Aspiration lung disorders in bovines: A case report and review

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Lung aspiration disorders in bovines are invariably diagnosed as infectious aspiration pneumonias. There is a distinct differentiation between aspiration pneumonia and aspiration pneumonitis in humans that can be applied to bovines. The nature and quantity of the aspirate can result in differing pathogeneses which can require differing therapeutic approaches. Whilst blood gases were important in detecting and prognosticating lung problems, changes in barometric pressure with altitude have to be considered when interpreting partial pressures of oxygen. Anatomical differences in the lungs of bovines can explain why this species is more prone to certain pneumonic problems. Pulmonary physiotherapy is important in treating lung disorders in humans and should be considered as an adjunct therapy in bovine respiratory conditions. A case work-up was used to highlight some of the points discussed in this article.

Introduction

Pulmonary aspiration in bovines is the inhalation of secretions, forestomach contents or foreign material into the larynx and the lower respiratory tract. The presence of abnormal substances in the airways and alveoli as a result of inhalation is usually referred to as aspiration pneumonia. Injury to the lung will depend, however, on the amount and nature of the aspirate, the frequency of aspiration, the distribution within the respiratory tract and the host's response to the aspirated material (Marik 2001). The resultant pulmonary disorder could be mechanical, chemical, infectious and/or a varying combinations of the three. Aspiration of foreign substances into the lung may, or may not, involve bacterial infection.

Several different pulmonary syndromes may therefore occur and each disorder can vary in pathophysiology, giving rise to differing clinical features and possibly necessitating a more specific therapeutic and managemental approach.

Although pneumonitis is a general term that refers to inflammation of lung tissue, aspiration pneumonitis in humans is usually reserved for describing the acute lung injury after inhalation of regurgitated gastric contents (Marik 2001). Aspiration pneumonia, however, is infectious in nature and is associated with an acute pulmonary response as a result of material that is colonised by pathogenic bacteria (Marik 2001).

Case report

Presentation

A valuable, 37.5 kg, 18-day-old Pinzyl bull calf was presented with breathing difficulty and a reluctance to suckle milk (Figure 1).

History

The calf had been bottle-fed since birth because the dam had no milk. Colostrum from a herd mate was fed within 12 hours of birth. The day prior to presentation the calf suddenly appeared to have difficulty in breathing and did not finish the milk offered. A sulphonamide injection was administered by the owner.

Clinical evaluation

The animal, although depressed, was in good body condition indicating that the problem was acute. There was respiratory distress with a severe tachypnoea (138 bpm) with a distinct abdominal component. Prominent and loud wheezes could be auscultated over the entire right-lung-area. The rectal temperature was 41.0 °C, the heart rate 150 bpm and the mucous membranes were congested. The calf had a slightly arched back and the abdomen was devoid of contents. There was a mild omphalitis that was draining a small amount of pus. Faeces and urine were normal. Blood was drawn for analysis and radiography was requested.

Haematology

The prominent abnormality found was a dramatic increase in the total white-cell count of 22.74×10^9 / L (*N* is 4.0–10.0) because of elevated mature neutrophils of 17.51×10^9/L (*N* is 0.6–4.0), and a moderate increase in immature neutrophils of 0.68×10^9 / L (*N* is 0.00–0.12). This indicated a severe regenerative left shift in response to an inflammatory condition of a few days' duration, mostly as a consequence of the omphalitis and possibly potentiated by the lung problem. Globulin values indicated that failure of passive transfer was not a problem.

Blood gas

The patient was severely distressed and was experiencing breathing difficulties; therefore a venous blood sample was taken. The blood venous pH was 7.3. Respiratory acidosis was evident as the partial pressure of venous carbon dioxide ($PvCO_2$) was 55.8 mmHg ($N = 45 \pm 3$). The partial pressure of venous oxygen (PvO_2) was 25.4 mmHg, which is low even for a venous sample (Martin 1999). Both venous gas results were abnormal; it can be concluded, therefore, that perfusion was probably poor because of dehydration, cardiac output dysfunction and/or lung pathology. Dehydration and lung pathology were probably the primary problems but this could only be ratified by arterial results. The base excess was raised at 8.0 mmol/L ($N = 0 \pm 3$) with a standard bicarbonate of 30.1 mmol/L (*N* is 24–27), indicating that the calf had a compensating respiratory acidosis. There was also a very mild hyperkalaemia and a very slight hyponatraemia, both of which were of no clinical significance.

