BestBETs for Vets

Supporting veterinary clinicians in making evidence-based decisions

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More efficient pneumonia detection in calves - thoracic ultrasound versus Wisconsin calf scoring

Clinical Scenario

At the end of the routine visit on one of your larger dairy farms, the client asks you to cast an eye over his brother's new calf rearing shed. The farm are planning to start a separate business buying in and rearing pre-weaned dairy cross calves alongside rearing some of their own calves for beef. After discussing building design and vaccination protocols, the farmer mentions that a neighbour has started ultrasound scanning his calves to check for pneumonia. He asks you whether this would be better at detecting pneumonia in groups of calves than the Wisconsin calf scoring that he has always used in his own animals.

You wonder if there is any evidence to support thoracic ultrasonography (TUS) leading to more efficient pneumonia detection than Wisconsin calf scoring .....

3-Part Question (PICO)

In [calves at risk of pneumonia] does [thoracic ultrasonography vs Wisconsin calf scoring] lead to [more efficient disease detection]?

Search Strategy

MEDLINE(R) In-Process & Other Non-Indexed Citations and MEDLINE(R) 1946 to Present using the OVID interface

(calf.mp. OR calves.mp. OR young cattle.mp. OR young bovine.mp. OR young bovines.mp. OR young stock.mp. OR youngstock.mp. OR exp cattle/)

AND

(pneumonia.mp. OR pneumonic.mp. OR respiratory disease.mp. OR respiratory diseases.mp. OR respiratory infection.mp. OR respiratory infections.mp. OR respiratory disorder.mp. OR respiratory disorders.mp. OR respiratory consolidation.mp. OR bovine respiratory disease.mp. OR BRD.mp. OR bovine respiratory disease complex.mp. OR BRDC.mp. OR lung disease.mp. OR lung diseases.mp. OR lung consolidation.mp. OR lung infection.mp. OR lung infections.mp. OR exp Pneumonia/ OR exp Respiratory Tract Diseases/ OR exp Respiratory Tract Infections/ OR exp Respiration Disorders/ OR exp Lung Diseases/ OR exp Bovine

Respiratory Disease Complex/)

AND

(thoracic ultrasonography.mp. OR thoracic US.mp. OR thoracic ultrasound.mp. OR TUS.mp. OR thoracic ultrasonographic.mp. OR transthoracic ultrasonography.mp. OR transthoracic ultrasound.mp. OR transthoracic ultrasonographic.mp. OR transthoracic US.mp. OR lung ultrasound.mp. OR lung ultrasonography.mp. OR lung ultrasonographic.mp. OR lung US.mp. OR thoracic sonography.mp. OR thoracic sonographic.mp. OR lung sonography.mp. OR lung sonographic.mp. OR exp Ultrasonography/ OR wisconsin calf scoring.mp. OR wisconsin calf score.mp. OR WCS.mp. OR wisconsin calf respiratory scoring system.mp. OR clinical respiratory score.mp. OR clinical respiratory scoring.mp. OR calf respiratory scoring chart.mp. OR CRSC.mp. OR calf respiratory scoring system.mp.)

CAB Abstracts 1910 to Present using the OVID interface

(calf.mp. OR calves.mp. OR young cattle.mp. OR young bovine.mp. OR young bovines.mp. OR young stock.mp. OR youngstock.mp. OR exp cattle/ OR exp calves/)

AND

(pneumonia.mp. OR pneumonic.mp. OR respiratory disease.mp. OR respiratory diseases.mp. OR respiratory infection.mp. OR respiratory infections.mp. OR respiratory disorder.mp. OR respiratory disorders.mp. OR respiratory consolidation.mp. OR bovine respiratory disease.mp. OR BRD.mp. OR bovine respiratory disease complex.mp. OR BRDC.mp. OR lung disease.mp. OR lung diseases.mp. OR lung consolidation.mp. OR lung infection.mp. OR lung infections.mp. OR exp pneumonia/ OR exp respiratory diseases/)

