Respiratory Disease of the Bovine Neonate

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Respiratory disease is a constant challenge for dairy replacement heifer rearing systems, and is responsible for 21.3\% of mortality in preweaned calves and 50.4\% of deaths in weaned heifers.\textsuperscript{1} There are many negative long-term consequences for survivors of subclinical, clinical, and chronic calf pneumonia including poor growth, reproductive performance, milk production, and longevity.\textsuperscript{2–4} These calves also become sources of infection for other calves, and can cause outbreaks after weaning in group pens.\textsuperscript{5} Contamination of the environment with bacterial and viral pathogens is the obvious source of respiratory disease in calves. When reviewing the literature and examining cases seen both in the authors’ hospital and during herd investigations, however, it was realized that treatment and prevention of calf pneumonia has evolved beyond recommendations for antibiotic therapy and vaccination protocols. The high cost of replacement heifers and the development of reproductive technologies have increased the need to detect and treat high-risk neonates suffering from respiratory disease. Many times those calves serve as sentinels for infectious disease that direct calf management decisions on the farm. This article discusses the normal physiologic changes from the uterine environment through parturition and methods to monitor the high-risk or abnormal neonate. Covered are causes of respiratory disease and different strategies for diagnosis and treatment that can be applied to herd investigations or individual animals. All herd investigation tools and forms can be found at the following Web site: http://www.vetmed.wisc.edu/dms/fapm/fapmtools/calves.htm.

THE POSTNATAL PERIOD, HYPOXIA, AND HYPERCAPNIA

Many physiologic changes occur rapidly in the transition from fetal life to the neonatal period. At parturition the neonate needs to assume responsibility for oxygenating its...
own blood from atmospheric air, and maintaining a normal blood pH and body temperature. In utero, the numerous placentomes that are distributed on the endometrial surface provide oxygen and nutrient-rich blood to the fetal placenta. Distribution of the oxygen and nutrients is accomplished by the fetal circulation shunting blood away from the pulmonary circulation by way of the ductus arteriosus and foramen ovale, which is facilitated by hypoxia-induced pulmonary arterial constriction. The fetus is quite hypoxic (80% O\textsubscript{2} saturation, Pa\textsubscript{O\textsubscript{2}} of 38 mm Hg) relative to the dam (98%–100% O\textsubscript{2} saturation, Pa\textsubscript{O\textsubscript{2}} of 100 mm Hg), but adapts well to this environment because of efficient O\textsubscript{2} extraction from maternal placental blood with fetal hemoglobin’s high affinity for O\textsubscript{2} and by increasing blood flow from nonessential organs to the brain, heart, and adrenal glands.

At birth massive changes in lung function and arterial blood gases occur as the fetal lung fluid is removed with uterine contractions and absorbed by the pulmonary circulation and lymphatics as the calf begins to breathe. Before stage 2 labor, the fetus should not be hypoxic as long as the umbilical cord remains attached, but during fetal expulsion, rupture of the fetal membranes and separation of the umbilical vessels lead to hypoxia and respiratory and metabolic acidosis. Respiratory acidosis (hypercapnia), detected by the chemosensitive area in the medulla, is the most important stimulus for respiration. This is aided by tactile stimulation from the dam (ie, licking) and a decrease in environmental temperature relative to in utero conditions. Hypoxia, detected by peripheral chemoreceptors in the carotid and aortic bodies, does not have a significant direct effect on the respiratory center in the brain. Dystocia can result in a severe respiratory and metabolic acidosis that may require treatment or can result in long-term detrimental effects on the neonate, such as hypoxic-ischemic encephalopathy. The degree of respiratory acidosis is dependent on the time between loss of maternal blood supply to the fetus and successful respiration. Metabolic acidosis is caused by lactic acid accumulation during hypoxia. Healthy calves have a surprising ability, however, to self-correct hypercapnia and hypoxia within the first hours of life. As respiration continues to increase pulmonary blood flow and improve oxygenation, the foramen ovale and ductus arteriosus close to end fetal circulation.