The calf was hyperventilating, and that increases the partial pressure of alveolar oxygen (PAO_2) and decreases the partial pressure of arterial carbon dioxide ($PaCO_2$), and helps to restore the normal partial pressure of arterial oxygen (PaO_2).

FIGURE 1: Nebulisation and percussion of the Pinzyl calf.

Radiography

The calf was too dyspnoeic to position in dorsal and ventral recumbency and consequently only lateral views were taken. There was almost complete opacity of the right-middle-lung lobe with a severe alveolar pattern and distinct air bronchograms. The cranial aspect of the right-caudal-lung lobe showed similar but less severe signs.

Diagnosis

A provisional diagnosis of aspiration pneumonia was made based on the severe leukocytosis, fever, respiratory signs, blood gas values and radiological evidence.

Treatment

Immediately on admission, oxytetracyclines, being the drug of choice for heartwater, were administered, because the calf was from a heartwater area and its mother had recently been introduced to the farm. The antibiotic, in being bacteriostatic, was not ideal because the drug relies on the host to kill the invading pathogens and the immune status of a calf of this age is probably at its lowest. Despite the early diagnosis it was decided to continue with the oxytetracyclines twice per day (b.i.d.) for a few days to try and prevent selection of resistant strains of bacteria with continuous swopping of antimicrobial drugs. Short-acting corticoteroids were also started as this drug is used for the treatment of heartwater (Shakespeare 1997), limits the over-exuberant inflammatory response in 'shipping fever', and also because its euphoric effect would help to stimulate appetite. The initial response to treatment was poor, so the antibiotic was replaced with danofloxacin for another 5 days.

Although radiographs 3 days later revealed an improvement of aeration of the affected lung lobes with slight resolution of the alveolar pattern, the animal's temperature and clinical signs waxed and waned according to the use, or not, of steroids. The antibiotics were changed to florphenicol every other day and physiotherapy was started. This consisted of percussion and vibration. Nebulisation, using sterile water with bisolvon linctus as a mucolytic, was carried out at the same time as percussion (Simasek & Blandino 2007). A few days later ceftiofer and amikacin were included in the sterile water used for nebulisation, with the first-mentioned drug administered in the morning and the second in the evening for another 3 weeks (Figure 1). The nebulisation combined with the percussion and vibration, stimulated paroxysmal bouts of productive coughing from the calf. Nebulisation helps to deliver micro-droplets with or without additives as deep into the pulmonary tree as possible to have a more direct and local effect on the pathological lesions, as well as to increase the concentrations of delivery of the additives to the area involved.

The calf progressively improved and was discharged 5 weeks after presentation weighing 56 kg, an 18 kg or equivalent of 50% weight gain. The right-medial-lung lobe still displayed some consolidation with faint bronchograms but this was probably a result of permanent fibrosis in that area.

Trans-tracheal washes and needle aspiration of the lungs were considered, but because antibiotic therapy had been given before presentation, isolation of infective organisms was considered unlikely and the stress associated with such procedures was considered to be detrimental to the calf at that time.

Ten months later the calf was reported to be doing well and had gained weight to such an extent that there was very little difference in size between the patient and other calves of a similar age.

Ethical considerations

This is a case that was treated in the same way as any other sick animal admitted to the veterinary hospital, with the necessary consideration for the animal's welfare.

Discussion

The bovine lung, although similar in many respects to other domestic species, has differences that can explain different respiratory presentations in this species.

The above case was diagnosed as aspiration pneumonia, but aspiration pneumonitis as defined in human medicine, should also have been considered. Factors pertinent to this case that may help to differentiate between the two conditions will be discussed.

Bovine lung anatomy and physiology

The bovine lung is situated within the thoracic cavity so that the dorsal border slopes at a dorsocaudal oblique angle (Pierson & Kainer 1980). When the animal stands, the trachea slopes down from the larynx into the thoracic inlet, then remains level to the main bifurcation, from which the primary bronchi slope upwards and backwards (dorsocaudally) towards the caudal lung lobes. Any exudate in the lungs will therefore gravitate into the ventral area.