AND

(thoracic ultrasonography.mp. OR thoracic US.mp. OR thoracic ultrasound.mp. OR TUS.mp. OR thoracic ultrasonographic.mp. OR transthoracic ultrasonography.mp. OR transthoracic ultrasound.mp. OR transthoracic ultrasonographic.mp. OR transthoracic US.mp. OR lung ultrasound.mp. OR lung ultrasonography.mp. OR lung ultrasonographic.mp. OR lung US.mp. OR thoracic sonography.mp. OR thoracic sonographic.mp. OR lung sonography.mp. OR lung sonographic.mp. OR exp ultrasonography/ OR wisconsin calf scoring.mp. OR wisconsin calf score.mp. OR WCS.mp. OR wisconsin calf respiratory scoring system.mp. OR clinical respiratory score.mp. OR clinical respiratory scoring.mp. OR calf respiratory scoring chart.mp. OR CRSC.mp. OR calf respiratory scoring system.mp.)

Search Outcome

MEDLINE

- **191** papers found in MEDLINE search
- **146** papers excluded as they don't meet the PICO question
- **22** papers excluded as they are in a non-English language
- **19** papers excluded as they are review articles/in vitro research/conference proceedings
- **4 total relevant papers from MEDLINE**

CAB Abstracts

- **124** papers found in CAB search
- **70** papers excluded as they don't meet the PICO question
- **22** papers excluded as they are in a non-English language
- **28** papers excluded as they are review articles/in vitro research/conference proceedings
- **4 total relevant papers from CAB**

Total relevant papers

4 relevant papers from both MEDLINE and CAB Abstracts

Comments

Other papers were considered in more detail, but were discounted; Buczinski et al. (2014) was excluded due to the data from this study also being used in the Buczinski et al. (2015) study which was retained for final critical analysis. The Buczinski et al. (2015) study directly compared the accuracy of clinical respiratory scoring (CRS) and TUS for the diagnosis of pneumonia in pre-weaned dairy calves and hence was more relevant to the PICO question.

Summary of Evidence

Buczinski et al. (2015) North America

Title: Bayesian estimation of the accuracy of the calf respiratory scoring chart and ultrasonography for the diagnosis of bovine respiratory disease in pre-weaned dairy calves

Patient group:

Data from 2 North American-based field studies involving pre-weaned dairy replacement heifers were used.

1. Ollivett et al. 2011 – involved 13 dairy farms with 85 calves in Quebec with high anticipated prevalence of calf pneumonia. This is a conference proceeding so there is little information available about the baseline study.

2. Buczinski et al. 2014 – involved 6 dairy farms with 106 calves in New York State with no history of calf pneumonia.

Study Type:

Both studies referenced within this study were cohort studies. The BET authors have used the diagnostic test critical appraisal sheet for this assessment, which was also informed by points in the STARD-BLCM reporting guidelines checklist.

This paper was a short communication.

Outcomes:

- **The following main outcomes were estimated/calculated based on *one* TUS case definition of ≥1 cm consolidation observed at any TUS scanning site & clinical respiratory scoring chart (CRSC) positive defined as a score of ≥5:**

- Estimates of sensitivity and specificity of Wisconsin CRSC using 4 Bayesian latent class models (BLCM)
- Estimates of sensitivity and specificity of thoracic ultrasonography (TUS) using 4 BLCM
- Estimates of prevalence of pneumonia in Quebec study using 4 BLCM
- Estimates of prevalence of pneumonia in New York study using 4 BLCM
- Estimates of covariance of the tests in Quebec in positive or negative pneumonia cases using 4 BLCM
- Estimates of covariance of the tests in New York in positive or negative pneumonia cases using 4 BLCM

Key Results:

- Kappa values for Buczinski = 0.133 (95% Confidence Interval (CI) -0.551 to 0.321) and Ollivett = 0.292 (CI 0.030 to 0.554).
- Model 1 (where it was assumed sensitivity and specificity of TUS and of CRSC was the same in both Buczinski and Ollivett study populations): Based on this main model, median CRSC sensitivity is estimated at 62.4% (95% Credibility Interval (CreI) 47.9-75.8), and specificity estimated at 74.1% (CreI 64.9-82.8). Comparatively the median TUS sensitivity was estimated at 79.4% (CreI 66.4-90.9) and specificity estimated at 93.9% (CreI 88.0-97.6). The Credibility Intervals for both tests are relatively wide for the sensitivity estimates.
- All estimates were broadly similar across all 4 models when prevalence priors were altered (variation of <5% between models), except TUS sensitivity where median across all models varied from 70.3% - 79.4%. Again the Credibility Intervals for both tests are relatively wide for the sensitivity estimates across the models.

Study Weaknesses:

- No sample size calculation was included in the methods section.
- No reasoning given for including data from these two studies particularly.
- Sample is unlikely to be representative of the target population as data from one of the studies was based on convenience sampling, and small numbers of farms from particular regions of the US were involved.
- Using the STARD-BLCM reporting guidelines to inform the assessment of the paper, the authors did discuss that many assumptions were made about the priors that were input into the models because of a lack of available baseline data. There was some description of rationale behind using informative/non-informative priors for a parameter, alongside how estimates were obtained from experts for informative priors. It could potentially be as a result of the short communication format, but more information about the priors and assumptions would have been useful to fully understand and interpret the results.
- The short communication format of this study may be responsible for the scant detail provided in some other areas, especially in relation to the diagnostic testing approach (including presence of independence and blinding), amount of basic data provided from both original studies and the explanation of the cutoffs used for accuracy (e.g. low, moderate, high) - this is reflected in the final conclusion particularly (definition of what was meant by 'acceptably high' accuracy that CRSC was concluded to provide was not provided).
- The aim stated in the introduction section was to estimate accuracy of both TUS and CRSC for pneumonia diagnosis in pre-weaned dairy calves (but in the abstract the stated aim was to estimate the accuracy of CRSC); the final conclusion pertains to characteristics of CRSC only.

Attachment:

Evidence appraisal (/soe_attachments/575/4155-Critical appraisal_Bucz_23.06.21.pdf)

Berman et al. (2019) Canada

Title:	Bayesian estimation of sensitivity and specificity of systematic thoracic ultrasound exam for diagnosis of bovine respiratory disease in pre-weaned calves

Patient group:	Data from 2 different prospective studies were included in the analysis. 1. Berman et al., 2017- The first study involved 209 veal calves from one farm in Quebec (conducted in 2014) – this was a randomized clinical trial to assess tildipirosin metaphylactic antimicrobial efficacy. Approximate age at enrollment of 7 days old. 2. Buczinski et al., 2018a- The second study involved 301 dairy calves from 39 herds visited by the ambulatory clinic of the veterinary faculty at the University of Montreal (conducted in 2015) – this was performed to assess prevalence of ultrasonographic lung lesions. Median age at enrollment of 38 days old. It should be noted that these calves were then part of a large study validating the Californian Clinical scoring system versus TUS (Buczinski et al., 2018b).
Study Type:	The studies referenced within this study were a randomised controlled trial (Berman et al. 2017) and a cross-sectional study (Buczinski et al. 2018a). The BET authors have used the diagnostic test critical appraisal sheet for this assessment, which was also informed by points in the STARD-BLCM reporting guidelines checklist. Part of the main aim of the study is not the same as the aim for the BET.
Outcomes:	• **Initial outcomes:** • Estimates of sensitivity, specificity and positive and negative likelihood ratio of different thoracic ultrasonography (TUS) case definitions; depth of consolidation ≥0 cm, ≥1 cm, ≥3 cm, using the main Bayesian latent class model (BLCM). • Estimates of sensitivity, specificity and positive and negative likelihood ratio of different TUS scan sites; right lung lobe cranial to the heart, right and left lung lobes caudal to the heart, right cranial and right and left lung lobes caudal to the heart, using the main BLCM. • **The following main outcomes were estimated/calculated based on *one* TUS case definition of ≥3 cm consolidation observed in right lung lobes caudal to the heart & CRSC positive defined as a score of ≥5:** • Estimates of sensitivity and specificity of Wisconsin clinical respiratory scoring chart (CRSC) using 4 BLCM. • Estimates of sensitivity and specificity of TUS using 4 BLCM. • Estimates of sensitivity and specificity of serum Haptoglobin concentration (Hap) ≥15 mg/dl using 4 BLCM. • Estimates of prevalence of pneumonia in dairy and veal calves using 4 BLCM. • Estimates of the covariance between the sensitivity of CRSC and TUS among pneumonia positive calves using one BLCM. • Estimates of the covariance between the specificity of CRSC and TUS among pneumonia negative calves using one BLCM. • Positive and negative predictive value for TUS.