Several methods have been described to monitor acid-base status and pulmonary function, and predict morbidity and mortality caused by respiratory disease in the neonate. Sternal recumbency should be attained within 2 to 3 minutes and the normal calf should attempt to stand within 15 to 30 minutes after birth. Hypoxic neonates, likely to be affected by respiratory acidosis, have a weak to absent suckle reflex, have difficulty maintaining sternal recumbency, and require more time to stand. The Apgar scoring index can be used to assess neonatal viability and predict early signs of peripartum asphyxia. Perhaps more practical on the dairy, Schuijt and Taverne described the time to attain sternal recumbency as a measure of neonatal viability. They reported a negative correlation between neonatal vitality and increased time for the calf to achieve sternal recumbency after birth. Calves that took greater than 15 minutes to achieve sternal recumbency had an 84% predictive value for nonvitality. Other critical elements of the physical examination when assessing for the presence of respiratory disease include mucous membrane color (vulvar mucous membranes); character and frequency of the respiratory effort; and thoracic auscultation.

If available, pulse oximetry and blood gas analysis can be valuable to assess pulmonary function and acid-base status. Pulse oximetry was validated in the calf as a relatively accurate, noninvasive, immediate, and portable method to monitor oxygen saturation (Sa\textsubscript{O\textsubscript{2}}). Bleul and Kähl describe using pulse oximetry during stage 2
labor to assess pulmonary function in valuable calves during delivery, because fetal reflexes are poorly correlated with fetal vitality in cattle. Despite the challenge of using the oximeter during parturition, calves with low SaO2 (<30%) for at least 2 minutes in stage 2 labor had a high predictive value for acidosis (blood pH <7.2). In a hospital setting, blood gas analysis is a direct measure of PO2, PCO2, concentration of bicarbonate (HCO3−), base excess, SaO2, and pH. Reference values for acidotic calves (pH <7.2) and normal calves (pH ≥ 7.2) were recently reported (Table 1). Evaluating pH and base excess values from venous blood are established methods; however PO2 and PCO2 need to be measured from arterial blood because of the CO2 and O2 exchange in peripheral tissues. There is no significant difference between using arterial blood from peripheral versus central arteries and the brachial, lateral metatarsal, or the branches of the caudal auricular artery are suitable collection sites. Plastic has replaced glass syringes in many settings because of cost, convenience, and resistance to breakage. It is important to note, however, that blood in plastic syringes needs to be analyzed immediately to ensure accuracy of the PO2 measurement.

Treatment of hypoxia and hypercapnia can be a challenge. Calves with significant hypoxia can be started on humidified oxygen by nasal administration at a rate of 2 to 10 L/min. Hypercapnia may persist despite oxygen therapy. The ventilatory drive caused by hypercapnia and associated respiratory acidosis is significantly stronger than the drive caused by hypoxemia. These calves might require treatment with respiratory stimulants, such as the methylxanthines (caffeine and aminophylline) or doxapram hydrochloride. Both of these drugs decrease the need for mechanical ventilation. Methylxanthines directly stimulate the respiratory center, improve diaphragmatic contractility, and antagonize adenosine, which slows respiration. Caffeine (NoDoz, 200 mg/tab) is readily available as an over-the-counter product but its oral bioavailability has been recently questioned in foals. Extrapolated from equine doses, caffeine can be administered orally or per rectum with a 10 mg/kg loading dose followed by a 2.5 to 3 mg/kg every 24 hour maintenance dose. When using aminophylline in the authors’ hospital the doses reported for horses are used (4–10 mg/kg every 8–12 hours) as a constant rate infusion (10–30 mg/kg/d). Doxapram hydrochloride stimulates the medullary respiratory centers by way of the aortic and carotid body chemoreceptors and can be given at a dose of 0.5 mg/kg IV or 5 to 10 mg/kg injected at the base of the tongue for emergency resuscitation and anoxia. Doxapram has a history of poor availability to practitioners and has been reported to increase cerebral oxygen consumption and decrease cerebral blood flow, which has negative long-term consequences for the neonate. A study in foals using an experimentally induced hypercapnia model, however, reported that doxapram restored ventilation without neurologic side effects in a dose-dependent manner. Acupressure is an alternative therapy for anoxia that has occasionally been used in small and large animal neonatology. In calves, the authors use a 20-gauge, 1-in hypodermic needle placed in the nasal planum immediately after parturition if the calf is anoxic. The mechanism behind this technique is stimulation of the Renzhong acupoint, which increases phrenic nerve activity. Ideally, serial blood gas analysis should be done to monitor the calf’s response to whichever therapies are implemented. Calves with persistent hypercapnia despite therapeutic intervention are candidates for mechanical ventilation if available.

