Short communication: Ultrasonographic assessment of the thorax as a fast technique to assess pulmonary lesions in dairy calves with bovine respiratory disease

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ABSTRACT

The aim of this study was to assess inter- and intraoperator agreement when assessing lung consolidation secondary to bovine respiratory disease (BRD) by thoracic ultrasonography. Ten calves were blindly assessed by 3 operators with varying expertise in thoracic ultrasound to look for lung consolidation and the presence of comet-tail artifacts (COMT). Systematic ultrasonography of the thorax was performed using an 18-site per side assessment with a linear 8.5-MHz probe. The status of the calves [healthy ($n = 4$) vs. treated for BRD ($n = 6$)] was not known by the operators. The interoperator kappa agreement for detecting consolidation was moderate to almost perfect (from 0.6 to 1.0) depending on the operator's experience (diagnosis of consolidation if depth ≥ 1 cm). The intraclass correlation coefficient for consistency was 0.71 for a single measurement and 0.88 for average measurement. The intraclass correlation coefficient for agreement was 0.73 for single measurements and 0.89 for average measurements. These values were considered good for single measurements and excellent for average measurements. Systematic ultrasonography of the thorax can be used routinely to assess lung consolidation in dairy calves and can therefore be of importance, especially for assessment of subclinical BRD.

Key words: dairy calf, pneumonia, lung consolidation, ultrasonography

Short Communication

Bovine respiratory disease (BRD) is one of the leading causes of losses in the beef and dairy industry; it is a major health issue in replacement dairy calves (McGuirk, 2008). The diagnosis of BRD may be difficult, especially in subclinical or chronic stages, and also because typical signs, including both increased rectal temperature and alteration of the respiratory

function (e.g., tachypnea, dyspnea, or nasal discharge), lack both specificity and sensitivity. Alteration of the respiratory function and spirometric parameters could be important even with minimal lung lesions, or calves could display minimal alterations of lung function and spirometric parameters in the presence of extensive lung lesions (Reinhold et al., 2002).

With lung consolidation, growth can be impaired, a phenomenon that has been extensively studied, especially in feedlot calves (Wittum et al., 1996). In dairy calves, BRD and its consequences are associated with increased costs of rearing, increased risks of mortality or relapses, as well as impaired growth and early culling (Bach, 2011). Recently, lung consolidation was mentioned as a predictor of impaired growth in dairy calves (Ollivett et al., 2011). For these reasons, it is important to be able to monitor more objectively the type of pulmonary lesions, as well as their extension, as possible tools for assessing the stages and effect of BRD on the health of calves, especially in subclinical cases in which the typical clinical signs are absent.

Thoracic ultrasonography has been previously mentioned as a noninvasive ancillary tool for assessing lung lesions and can give information that is complementary to more classical lung function tests (blood gas analysis or spirometric measures). Thoracic ultrasonography has been shown to be highly correlated with radiographic (Jung and Bostedt, 2004) and necropsic lesions (Rabeling et al., 1998; Reinhold et al., 2002) in calves. The correlation between thoracic ultrasonography and tests assessing lung and respiratory function is less obvious than that for lung lesions. Thoracic ultrasonography did not correlate with lung function testing changes in experimentally induced pneumonia, except for changes in tidal volume and respiratory rate (Reinhold et al., 2002). One of the most interesting assets of thoracic ultrasonography is that it can be easily performed calf-side and gives an immediate result, in contrast to radiographs. For these reasons, it could be potentially useful in the field when examining a calf with suspected BRD, and as a research tool when monitoring subclinical BRD, especially focusing on the extent of lung consolidation. However, as with every imaging technique

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and procedure, it is difficult to be sure that it could be used in the field for clinical and research purposes if not validated for intra- and interobserver agreement. Most of the available studies of thoracic ultrasonography have been performed by clinicians in hospital conditions with substantial skills in this imaging technique; therefore, it is unclear whether the results obtained could be used by an operator who does not have extensive knowledge of bovine ultrasonography, especially if it is to be applied in a field setting. The aim of this short communication, therefore, was to validate a simple and fast systematic ultrasonographic procedure to evaluate calves with suspected pulmonary pathology to use this technique as a new calf-side tool for BRD assessment for clinical and research purposes.