Key Results:

- Model 1 (Initial BLCM): In the initial model, median CRSC sensitivity was 0.69 (Credible Intervals (CreI) 0.40-0.97), and specificity 0.95 (CreI 0.92-0.97). Comparatively the median TUS sensitivity was 0.89 (CreI 0.55-1.00) and specificity 0.95 (CreI 0.92-0.98). The CreIs were quite wide (indicating uncertainty) for sensitivity, but were much narrower for specificity.
- There was little effect on TUS sensitivity and specificity estimates when dependency between tests was considered (Model 2); although CRSC sensitivity became much lower (0.48) and there was more evidence of dependency when calves did not have active pneumonia (CreI Covn 0.004).
- The sensitivity and specificity estimates did not vary greatly when taking into account the farming

system (veal versus dairy; Model 3&4).
- Regardless of model used or sample (veal or dairy), credible intervals for sensitivity and specificity overlapped between TUS and CRSC scoring systems

Study Weaknesses:

- No sample size calculation was included in the methods section.
- No reasoning given for including data from these two studies in particular.
- Sample is unlikely to be representative of the target population as data from one of the studies was based on outcomes from just one veal farm.
- Unclear whether TUS and CRSC were independently performed as combinations of the same operators performed both tests (although states TUS operators were blinded to CRSC results).
- Origin of CRSC data in original studies challenging to identify; clear use of CRSC in Berman et al., 2017, however use is not stated in the second original study Buczinski et al., 2018a. The BET authors had to reference the third larger study that the second study data was part of, to confirm CRSC data origins (Buczinski et al., 2018b).
- It would have been preferable to include more detail about general practical approach and husbandry processes performed in both studies of origin, however expected to a lesser extent when previous studies are utilised as data sources and enough detail is included on the latent class analysis in the main study.
- Using the STARD-BLCM reporting guidelines as a basis, there appeared to be a lack of information concerning the definition and rationale of the prior information provided; in particular, the use of non-informative priors for CRSC/TUS. There did not appear to be enough information provided to fully understand and interpret the priors which is vital for accurate assessment of the results.
- Low prevalence of pneumonia in both populations studied, this would have impacted on the precision of the estimates (however the authors of the paper do discuss this).

Attachment:

Evidence appraisal (/soe_attachments/575/4160-Critical appraisal_Berman_23.06.21.pdf)

Cuevas-Gomez et al. (2020) Ireland

Title:	Growth performance and hematological changes of weaned beef calves diagnosed with respiratory disease using respiratory scoring and thoracic ultrasonography
Patient group:	153 weaned ‘suckler’ beef male (n=79) and female (n=74) calves (average age: 209 days old) purchased via 10 auction markets and housed at a research centre in Ireland. 47 were sired by Aberdeen Angus and Hereford breeds and 106 by Charolais and Limousin breeds. The average age of the calves here is much older than the target population of pre-weaned calves this BET is based upon.
Study Type:	Cohort study; however, the BET authors used a diagnostic test critical appraisal sheet to assess the sources relevant to the aim of the BET. The second primary aim of the study was the same as for this BET.