**PERSISTENT PULMONARY HYPERTENSION**

Persistent pulmonary hypertension is a syndrome characterized by significant cellular proliferation and extracellular matrix protein production in pulmonary endothelial cells.
### Table 1
Mean (SD) values of arterial and venous blood gas and acid-base analyses in 57 newborn calves from birth to 24 hours

<table>
<thead>
<tr>
<th>Variable</th>
<th>Blood</th>
<th>At Birth</th>
<th>30 Minutes</th>
<th>4 hours</th>
<th>12 Hours</th>
<th>24 Hours</th>
<th>( P^a )</th>
<th>( P^b )</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>Arterial</td>
<td>7.30 (0.06)</td>
<td>7.36 (0.04)</td>
<td>7.38 (0.03)</td>
<td>7.42 (0.03)</td>
<td>7.43 (0.04)</td>
<td>&lt;0.001</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Venous</td>
<td>7.24 (0.09)</td>
<td>7.30 (0.04)</td>
<td>7.33 (0.03)</td>
<td>7.38 (0.04)</td>
<td>7.40 (0.06)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>( P_{CO_2} ) (mm Hg)</td>
<td>Arterial</td>
<td>57.31 (4.98)</td>
<td>52.58 (5.00)</td>
<td>48.70 (3.73)</td>
<td>43.71 (4.75)</td>
<td>44.22 (4.32)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Venous</td>
<td>67.34 (10.39)</td>
<td>58.23 (6.45)</td>
<td>54.38 (6.10)</td>
<td>47.03 (5.75)</td>
<td>46.67 (6.24)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>( P_{O_2} ) (mm Hg)</td>
<td>Arterial</td>
<td>45.31 (16.02)</td>
<td>58.08 (13.12)</td>
<td>67.66 (14.55)</td>
<td>71.89 (8.32)</td>
<td>66.77 (14.21)</td>
<td>&lt;0.001</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>Venous</td>
<td>20.94 (5.30)</td>
<td>27.95 (5.42)</td>
<td>29.15 (4.41)</td>
<td>29.33 (5.52)</td>
<td>27.62 (3.04)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>( HCO_3^- ) (mmol/l)</td>
<td>Arterial</td>
<td>26.76 (3.39)</td>
<td>28.01 (2.44)</td>
<td>27.40 (2.32)</td>
<td>26.96 (2.94)</td>
<td>28.31 (3.26)</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Venous</td>
<td>27.24 (3.70)</td>
<td>27.48 (3.81)</td>
<td>27.42 (3.18)</td>
<td>26.42 (2.82)</td>
<td>27.87 (3.35)</td>
<td>&gt;0.05</td>
<td></td>
</tr>
<tr>
<td>Base excess (mmol/L)</td>
<td>Arterial</td>
<td>0.86 (4.12)</td>
<td>2.9 (2.88)</td>
<td>2.52 (2.64)</td>
<td>2.78 (3.23)</td>
<td>4.42 (3.59)</td>
<td>&gt;0.05</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Venous</td>
<td>1.01 (3.49)</td>
<td>1.53 (4.37)</td>
<td>1.89 (3.48)</td>
<td>1.59 (3.08)</td>
<td>3.40 (3.92)</td>
<td>&gt;0.05</td>
<td></td>
</tr>
<tr>
<td>( S_O_2 ) (%)</td>
<td>Arterial</td>
<td>64.16 (20.82)</td>
<td>82.08 (9.98)</td>
<td>89.23 (6.84)</td>
<td>92.84 (2.32)</td>
<td>89.75 (8.31)</td>
<td>&lt;0.001</td>
<td>&gt;0.05</td>
</tr>
<tr>
<td></td>
<td>Venous</td>
<td>22.64 (10.00)</td>
<td>39.26 (10.98)</td>
<td>44.19 (9.39)</td>
<td>47.41 (12.06)</td>
<td>47.81 (15.41)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

**Abbreviations:** \( HCO_3^- \), bicarbonate; \( P_{CO_2} \), partial pressure of carbon dioxide; \( P_{O_2} \), partial pressure of oxygen; \( S_O_2 \), oxygen saturation.

\( a \) Analysis of variance for repeated measures within groups.