The experimental protocol was approved by the Comité d'Éthique et d'Utilization des Animaux of the Université de Montréal. The study used 10 male dairy calves in a preweaning veal calf unit. The unit's full capacity was 475 calves, and all calves enter the unit at 7 d of age. Despite vaccination in the early feeding period, appearance of clinical respiratory signs by the end of the first month could not be prevented successfully on the herd level. The producer was asked to select 10 calves (6 treated for BRD the week before the examination and 4 considered healthy) to participate in the study, and to select calves that did not present any obvious signs of pneumonia to avoid any influence on the operator's ultrasonography. Consequently, the operators did not know the status of the calf (case vs. healthy control) when performing the examination.

To assess interobserver repeatability, 3 operators (observers, **Obs**) performed the ultrasonographic examination of the thorax of the calves. To assess intraobserver repeatability, the examination was repeated 24 h apart for 2 operators. The operators did not observe the examinations performed by other operators and were blinded to their results. Operator 1 (S.B., Obs 1) was a senior operator who was experienced in bovine extra-genital ultrasonography, especially in thoracic ultrasonography. Operator 2 (G.F., Obs 2) was a newly graduated veterinarian doing an internship at the bovine ambulatory clinic and was therefore considered a novice operator in extra-genital ultrasonography. Operator 3 (A.M.B., Obs 3) was a senior operator who was also experienced in bovine extra-genital ultrasonography, but to a lesser extent than operator 1, but who had no specific experience in thoracic ultrasonography. Before the examination, consensus was reached between the 3 operators to define every thoracic anomaly that needed to be collected during the examination procedure (Buczinski, 2009).

The thorax of each calf was systematically scanned in each intercostal space from the 11th to the 4th. Each

side was divided into 3 equal longitudinal parts: the dorsal (A), the medium (B), and the ventral part (C) (Figure 1). A total of 18 sites for each side were investigated for the presence of normal ultrasonographic findings (Jung and Bostedt, 2004). The ultrasonography was performed using an 8.5-MHz linear probe (Ibex Pro, EI Medical, Loveland, CO), which was directly applied on the thorax after 70% isopropyl alcohol had been sprayed onto the area of interest to achieve a good image quality. To be compatible with future rapid use in a field setting, the area of interest was not clipped. The different anomalies (Babkine and Blond, 2009; Buczinski, 2009) noted were the presence of comet-tail artifacts (**COMT**), the number of sites with COMT (**ΣCOMT**), pleural fluid accumulation, and consolidated lung [if present: depth of consolidation (cm), and depth directly manually counted with the squared screen of the ultrasound unit, **Depth**]. The sum of the Depth value found in each calf was also recorded (**ΣDepth**).

The data were compiled in a spreadsheet and were analyzed using commercial statistical software (SAS software, version 9.2, SAS Institute Inc., Cary, NC; and MedCalc, version 12.3.0.0, Mariakerke, Belgium). Because of the small number of observations, only descriptive statistics were performed. The median, minimal, and maximal values were summarized for each parameter of interest. The interobserver (Obs 1, 2, 3) and intraobserver agreements (Obs 1, 2) were determined using Cohen's kappa (κ) procedure for categorical observations to define the presence of significant lung consolidation (defined as depth ≥ 1 cm). The κ agreement was considered slight for $0.20 \leq \kappa < 0.40$, fair when $0.40 \leq \kappa < 0.60$, moderate when $0.60 \leq \kappa < 0.80$, substantial when $0.80 \leq \kappa < 0.90$, and almost perfect when $0.90 \leq \kappa < 1.00$. The intraclass correlation coefficients (**ICC**) were used to assess consistency (**ICC_C**) and agreement (**ICC_A**) of depth value for the 3 operators, as previously described (McGraw and Wong, 1996). The ICC were considered poor for values of $\text{ICC} < 0.4$, fair when $0.4 \leq \text{ICC} < 0.6$, good when $0.6 \leq \text{ICC} < 0.8$, and excellent if $\text{ICC} \geq 0.8$.

A receiver operating characteristic (**ROC**) curve was drawn to model the diagnostic capacity of the Depth value to differentiate a calf treated for BRD from a healthy calf, and the area under the ROC curve was calculated. The ROC curves were also drawn to assess the diagnostic accuracy of ΣCOMT as a predictor to differentiate a BRD-treated calf from a healthy calf.