The bronchus for the right-cranial-lung lobe emerges directly from the right side of the trachea some distance from the tracheal bifurcation. This results in the common assumption that the right-cranial-lung lobe is most susceptible to damage from any inhaled aspirate. The opening, however, is significantly smaller than the trachea, is situated midway up the tracheal circumference and is recessed in such a manner that any fluid flowing down the trachea will bypass the opening unless large volumes are involved (Figure 2). If abnormal, viscous material is present close to the opening, then infective micro-droplets could be drawn into the right-cranial-lung lobe.

The bovine lung has the smallest relative lung volume in domestic species (Gallivan, McDonell & Forrest 1989). It is about 0.7% of the body weight and the right lung is almost twice the size of the left (Gallivan *et al.* 1989). Because the cow is a foregut fermenter with about 70% of the gut contents in the cranial abdomen, the diaphragm is almost vertical and fairly flat, which results in the bovine lung lying cranial to the abdomen. Monogastric hindgut fermenters generally have about 70% of their gut content in the caecum and colon and the conically shaped diaphragm enables a large portion of the lung to be dorsal to the abdomen (Gallivan *et al.* 1989). The large and heavy bulk of the rumen immediately caudal to the diaphragm dramatically limits diaphragmatic movement so that shallower and faster respiration is more efficient for cows (Gallivan *et al.* 1989). Decreased lung compliance will also increase frequency and will decrease tidal volume to minimise the effort of breathing. The total lung capacity in bovines is ± 85 mL/kg with an average respiratory rate of 28 breaths per minute (Gallivan *et al.* 1989). The relatively smaller lung volume implies less contact area for oxygen exchange and therefore, to extract sufficient oxygen (O_2), the minute-volume needs to be increased for a faster turnover of air. Comparatively, bovines have a large minute-volume of ± 218 mL/kg per minute, mainly because of a faster respiratory rate (Gallivan *et al.* 1989). Likewise, to maintain adequate oxygen delivery, the blood flow rate through the lungs must be relatively faster which implies a faster normal heart rate. This faster turnover of air will restrict the effectiveness of collateral circulation within the lungs as less time is available for diversion and recirculation of air and this may account for the lack of collateral circulation via the channels of Lambert and Martin and the pores of Kohn in ruminants (Rhodes 2005).

Species with collateral ventilation can counter ventilation-perfusion mismatching incurred by regional hypoxia by moving normoxic air via these channels into hypoxic

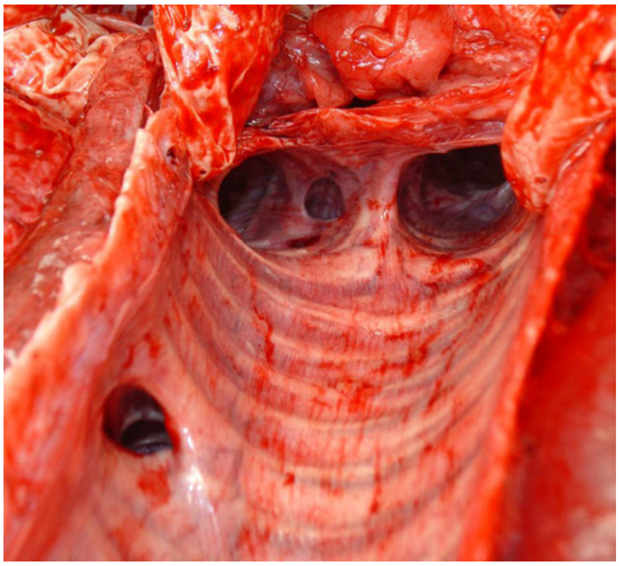

FIGURE 2: Bifurcation of the trachea illustrating the recessed bronchus to the right-cranial-lung lobe.

regions. Cattle, which lack collateral channels, rely mostly on altering perfusion via pulmonary vasoconstriction to adjust ventilation-perfusion mismatches in response to regional hypoxia. However, at high altitudes (> 2500 m) cattle have generalised chronic hypoxia and recurring, continuous vasoconstriction. This results in profound structural remodelling of especially the medial smooth muscle in the small pulmonary arteries, which eventually leads to pulmonary hypertension and right-ventricle hyperplasia (Rhodes 2005). This is the reason bovines are relatively more susceptible to 'brisket disease'.