\( b \) Analysis of variance for repeated measures between groups.

It occurs in response to persistent hypoxemia and vasoconstriction, which causes reversion to fetal pulmonary circulatory patterns with right-to-left shunting. Pulmonary hypertension can also be secondary to failure of the neonate’s cardiopulmonary circulation to transition from the fetal state. The disorder has been recognized in human and equine neonates, and the calf is used as a model to study pulmonary hypertension. Pulmonary hypertension can be secondary to many different factors, such as persistent hypoxia caused by pneumonia, high altitude, or meconium aspiration, but the primary disorder is often idiopathic. Recently, persistent pulmonary hypertension has been increasingly recognized in calves derived from somatic cell clone technology.

Calves with persistent pulmonary hypertension are hypoxic (PaO$_2$ <80 mm Hg) and tend to be hypercapnic. Diagnosis can be based on repeated arterial blood gas measurements when all other causes of hypoxemia are ruled out. Other diagnostic tests for persistent pulmonary hypertension include radiographs or CT, cardiac catheterization, and echocardiography. Radiographs and CT show atelectasis and diminished vascular patterns from pulmonary hypoperfusion. Cardiac catheterization shows elevated pressure in the pulmonary artery, right ventricle, and right atrium.

Treatment of persistent pulmonary hypertension centers on oxygen supplementation and mechanical ventilation if hypoxemia and hypercapnia persist. If acidosis is severe, bicarbonate therapy may be indicated. Nitric oxide is frequently used in human and equine neonates as a vasodilator. Vasodilation with a phosphodiesterase-5 inhibitor, sildenafil (Viagra) given orally or as a suppository, has been used to treat persistent pulmonary hypertension in human infants and foals with varying success.

**ASPIRATION PNEUMONIA**

Aspiration pneumonia occurs when solid materials, typically a liquid or meconium, are inhaled. The most common cause of neonatal aspiration pneumonia seen in the authors’ practice is from misuse of oral esophageal feeders. The use of oral esophageal feeders to “tube-feed” a calf has increased on farms to ensure timely feeding of an appropriate volume of clean, good-quality colostrum. Feeding calves with bottles can be time consuming and calves left to suckle the dam have high rates of failure of passive transfer. Even though the esophageal groove does not close when using esophageal feeders, there is no significant difference in calf serum IgG concentrations or morbidity when compared with calves that suckle colostrum from a bottle. Proper training of on-farm personnel is important to ensure placement of the feeder in the esophagus. Important points to review with personnel responsible for calf feeding are to use lubrication, to use an oral esophageal feeder that has a mechanism to control flow rates in case problems occur, and to maintain the calf’s neutral head position during feeding while the calf is standing or in sternal recumbency.

Another cause of aspiration pneumonia, meconium aspiration, is associated with fetal distress syndrome and frequently results in increased mortality. Gross and histopathologic lesions are similar to those described in human infants with meconium aspiration syndrome and consist of acute and long-term sequelae. In the acute phase of the syndrome, complete and partial airway obstruction leads to hyperinflated pulmonary tissue, ventilation-perfusion mismatch, pulmonary hypertension, and increased risk for pneumothorax. Chronic effects of meconium aspiration include chemical pneumonitis and disruption of surfactant function, which has been proposed to be a significant contributor to meconium aspiration syndrome.

With large quantities of aspirated foreign material the calf may die acutely. Generally, the aspiration causes a gangrenous bronchopneumonia and animals display
the typical clinical signs of depression, respiratory distress, fever, and malodorous breath. Auscultation of the lung fields bilaterally may reveal crackles, wheezes, and pleural friction rubs. The calf may be hypoxic and hypercapnic on arterial blood gas analysis. History and clinical signs aid in diagnosis; however, hematology, radiographs, and pleural ultrasound examination are required to define better the extent of disease. Treatment almost always involves long-term antimicrobial and anti-inflammatory therapy.

**BACTERIAL PNEUMONIA**

Bacterial pneumonia in the first few days of life can be from sepsis, aspiration pneumonia, or gross bacterial contamination of colostrum. Most septic calves with pulmonary disease present depressed and lethargic. The physical examination, specifically thoracic auscultation, is not always consistent with pulmonary disease. The authors have found that inducing a cough by firmly shaking the trachea at the level of the larynx is helpful in confirming the diagnosis of pulmonary disease. Definitive diagnosis requires radiographs, transtracheal wash, or bronchial alveolar lavage. The authors have implemented bronchial alveolar lavage in the clinic and on-farm as an efficient way to get diagnostic samples representative of lower airway fluid for culture (Sheila M. McGuirk, DVM, PhD, unpublished data, 2007).

