 mL per 100 lb. Unlike the protocol for respiratory disease, calves with diarrhea receive a daily dose for 3 days.

Route: Subcutaneously

Frequency: One dose daily for 3 days

Treatment is successful if the calf is aggressively eating and has a bright attitude, even if the feces stay somewhat loose (score 1 or 2). It may take 5 to 7 days for return to normal intestinal function and fecal consistency.

## **Solving respiratory disease problems of calves and heifers**

Pneumonia is responsible for 21.3% and 50.4% of preweaned and weaned heifer deaths, respectively, at an estimated cost of almost \$15 per calf year [3,32]. Despite the importance of the disease, early detection is hampered by use of diagnostic criteria that are poor predictors of pneumonia in the preweaned calf age group. Delayed diagnosis results in prolonged use of antibiotics, a high recurrence rate, the development of refractory sequelae, such as pulmonary abscessation, ear infections, and endemic herd problems. Dairy calf and heifer pneumonia has serious economic consequences because subclinical, clinical, and chronic pneumonia of calves has a negative impact on growth, reproductive performance, milk production, and longevity [33–35]. Pneumonia is typically viewed as a postweaning problem of dairy heifers but preweaned calves are frequently affected [36,37] and are the source of pneumonia outbreaks in group pens. Early detection of pneumonia is a significant problem in dairy calves, however, because typical signs of illness, such as depressed appetite, dull attitude, or an infrequent cough, are not exhibited.

In investigating a dairy calf or heifer pneumonia problem, the review of records to determine morbidity and mortality data, seasonal patterns, health, management, housing, number of calves at maximum occupancy, nutrition, vaccinations, procedures, case definition, and treatment protocols is important. The site for disposal of liquid and solid feed refusals and pen management between successive calf occupants is also important. Calf housing, with the number of calf pens or hutches, barn and pen construction, layout and dimensions, type, amount and condition of the bedding, calf traffic patterns, and stocking density have an impact on respiratory disease that is described elsewhere in this issue. Weaning parameters, age of weaning, and routine health management procedures are additional data of importance. Tests for colostrum immunity, infectious disease testing, and laboratory or postmortem data are assembled and reviewed.

The true age of onset of respiratory disease and prevalence is determined on the day of the herd investigation using a respiratory disease screening tool [37,38] (<http://www.vetmed.wisc.edu/dms/fapm/fapmtools/calves.htm>). Individual calves in pens are examined and assigned a clinical score of 0 (normal), 1 (variation of or slightly abnormal), 2 (abnormal), and 3 (severely abnormal) for temperature, nasal discharge, cough and eye discharge, and ear position. Calves with a total respiratory score over 4 are considered to have respiratory disease based on bronchoalveolar fluid cytology and culture validation (McGuirk, unpublished data, 2007). All of the calves are scored if there are less than 20 calves. For larger groups, a representative sample up to 50 calves are screened by the scoring system to determine the earliest age of onset and barn, pens, or location of most of the affected calves. In group pens, respiratory disease evaluations are similar but based on the percentage of calves in the pen with abnormal ocular or nasal

discharge, abnormal ears, or coughing as shown in Table 5. With completion of the scoring examinations, a detection rate is calculated by dividing the number of calves currently on treatment for respiratory disease by the total number of calves with a total respiratory score greater than 4. As with enteric disease, the goal is detection of at least 85% of the calves that require treatment, but this goal is rarely met until the farm is trained to use the respiratory screening procedure. With digital thermometers that have a 15-second reading time, an individual examination can be completed in less than 2 minutes per calf. Calves are easiest to examine between milk feedings when they are resting. The nasal discharge, eye, and ear scores can be assigned without entering the calf pen. Spontaneous coughing can also be noted from outside the pen, giving the calf 3 points in that category and obviating the need to use tracheal compression for cough induction. Proactive use of the respiratory scoring system improves early detection, provides more reliable information on case rate, monitors for treatment efficacy, and determines which calves can move into the postweaning group pen.

Having identified the age of onset of respiratory disease through scoring, the youngest age group of affected calves is used for further diagnostic testing. If the goal of the investigation is simply to improve early detection and initiate a more effective treatment protocol, nasal swabs are obtained from six untreated calves with respiratory disease. From each calf, two deep nasal swabs are taken using flexible culturettes that contain a transport system for aerobic and anaerobic bacteria (BBL Culture Swab Plus, Benton Dickenson, Sparks, Maryland). One of the swabs is submitted for bacterial culture and the second is submitted for *Mycoplasma bovis* culture. From the nasal *Pasteurella multocida*, *Mannheimia haemolytica*, and *Histophilus somnus* isolates, the antibiotics to which all isolates are susceptible are used to predict

Table 5  
Respiratory disease evaluation in group pens on a dairy with pneumonia

Group pen: % with abnormal (score 2 or 3) scores (goal: 10% or fewer in any category)							
Group pen ID	Age range (wk)	Number of calves	% Nasal discharge	% Coughing	% Eyes	% Ears	Comments
21A	13–14	7	0	14.3	42.9	14.3	Respiratory disease
21B	11	5	20	0	0	20	Two calves
21C	11	5	0	20	0	0	Calf #4076
21D	11–12	7	0	14.3	28.6	57.1	Respiratory disease
21E	12	8	14.3	25	25	25	Respiratory disease
21F	12–13	8	25	0	37.5	0	Conjunctivitis
21G&H	14–16	17	6.3	25	25	12.5	Respiratory disease
22J	16–18	20	0	10	10	5	Watch this pen
22K	18–20	22	9.1	30	9.1	30	Respiratory disease
22L	23–25	21	19	9.5	9.5	9.5	Watch this pen
22M	20–23	20	15	35	35	20	Respiratory disease

the susceptibility of bacterial isolates from the lung [39]. If more than one of six calves cultures *M bovis* from the nose [40],  $\beta$ -lactam antibiotics are not recommended for the routine treatment protocol. From the nasal swab antibiotic susceptibility patterns shown in Table 6, ceftiofur, florfenicol, trimethoprim-sulfonamide combination, and tulathromycin are considered suitable for respiratory disease treatment if fewer than two of six calves cultures *M bovis* from the nasal swab. Prioritization of the antibiotic protocols is based on the farm, age of calves being treated, compliance, acceptance, and cost of the drugs.