The results of the ultrasonographic examination are summarized in Table 1. The total examination duration time was from 7 to 9 min per calf. The consolidation sites were never observed on the dorsal part of the thorax (area A, Figure 1). No significant pleural effusion

Figure 1. Each side of the thorax was divided into dorsal (A), medium (B), and ventral (C) parts. The intercostal spaces (from the 3rd to the 11th) are indicated by a dashed line. The different intercostal sites that were scanned with ultrasound are numbered from 1 to 18 (from the 11th to the 4th intercostal space). This examination protocol was performed in both sides of the thorax beginning at the 1st to the 18th site..

was recorded. The κ -values of inter- and intraobserver agreement for detecting consolidation are summarized in Table 2. They showed moderate to excellent agreement among the operators. The intraoperator agreement was fair (0.4 for comparison Obs 2 – Obs 2.1) to moderate (0.6 for Obs 1 – Obs 1.1) when the examination was performed twice at a 24-h interval; however, the agreement between Obs 1 and Obs 2 was strong when comparing Obs 1.1 and Obs 2.1, possibly indicating that some changes in consolidations could have occurred in a 24-h period (compared with Obs 1 and Obs 2). The ICC_C was 0.71 for single measurements and 0.88 for average measurements. The ICC_A was 0.73 for single measurements and 0.89 for average measurements.

The Depth value had better diagnostic accuracy for differentiating cases from control calves for Obs 1 and Obs 2 (AUC = 0.896) than for Obs 3 (AUC = 0.687; Figure 2). The diagnostic accuracy of Σ COMT was low for each operator (Figure 3).

The aim of this short communication was to define the agreement of different operators when diagnosing consolidated lung tissue in calves with a history of respiratory disease. Bovine respiratory disease is a major issue in calves (McGuirk, 2008). One of the most challenging aspects of this syndrome is that, in many cases, clinical signs are not obvious (Ollivett et al., 2011; Leruste et al., 2012). There is an important need for clinical tools that help in the diagnosis of subclinical forms of BRD, which may lead to decreased performance of affected calves (Leruste et al., 2012).

The results of this study have limitations, mainly because of the small number of animals observed and because no gold standard tests have been used to define consolidation, as necropsy was not performed. However, previous studies have shown that ultrasonography correlates well with pathologic findings in calves (Rabeling et al., 1998; Reinhold et al., 2002). Despite the fact that we focused on the ultrasonographic detection of lung consolidation as a marker of infected lung parenchyma,

Table 1. Thoracic ultrasonographic examination [median (minimum – maximum)] in calves with suspected bronchopneumonia¹

Parameter ²	Observer		
	1	2	3
Depth			
Case	2.25 (0–6)	2 (0–4.5)	1.75 (0–6)
Control	0 (0–0.5)	0 (0–0.5)	0 (0–3)
ΣDepth			
Case	4.5 (0–20)	3 (0–20.5)	5.5 (0–17)
Control	0 (0–0.5)	0 (0–0.5)	0 (0–4.5)
ΣCOMT			
Case	12.5 (5–22)	9 (1–14)	10.5 (7–25)
Control	9 (6–17)	8.5 (2–11)	12.5 (5–19)

¹Observer 1 = senior ultrasonographer experienced in thoracic ultrasonography; observer 2 = junior ultrasonographer; observer 3 = senior ultrasonographer in gastrointestinal ultrasonography, no specific experience in thoracic ultrasonography.

²Depth = maximal depth (cm) of consolidated lung determined when performing systematic thoracic ultrasonography; ΣDepth = sum of the different depths of consolidated lungs noted during systematic thoracic ultrasonography; ΣCOMT = total number of sites in which comet-tail artifacts were seen during systematic thoracic ultrasonography. Case = 6 of 10 calves considered affected by respiratory disease and treated with long-acting antibiotics; Control = 4 of 10 calves considered healthy and not treated.