The bronchial alveolar lavage procedure is described next. Calves are sedated with xylazine (0.1 mg/kg IM) and the head is restrained by pushing the poll down while elevating the nose to ease placement of a flexible 10-French catheter with a 3-mL balloon cuff (Mila International, Medical Instrumentation for Animals, Florence, Kentucky) into the trachea by way of the nares (Fig. 1). Repeated coughing is observed with proper placement of the catheter. The catheter is passed until it is wedged in a terminal bronchus and the balloon is inflated to create a seal to allow alveolar fluid to be aspirated. This is an example of an on-farm bronchial alveolar lavage procedure. A flexible 10F catheter has been inserted into the trachea by the nares and advanced until it is wedged in a terminal bronchus. See text for further details on the procedure.
lavage. A total of 240 mL of 0.9% NaCl is lavaged (two separate 120-mL samples). Following administration, as much saline as possible is then aspirated back through the catheter. An appropriate sample volume is 10 to 40 mL of clear to mildly turbid, foamy fluid. The samples from both lavages are mixed and should be refrigerated or analyzed fresh within 2 hours. Five milliliters of sample should be submitted for aerobic and Mycoplasma cultures. The remaining fluid should be submitted for cytologic interpretation from cytospin and direct smear. Bronchial alveolar lavage fluid that yields homogenous (>10^6 CFU/mL) bacterial or positive Mycoplasma bovis culture is considered abnormal. A disproportionate decrease in the percentage of macrophages (<75%) or an elevation in neutrophils (>25%) provides evidence of an inflammatory response with or without a positive culture. Using this technique it is possible to sample six to eight calves in a 2-hour period. Identifying which calves are good candidates for bronchial alveolar lavage during an on-farm herd investigation can be challenging. The authors have developed a respiratory disease screening tool (Fig. 2) to identify these calves for diagnostic testing and treatment that can be used by veterinarians and farm personnel. This tool can be found at http://www.vetmed.wisc.edu/dms/fapm/fapmtools/calves.htm.

Because the topic of interest is the calf, it is important to note that sepsis and bacteremia can cause interstitial pneumonia. Blood culture is important for diagnosis in these cases and fecal coliforms, most notably Escherichia coli, are the most commonly isolated bacteria from bacteremic calves. Recently, Salmonella dublin has become increasingly more prevalent in septic calves admitted to the authors’ hospital. S dublin is shed in colostrum and milk, and is associated with severe interstitial pneumonia along with fever, depression, and gastrointestinal disease. Antemortem diagnostics submitted in the authors’ hospital when S dublin is suspected include blood culture, fecal culture, and bronchial alveolar lavage. It is important to send Salmonella isolates for speciation. Postmortem samples should also include culture of liver, lung, and spleen.

Treatment is often initiated at the farm with one or more broad-spectrum antibiotics. Antibiotic therapy can be tailored to culture and sensitivity results, and in the authors’ opinion should be continued for a minimum of 6 days (Table 2). For herd investigations, nasal swabs can be used to screen for Mycoplasma sp and to guide antibiotic therapy. To accomplish this, six untreated calves are sampled with two deep nasal swabs with flexible culturettes that contain transport media for aerobic and anaerobic bacteria (BBL Culture Swab Plus, Benton Dickenson, Sparks, Maryland). One swab is used for bacterial culture and the other is submitted for Mycoplasma sp culture. Clinical response to therapy or complete blood cell analysis with fibrinogen can be used in the decision to extend antibiotic therapy. Depending on severity of clinical signs, supportive care with anti-inflammatory drugs, nutritional support, and nasal administration of oxygen may be indicated.