Bronchoalveolar fluid collection from preweaned calves in a herd with respiratory disease is a relatively efficient way to confirm and characterize the type and severity of respiratory inflammation and provide fluid for bacterial culture. The bronchoalveolar fluid is collected from sedated calves using a sterilized, flexible 10  $\times$  36-in French catheter with a 3-mL balloon cuff (Mila International, Medical Instrumentation for Animals, Florence, Kentucky). Five to 10 minutes after administration of 0.1 mg/kg xylazine intramuscularly, the sedated calf is restrained and the nostrils are cleaned with a dry 4  $\times$  4-in gauze sponge. The head and neck of the calf are extended to facilitate passage of the sterile bronchoalveolar catheter by a person wearing surgical gloves. Before catheter introduction into the nostril, sterile saline is dripped into the catheter to lubricate the guidewire stylette. The bronchoalveolar catheter is introduced into the ventral meatus of the nose through which it is advanced until it encounters resistance in the caudal pharynx. At that point, the restrainer pushes the poll of the calf's head ventrally while simultaneously elevating the ventral mandible and the catheter is advanced down the trachea during the inspiratory phase of the respiratory cycle. Repeated coughing is induced with proper catheter placement and it is rapidly advanced until resistance is met as it wedges in a cranial lung lobe bronchus. A failure to induce spontaneous coughing subsequent to passage beyond the pharynx usually implies passage into the esophagus. In the wedged position, the catheter is held firmly in place while the guidewire stylette is removed. The balloon cuff is then inflated with 3 mL of air and

Table 6  
Nasal swab bacterial isolates and antibiotic susceptibilities

Antibiotic	<i>Pasteurella multocida</i>	<i>Mannheimia haemolytica</i>	<i>Histophilus somnus</i>
Amp/amoxicillin	Sensitive	Resistant	Resistant
Ceftiofur	Sensitive	Sensitive	Sensitive
Florfenicol	Sensitive	Sensitive	Sensitive
Spectinomycin	Sensitive	Sensitive	Incomplete
Tetracycline	Resistant	Resistant	Incomplete
Trimethoprim-sulfonamide	Sensitive	Sensitive	Sensitive
Tilmicosin	Sensitive	Sensitive	Sensitive
Tulathromycin	Sensitive	Sensitive	Sensitive

120 mL of sterile saline is infused using 60-mL syringes with a stopcock and catheter-tipped adapter attached. Immediately after the 120-mL infusion, negative pressure is applied to aspirate fluid, a process that usually yields 10 to 40 mL of clear to mildly turbid, foamy fluid. The returned fluid sample is placed into a sterile 4-oz specimen cup. A second 120-mL infusion is introduced and aspirated as described and the pooled fluid is sealed in the specimen cup and preserved in a cooler until it can be processed. The fresh bronchoalveolar fluid sample is processed within 2 hours of collection or refrigerated until it can be analyzed. A 5-mL aliquot of the pooled sample is used for bacterial and *Mycoplasma* cultures. The remaining fluid is submitted for cytologic interpretation, which is based on routine staining of cytospin and direct smear preparations. Bronchoalveolar fluid that yields homogenous ( $>10^6$  CFU/mL) bacterial or positive *M bovis* culture is considered abnormal. A disproportionate lowering of macrophages ( $<61\%$ ) or elevation of neutrophils ( $>39\%$ ) provides evidence of an inflammatory response with or without a positive culture (McGuirk, unpublished data, 2007).

The ability to troubleshoot respiratory problems in calves is hampered if the problem is not respiratory disease; the methods for and detection of the problem are neither sensitive nor specific; or the treatments use inappropriate drugs, routes of administration, dose administered, duration of therapy, or storage. The perceived problem of high morbidity or poor cure rates may be a problem of poor disease definition, inaccurate diagnosis, overwhelming exposure, unusual susceptibility, ineffective treatments, or a combination of these factors.

Respiratory disease management of calves and heifers is not complete without a thorough review of the vaccination protocols for the herd. With preweaned respiratory disease problems, the emphasis is placed on vaccination of the adult cows and an effective colostrum feeding program. As more and more is learned about the effectiveness of vaccinating calves for respiratory pathogens in the face of maternal immunity, vaccination of preweaned calves may become more common [41]. Where colostrum immunity is consistently good, most dairy heifers have the first modified live virus vaccines at 3 or 4 months of age. In the absence of adequate colostrum immunity, earlier vaccination schedules have been instituted and, at least for viral respiratory pathogens, are relatively safe.

Respiratory disease investigations present three opportunities to reduce endemic problems in calves and heifers. Regular implementation of a screening examination can find calves at an early age when treatment is extremely effective. Scoring calves after a 5- or 6-day treatment protocol can determine which calves are cured and which require additional treatment. Calves scored before moving into a group pen can result in fewer uncured pneumonia cases causing a respiratory disease outbreak in the weaning pen. Nasal swab results can guide the implementation of effective treatment protocols and bronchoalveolar fluid can more specifically characterize respiratory inflammatory changes. Finally, characterizing and resolving calf housing risk

factors for respiratory disease can reduce the exposure to aerosolized bacteria and lower the prevalence of respiratory disease.

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