Figure 2. Receiver operating characteristics (ROC) curves of determination of the maximal depth of consolidated lung parenchyma as a predictor of a calf being treated or not for respiratory problem. Observer (Obs) 1 = senior ultrasonographer experienced in thoracic ultrasonography; observer 2 = junior ultrasonographer; observer 3 = senior ultrasonographer in gastrointestinal ultrasonography, no specific experience in thoracic ultrasonography. The area under the ROC curve was 0.896 for Obs 1 and Obs 2, and 0.687 for Obs 3. The diagonal line from the origin represents the line of identity ($y = x$), representing a test having 50% sensitivity and specificity.

it is also important to remember that, due to the specificity of bovine lung anatomy, mainly because of the high degree of lung lobulation (McLaughlin et al., 1961) and lack of collateral airways (Veit and Farrell, 1978), the bovine lung is more susceptible to atelectasia secondary to airway obstruction. The atelectatic lung parenchyma will have the same ultrasonographic aspect of “consolidated lung” whether caused by inflammation or atelectasia (Babkine and Blond, 2009). The clinical importance of this phenomenon remains unknown, but should be kept in mind when observing consolidated lung by ultrasonography. Another limitation of ultrasonography as an imaging tool is that, unlike thoracic radiographs, deep lesions in the parenchyma will not be seen if they are surrounded by normal parenchyma filled with air, as reverberation of the ultrasound will occur due to the tissue–gas surface (Reinhold et al., 2002; Buczinski, 2009).

Table 2. Interobserver and intraobserver agreement [Cohen’s kappa (κ) procedure] for detecting the presence of consolidation in calves with or without respiratory diseases

Item ¹	κ -value
Obs 1 – Obs 2	1.0
Obs 1 – Obs 3	0.6
Obs 2 – Obs 3	0.6
Obs 1 – Obs 1.1	0.6
Obs 2 – Obs 2.1	0.4
Obs 1.1 – Obs 2.1	0.8

¹Observer (Obs) 1 = senior ultrasonographer experienced in thoracic ultrasonography; observer 2 = junior ultrasonographer; observer 3 = senior ultrasonographer in gastrointestinal ultrasonography, no specific experience in thoracic ultrasonography; Obs 1.1 = observation made by the first operator at a 24-h interval from Obs 1; Obs 2.1 = observation made by the second operator at 24-h intervals from Obs 2.

Figure 3. Receiver operating characteristics (ROC) curves of determination of the total number of intercostal sites with comet-tail artifacts (Σ COMT) as a predictor of a calf being treated or not for respiratory problem. Observer (Obs) 1 = senior ultrasonographer experienced in thoracic ultrasonography; observer 2 = junior ultrasonographer; observer 3 = senior ultrasonographer in gastrointestinal ultrasonography, no specific experience in thoracic ultrasonography. The area under the ROC curve was 0.583 for Obs 1, 0.562 for Obs 2, and 0.604 for Obs 3. The diagonal line from the origin represents the line of identity ($y = x$), representing a test having 50% sensitivity and specificity.

This study is the first to assess the effect of the operator on the ultrasonographic results. We used 2 different approaches to assess the variation in ultrasonographic examinations using a dichotomous result (e.g., consolidated vs. nonconsolidated) as well as the ICC, which may be particularly interesting for further studies assessing the effect of the Depth value on the outcome of the calf. The study showed that ultrasonographic assessment of lung consolidation has a good-to-excellent ICC, which is compatible with its use for future studies.

Only 2 studies are available concerning the prognostic use of thoracic ultrasonography in cattle; however, the results are conflicting. On the feedlot side, a targeted thoracic examination did not find any interest in ultrasound for predicting the outcome of BRD-affected calves (responder vs. nonresponder or survivors vs. nonsurvivors; Abutarbush et al., 2012). On the dairy side, a study showed that subclinical pneumonia diagnosed using lung consolidation when performing a systematic ultrasonographic thoracic screening was associated with significant impaired growth in heifers diagnosed with significant lung consolidation (Ollivett

et al., 2011). Neither of these studies mentioned the possible effect of the operator on the impact of the results.

The presence of COMT has previously been presented as an early sign of pneumonia or emphysema (Babkine and Blond, 2009); however, COMT was found in both cases and controls and in multiple intercostal spaces. For these reasons, the significance of the presence of COMT, even if present in high numbers, when performing ultrasonography should not be systematically interpreted as associated with BRD.

In conclusion, systematic ultrasonographic assessment of the thorax in calves is a feasible technique that is directly applicable on the farm, which may be promising for research and clinical assessment of the effect of subclinical BRD in dairy heifers.

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