Prevention of bacterial sepsis and associated pneumonia centers on providing the calf with appropriate amounts of maternal antibodies for passive transfer by maternal colostrum. Herds that have problems with gross bacterial contamination of colostrum or those that are trying to decrease the prevalence of pathogens present in maternal colostrum including Mycobacterium paratuberculosis, S dublin, and bovine leukemia virus should use a colostrum replacement product that provides the calf with a minimum of 175 g of immunoglobulin. Prompt removal of the calf from the maternity pen is perhaps equally important in preventing exposure of the animal to a highly contaminated environment. The early environment poses a high risk for pathogen exposure to the calf trying to stand and frequently crashing head first into the maternity pen pack. In addition, calves attempting to nurse frequently suckle other
Fig. 2. (A) Calf respiratory scoring chart developed to identify calves for diagnostic treatment and treatment. Calves are assessed based on four categories: rectal temperature, nasal discharge, cough, and eye or ear. Scores from each category are combined to come up with a total respiratory score. (B) Calf health scoring criteria for the scoring chart pictured in (A).
Table 2
Antibiotics commonly used to treat respiratory disease in dairy replacement heifers

<table>
<thead>
<tr>
<th>Drug</th>
<th>Antibiotic Class</th>
<th>Trade Name</th>
<th>Dosage</th>
<th>Dose for 45-kg (100-lb) Calf</th>
<th>Route</th>
<th>Frequency</th>
<th>Label for Mycoplasma?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trimethoprim-sulfa</td>
<td>Sulfonamides</td>
<td>Tribrissen</td>
<td>20 mg/kg, 40 mg/kg</td>
<td>(960 mg tablet)</td>
<td>Oral</td>
<td>1. Calves &lt;2 wk: BID for 6 d 2. Calves 2–3 wk: TID for 6 d</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>loading dose</td>
<td>1 tablet, 2 tablet loading dose</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceftiofur</td>
<td>β-lactams</td>
<td>Naxcel</td>
<td>2.2 mg/kg</td>
<td>2 mL</td>
<td>IM, SQ, or IV</td>
<td>SID</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Excenel</td>
<td>2.2 mg/kg</td>
<td>2 mL</td>
<td>IM or SQ</td>
<td>SID</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exceed</td>
<td>6 mg/kg</td>
<td>1.5 mL</td>
<td>SQ at the base of the ear</td>
<td>Once</td>
<td>No</td>
</tr>
<tr>
<td>Florfenicol</td>
<td>Florfenicols</td>
<td>Nuflor</td>
<td>20 mg/kg</td>
<td>3 mL</td>
<td>IM in the neck</td>
<td>Q 48 h, 3 doses</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>40 mg/kg</td>
<td>6 mL</td>
<td>SQ in the neck</td>
<td>Once</td>
<td>No</td>
</tr>
<tr>
<td>Tilmicosin</td>
<td>Macrolides</td>
<td>Micotil</td>
<td>10 mg/kg</td>
<td>1.5 mL</td>
<td>SQ in the neck</td>
<td>Q 48 h, 3 doses</td>
<td>No</td>
</tr>
<tr>
<td>Tulathromycin</td>
<td>Macrolides</td>
<td>Draxxin</td>
<td>2.5 mg/kg</td>
<td>1.1 mL</td>
<td>SQ in the neck</td>
<td>Once</td>
<td>Yes</td>
</tr>
<tr>
<td>Enrofloxacin</td>
<td>Fluoroquinolones</td>
<td>Baytril 100</td>
<td>7.5–12.5 mg/kg</td>
<td>3.5–5.5 mL</td>
<td>SQ</td>
<td>Once</td>
<td>No&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5–5 mg/kg</td>
<td>1.5–2 mL</td>
<td>SQ</td>
<td>SID for 6 d</td>
<td>No&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Labeled for treatment of bovine respiratory disease in dairy replacement heifers less than 20 months of age. Off-label use of fluoroquinolones is strictly prohibited. In mixed respiratory infections, *Mycoplasma bovis* has been shown to be susceptible to enrofloxacin. 124,125
prepartum cows and make erratic nursing attempts on potentially heavily contaminated areas (tail, hock, brisket). These normal behaviors in the maternity pen put calves at risk of massive oral contamination and possible colonization of the gastrointestinal tract. This along with an exposed umbilicus and high concentration of aerosolized bacteria are potential causes of sepsis.