The distinct lobules in the bovine lung are clearly defined by prominent, well-developed, complete interlobular connective tissue (septa) that reduce lung compliance and would reduce the effectiveness of any collateral channels and pores if they existed.

The main function of the lungs is gaseous exchange and to facilitate this rapid exchange of O_2 and carbon dioxide (CO_2), the barrier between inhaled air and circulating blood must be very thin with a large surface area. The total surface area of the alveolar epithelium in bovines is 25 to 30 times that of the body surface area (Pierson & Kainer 1980). Taking into consideration the surface area of Holstein cattle weighing between 41 kg and 617 kg to be $0.14 \times W^{0.57}$, it follows that a 500-kg cow will have an absorptive lung surface area of $0.14 \times 500^{0.57} \times 27.5 = 133$ m^2 (which is approximately 11.5 m by 11.5 m square) (Berman 2003). This area is constantly exposed to irritants and potential pathogens and injury to this interface could readily occur. For protection against these assaults, the lungs must have defence mechanisms which include the cough reflex, the mucociliary system and the usual cellular and humoral immune mechanisms.

Apart from gaseous exchange, the lungs perform other functions that may be affected when the respiratory tract is compromised:

- Acid-base balance. Maintenance of body pH homeostasis is a critical and fundamental problem faced by an organism and CO_2 regulation via the lungs is a rapid and major contributor.
- Body temperature regulation via heat exchange utilising evaporation and dead space within the respiratory tract.
- Fine and rapid body fluid volume regulation. The body humidifies all air that is inspired to a water vapour pressure of about 47 mmHg. Sheep can lose about 9% body weight through the loss of body water per day via the respiratory tract (Shakespeare 1997). Dehydration will make the mucociliary blanket tackier and therefore affects the efficiency of this system to clear foreign material and debris. Maintaining normal body hydration is therefore essential with infectious respiratory problems.
- Fine sieve or filter for platelet clumps and foreign particulates within the circulatory system.
- Cushioning of the heart from external trauma.
- Metabolic and endocrine capabilities. The vast surface area of the pulmonary capillary endothelium has access to the entire cardiac output and this endothelium is able to activate, inactivate, degrade and remove various plasma constituents that will influence the composition of arterial blood (Morrison 1986). Approximately 40 cell types within the respiratory system attest to this fact (Morrison 1986).

Aspiration pneumonitis

Aspiration pneumonitis is a term for chemical pneumonitis that is mainly reserved to describe the aspiration of acidic gastric contents in humans. This syndrome usually occurs in patients who have a marked disturbance in consciousness, especially with seizures, cerebrovascular accidents and general anaesthesia. In humans, it is a well-recognised complication of general anaesthesia occurring in 1 of 3000 procedures and accounting for 10% to 30% of all anaesthetic deaths (Marik 2001). Obviously, the severity of lung injury increases significantly as the volume of aspirate increases and the pH decreases. In humans, a volume greater than 0.3 mL/kg (B.W.) and with a pH < 2.5 are required to cause aspiration pneumonitis (Marik 2001). This volume sensitivity in humans indicates the ability of the lungs to deal with a certain amount of inhaled, sterile fluid. The equivalent inhaled volume in a 50-kg calf would be about 15 mL. The low pH results in a direct chemical burn to the cells lining the tracheobronchial tree and the pulmonary parenchyma and causes an intense inflammatory reaction and increased capillary permeability within 1–2 hours. This is the initial phase of the injury pattern. The second reaction that takes place usually peaks after 4–6 hours and is associated with an acute inflammatory response with infiltration of inflammatory mediators into the alveolar and lung interstitium. The gastric acid prevents bacterial growth in the early stages. Aspiration of significant amounts can be readily noticed by non-productive coughing, acute tachypnoea and dyspnoea, wheezing, bloody or frothy sputum, hypoxia and tachycardia developing into severe respiratory distress after 2–5 hours (Nseir *et al*. 2011). Bronchospasm occurs later and the cellular injury enables fluids and cellular elements to leak into the interstitial space and the alveoli, which can dilute and decrease production of surfactant, resulting in atelectasis (De Bendictus, Carnielli & De Benedictis 2009).