The calf’s environment after the maternity pen is another source of bacterial pathogens that can cause respiratory disease. Calf raisers continue to build naturally ventilated barns to be more efficient and provide a more hospitable environment for labor despite the long-standing recommendations that individual hutches are the ideal environment to raise preweaned replacement heifers. Lago and colleagues reported that these naturally ventilated calf barns frequently have poor air quality and despite ventilation, calf stalls may continue to have high aerosolized bacterial counts. Their recommendations for calf stalls are that there should be a minimum area of $3 \text{ m}^2$ or more per calf, solid panels on two sides to provide a physical barrier between calves, mesh panels in the front and rear to allow air flow, and deep loose bedding in colder temperatures. A more thorough review of calf barn design can be found in a previous edition of this publication.

**VIRAL PNEUMONIA**

The most commonly identified causes of viral pneumonia in calves during the first few weeks of life are bovine herpes virus type 1 or infectious bovine rhinotracheitis and bovine respiratory syncytial virus. Parainfluenza-3 and bovine viral diarrhea virus are also capable of infecting the respiratory tract and predisposing calves to bacterial pneumonia. Prevention of viral pneumonia, as with bacterial pneumonia, centers on passive transfer of maternal antibodies and the innate immune response. As maternal antibody levels decline, active immunity and vaccination become mainstays of prevention for both viral and bacterial pneumonia. Vaccination recommendations for calves have been reviewed recently by Chase and colleagues, and in the article by Cortese elsewhere in this issue. Treatment for viral pneumonia is primarily supportive and includes metaphylactic or prophylactic antibiotic therapy.

**TRAUMATIC INJURY, PNEUMOTHORAX, AND ANAPHYLAXIS**

Traumatic injury to the lung has declined over the years because fewer animals have horns. Fractures are possible in calves if they are stepped on in the maternity pen or may occur following dystocia. Rib fractures are diagnosed during physical examination and confirmed with radiographs. Treatment is usually not required unless complications, such as myocardial injury, hemothorax, or pneumothorax, occur.

Pneumothorax of clinical significance is rare in cattle and little information exists in the literature. Most reports are of adult cattle with rupture of emphysematous bullae associated with straining, coughing, or parturition. Pneumothorax has been reported in a preweaned calf as a result of bovine respiratory syncytial virus and in neonates that have undergone mechanical ventilation, both of which may lead to bullae formation and rupture. In a retrospective study of 30 animals, 2 of the cases were neonates. Traumatic injury was not identified in those cases but blunt thoracic trauma could not be definitively ruled out. The authors suggested idiopathic pneumothorax secondary to rupture of subpleural blebs or cysts as possible causes. Mecocnium aspiration leading to pneumothorax has been reported to be a significant risk in human infants. Slack and colleagues described pneumothorax and pneumomediastinum in a calf born by caesarian section with substantial meconium staining. The calf was resuscitated with mechanical ventilation, however, so both of these
could have been contributory. Calves with pneumothorax frequently have dyspnea, tachypnea, and absent lung sounds in the dorsal lung field. Cattle have a complete mediastinum, and pneumothorax may be limited to one hemithorax depending on the inciting cause. Treatment of pneumothorax involves therapy for the primary disease together with evacuation of air from the pleural space. In the field, suction of air can be done with a teat cannula or an 18-gauge 3.5-in (51-mm) catheter, a three-way valve, and a syringe. This procedure may need to be repeated as dictated by the clinical signs of the calf. Severe, persistent pneumothorax may require hospitalization and continuous suction with a device as described by Peek and colleagues.117

Dyspnea and tachypnea from pulmonary edema or laryngeal edema can occur with anaphylactic reactions in calves induced by exogenous antigens. Anaphylactic reactions are type 1 hypersensitivity reactions mediated by IgE. Antibiotic therapy with penicillin G, sulfonamides, tetracyclines, epidural analgesia with lidocaine or Carbocaine, and vitamin E and selenium injection have been associated with anaphylactic reactions in cattle.115 Plasma and other blood products have the potential for anaphylaxis and animals receiving transfusions need to be monitored closely. Treatment is dependent on severity of clinical signs and can include epinephrine (0.01 mg/kg); corticosteroids (dexamethasone, 0.1–0.2 mg/kg); antihistamines (tripelennamine hydrochloride, 1 mg/kg IM or SQ); furosemide (0.05–1 mg/kg IM or IV), nonsteroidal anti-inflammatory drugs (flunixin meglumine, 1.1 mg/kg IM or IV); and nasal administration of oxygen.115,117

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