The clinical course of this chemical pneumonitis therefore varies. Around 60% of human cases show 'silent aspiration' where aspiration of small amounts occurs without recognition, especially in patients with altered level of consciousness, and these cases manifest only as arterial desaturation. Improvement occurs over 2–4 days as the lung infiltrates rapidly resolve (Bynum & Pierce 1976; Nseir *et al.* 2011). In about 15% of cases there is rapid deterioration over 24–36 hours that progresses to hypoxic respiratory failure and acute respiratory distress syndrome (Bynum & Pierce 1976). The other approximately 25% show an initial improvement which then worsens as a secondary bacterial infection sets in and death is a common sequela (Bynum & Pierce 1976).

Radiography may reveal infiltrate in the most dependent regions of the lung. The very young calf can present with an aspiration pneumonitis as seen in monogastrics if abomasal contents with a pH around 2 to 3 refluxes back into the rudimentary reticulo-rumen and back up the oesophagus. A similar scenario will be seen after dosing vinegar down the lungs. Calves are regularly tubed or bottle-fed with milk that may or may not be medicated, which can predispose them to aspiration pneumonitis.

Therapy in cases of uncomplicated chemical pneumonitis involves airway clearance, correcting the hypoxia by using oxygen supplementation, positive pressure ventilation if needed, intravenous fluids and anti-inflammatories. Antibiotics can be delayed until a definite infection is diagnosed to prevent unnecessary antibiotic use that could cause possible selection for resistant organisms.

Inert fluids such as water, liquid paraffin, barium, electrolytes and, possibly milk, could be dosed straight into the lungs and could cause reflex airway closure. Acute dyspnoea or even apnoea, cyanosis, pulmonary oedema and hypoxia can result. Water, depending on the volume aspirated, may produce fleeting clinical signs that often resolve within hours. Therapy should include tracheal suction as soon as possible with correction of the hypoxia with an oxygen mask or a nasal tube.

Aspiration pneumonia

Aspiration of colonised material from the oropharynx is a major mechanism whereby bacteria gain entrance to the pulmonary tree. However, even though up to half of healthy human adults aspirate small amounts of oropharyngeal secretions whilst sleeping, very few develop problems as a result of low burdens of virulent bacteria in normal secretions together with forceful coughing, active ciliary transport and normal humoral and cellular immune mechanisms resulting in adequate clearance and prevention (Marik 2001).

Aspiration pneumonia is the most common cause of death in human patients with dysphagia because of neurological disorders (Marik 2001). Up to 38% of critically ill, intubated, human patients who receive feeding through small-bore nasogastric tubes aspirate oropharyngeal contents despite having cuffed tracheal tubes (Nseir *et al.* 2011).

Clinical features are usually insidious in onset with a productive cough, fever and purulent sputum. Leukocytosis is common. Radiography may reveal an interstitial pattern mainly in the lobe bases, which may also show cavitations.

Therapy comprises mainly antibiotics, anti-inflammatories and secondary support.

In mature bovines, because of the size of the rumen and the magnitude of contents that can be regurgitated, overwhelming aspiration of regurgitated contents will cause instant death as a result of mechanical asphyxiation. The pH of these contents, even with a severe ruminal acidosis, is more alkaline than that seen in monogastrics, and the chemical burn as seen in the latter is unlikely. However, contamination of the pulmonary tree with pathogenic bacteria is a distinct possibility and even small amounts aspirated can cause aspiration pneumonia after a day or two.

If rumen content is dosed or aspirated, tracheal suction immediately after the event will be necessary. Bronchial and pulmonary lavage is contra-indicated as this practice disseminates the aspirate further into the pulmonary tree and increases the damage (Nseir *et al.* 2011).

Aerosol therapy and physiotherapy can be used to facilitate both delivery of antibiotics to the respiratory tree and the elimination of exudates and excessive respiratory secretions. This aspect of the treatment is under-utilised in bovine practice.

Exogenous lipoid pneumonia can result from the aspiration of various oils often used as laxatives. Small amounts of aspirated vegetable oils provoke very little reaction and are mostly removed by expectoration. Animal oils cause mononuclear and giant cell inflammation, and connective tissue proliferation. Mineral oils, which are relatively inert and non-irritating can enter the tracheobronchial tree without stimulating glottis closure or the cough reflex and once there, are expelled with difficulty because the oil impairs the mucociliary transport system (Banjar 2003). These oils are initially emulsified and ingested by macrophages but after several months are liberated and coalesce, forming larger masses of oil surrounded by giant cells and fibrosis. The alveolar septa may become oedematous and the oil elicits a foreign body reaction consisting of lymphocytes, plasma cells and giant cells (Banjar 2003). Elastic tissue degeneration of the walls of the bronchi and bronchioles can lead to atelectasis. These cases are normally asymptomatic but may show a chronic cough and dyspnoea.

Aspiration of particulate matter or foreign bodies will cause mechanical obstruction, and depending on the size and location of the obstruction can cause acute apnoea with rapid asphyxiation to a chronic, irritating cough with recurrent low grade infections. Extraction via bronchoscopy is probably necessary.

Pertinent diagnostic tests

Detecting the cause of the lung disorder will involve collating a sound history, including management practices, with a thorough clinical examination with emphasis on the respiratory system. Radiography, blood gases and haematology will be helpful additions.

In diseased lungs, there can be a marked mismatch between ventilation and perfusion. Ventilation perfusion (V-Q) imbalance can be measured by determining the differences between alveolar (A) and arterial (a) oxygen (O_2) partial pressure (P), abbreviated as ($P[A\text{-}a]O_2$). This difference will vary with the fraction of inspired oxygen (FIO_2), which is normally 0.21 in any atmosphere. $P(A\text{-}a)O_2$ normally ranges between 5 mmHg and 20 mmHg (assume an average of ± 10 mmHg) with older patients usually having the larger difference. If this value is excessive, there is a defect in oxygen transfer within the lungs which is almost always a consequence of a V-Q mismatch.

An estimate for alveolar oxygen partial pressure (PAO_2) can be determined from the equation:

$$PAO_2 = FIO_2 \times (P_B - 47) - 1.2 \times PaCO_2 \quad \text{[Eqn 1]}$$

where P_B is the barometric pressure, $PaCO_2$ is the partial pressure of carbon dioxide in the arterial blood and 47 is the partial pressure of water vapour in the trachea at 37 °C (Martin 1999).

At sea level where the barometric pressure is about 760 mmHg and assuming water vapour at 37 °C is 47 mmHg, the partial pressure of O_2 in the trachea when breathing air will be (760 – 47) × 0.21 = 150 mmHg. Partial pressure of O_2 in the alveoli (PAO_2) (using the above formula and assuming $PaCO_2$ approximately 40) will be about 100 mmHg at sea level. The factor 1.2 × $PaCO_2$ can be approximated by $PvCO_2$. However, this will then necessitate taking both arterial and venous samples.

With hyperventilation, PAO_2 will increase as $PaCO_2$ decreases, which will correspondingly increase PaO_2. With oxygen supplementation, FIO_2 will increase and PAO_2 can be over 200 mmHg, which will result in a normal PaO_2 of over 100 mmHg. Breathing 100% oxygen will cause a normal $P(A\text{-}a)O_2$ range of around 110 mmHg.

Barometric pressure (P_B) will affect partial pressure of inspired O_2, which will similarly affect PAO_2 and likewise PaO_2. The altitude of the patient should be noted and if necessary, barometric pressure adjusted according to the following formula:

$$P_B(h) = 760 \times 10^{-0,000054h} \quad \text{[Eqn 2]}$$

where h = altitude in m a.s.l.

At an altitude of 1500 m a.s.l. (e.g. the altitude of the farm and the clinic) the barometric pressure has dropped from 760 mmHg to 634 mmHg and the PAO_2 will also drop significantly to ± 75 mmHg. PaO_2 will also decrease (75 – 10 = 65 mmHg) which, if altitude was not considered, would indicate severe functional lung pathology. Arterial blood is preferable for these estimates but in the case described above, the patient's welfare took priority and the less stressful venous sample was taken. In the above case, if the $PvCO_2$ value = 55 mmHg is used, then PAO_2 will be around 68 mmHg and an expected PaO_2 of ± 58 mmHg will indicate adequate oxygenation by the lungs.

P_B can vary with season, between morning and evening, and with changing weather conditions, but this variation is usually less than 2% and will therefore have very little effect on partial pressure calculations (Martin 1999).

Respiratory physiotherapy

This is a very under-utilised but important aspect of the treatment for respiratory conditions in bovines. In many pneumonic states, coughing and mucociliary clearance is impaired as a result of a number of reasons, including weakness and reduced mobility of the patient and also because of dehydration and reduced humidification, leading to more viscous secretions. Sputum retention and increased airway resistance will increase the effort needed to breathe, all of which potentially exacerbate the existing problem.

Physiotherapy includes a number of modalities and involves a combination of techniques, including multiple bronchial drainage positions, percussion and vibration (Ciesla 1996). The use of positioning and postural drainage relies on gravity to encourage clearance of secretory and exudative material from the more peripheral areas of the lung lobes towards the central upper airways whilst simultaneously performing percussion on the chest wall. A number of these positions are described in humans, each of which targets a desired lung region or segment (Ciesla 1996). Restraining a compromised, dyspnoeic animal in similar positions is impractical. The caudally-directed, upward-sloping lungs in the standing bovine will assist postural drainage to some extent. Percussion and manual vibration and shaking, however, can be practically and readily applied.

Percussion produces micro-vibrations to the outer lung with the aim of loosening and dislodging particulate matter in the outer bronchi and bronchioles. This involves cupping the hands, allowing a cushion of air to soften the 'clapping' of the chest wall. The movement should come mostly via the wrist and is fairly vigorous and rhythmical and involves percussing ('clapping') the lung area, starting at the dorsal caudal border and working slowly forward before returning caudally and slightly lower, and repeating the procedure until the whole lung area is covered. This is performed for 3–5 min during both inspiration and expiration.

Percussion is often followed by manual vibration over the same lung segment for an additional approximately 15 seconds or for 5 exhalations (Ciesla 1996). Vibration is more forceful and involves vibrating only the chest wall during expiration, using a similar pattern to that used with percussion. This enhances drainage of dislodged material towards the central airways in the same direction as the airflow during expiration. The flattened hands in this case are placed firmly on the chest wall and by tensing the arm musculature, a fine, firm shaking motion can be created. The recommended frequency of both percussion and vibration is 12–20 beats per minute to mimic the cilia beat frequency.

The entire procedure, involving all lung segments, can be performed for 20–40 min. If coughing, which is needed to clear debris from the upper airways, has not been stimulated, this can be encouraged by physical shaking and by gentle but forceful abdominal pressure to enhance the magnitude of the expiratory phase. Tracheal suctioning may have to be considered if the coughing reflex is inadequate.

The above procedures are very intensive and time-consuming and require some practice and expertise. Various physiotherapy devices are used for humans to increase patients' compliance, and are effective for mucus and secretory expectoration and improved pulmonary function (Hristara-Papadopoulou *et al*. 2008). One such device that has practical application for younger cattle produces and also known as high-frequency chest wall oscillation. Positive pressure air pulses are applied to the chest wall by means of an air pulse generator producing a pressure of 50 cm water at a frequency of just over 500 Hz delivered by a pneumonic, inflatable vest. The vibrations cause transient air flow increase in the airways, loosen mucus and produce cough-like shear forces. This device has been shown to mobilise more mucus and secretions than standard, manual chest physiotherapy (De Benedictis *et al.* 2009).

Conclusion

There is a definite distinction between aspiration pneumonitis and aspiration pneumonia. Many causes of aspiration in bovines lead to aspiration pneumonia, but there are times where this is not the case. The attending clinician should be aware of this and after considering the differing pathogeneses may want to consider a therapy more in line with the aspiration disorder diagnosed.

Blood gas measurement and its interpretation is definitely becoming an invaluable tool in bovine medicine, especially with lung and metabolic problems. Compensating for reduced barometric pressure at the higher altitudes should always be carried out before interpreting arterial blood partial pressure of oxygen. If supplementary oxygen is given, knowledge of how to calculate expected oxygen levels and differences is crucial.

An important therapeutic consideration with lung disorders is physiotherapy which, although very time-consuming, can be a useful adjunct to treatment.

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Competing interests

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