- **Multiple TUS & CRSC case definitions were used:**

- Thoracic ultrasonography (TUS) score (from any scanning site)- TUS score 2 : ≥1cm lung consolidation , TUS score 1: 1+ comet tail artefacts, TUS score 0: no lung consolidation. Measured at day 0, 7, 14, 28.
- Wisconsin clinical respiratory score (CRS) status - measured rectal temperature, cough presence, presence of nasal and ocular discharge and ear position, assigning score 0 (normal) to 3 (very abnormal) to each aspect. CRS positive: total score ≥5, CRS negative: total score <5.
- Combined classification- BRD- con: CRS and TUS score ≥5 with consolidation, BRD-no con: CRS and TUS score ≥5 with no consolidation, sBRD: CRS and TUS score <5.

Outcomes:

- **The following main outcomes were estimated/calculated based upon the above case definitions:**

- Distribution of CRS, TUS scores and combined classification and prevalence of the 5 CRS clinical signs and TUS score 2 at day 0, 7, 14, and 28,
- Pearson correlation coefficient between the 5 CRS clinical signs and lung consolidation (TUS score 2) at day 7, 14, 28.
- Least squared mean haematology variables for healthy, sBRD, BRD-con, BRD-no con groups (e.g. white blood cell (WBC), neutrophil, lymphocyte, basophil, monocyte, eosinophil, red blood cell (RBC) and platelet count, neutrophil:lymphocyte ratio (N:L), %haematocrit and haemoglobin concentration) measured at 7 days before, after and on the day of pneumonia treatment (matched healthy controls selected retrospectively from the nearest pen to compare hematology variables at the same sample times).
- Least squared mean average daily weight gain (ADG) for day 0 to day 28, day 28 to day 65 and overall average daily gain, for healthy, sBRD, BRD-con, BRD-no con groups. Also least squared mean ADG for pre and post pneumonia treatment across groups. Weight measured at day 0, 7, 14, 21, 28, 65.
- Average daily gain estimates for day 0 to day 28, day 28 to day 65 and overall average daily gain, for CRS positive/negative status and TUS positive/negative status (TUS positive: ≥1cm lung consolidation) were performed in a multivariate linear regression model.

Key Results:

- 56% of calves classified as CRS positive had no lung consolidation detected by TUS.
- 28% of calves classified as CRS negative had lung consolidation detected by TUS.
- 50% of pneumonia cases were detected within the first 7 days post-arrival.
- 81% of pneumonia cases detected within the first 14 days.
- Greater number of pneumonia cases detected on the days when both TUS and CRS were used together.
- TUS detected an additional 18% calves that wouldn't have been detected by CRS alone.
- No correlation between percentage of calves with clinical respiratory signs and lung consolidation at days 14 and day 28 (P>0.05).

Study Weaknesses:

- Unknown how representative these animals might be of all beef production systems in Ireland.
- Sample size was not justified with sample size calculation.
- Cranial lung lobes were not accessible to be scanned in this study due to the increased age of calves and resultant detection of pneumonia may have been limited by this.
- All calves were assessed using Wisconsin calf scoring (CRS) and thoracic ultrasonography (TUS)

by the same trained research vet and therefore the assumption is that these assessments were not independent or blinded.

- More details of the statistical methods used would have been preferable. If one of the secondary aims of this paper was to compare these diagnostic tests, it would have been useful to have seen diagnostic indices reported (e.g. sensitivity, specificity etc)
- The incidence of calves with clinical signs of pneumonia was 35% in this study, however animals were vaccinated against major respiratory pathogens on day 0 of the study which may have impacted disease incidence. This smaller incidence may have made the associations drawn between clinical signs, TUS scores and other outcomes measured less credible. However, this is not stated as a limitation by the authors.

Attachment:

Evidence appraisal (/soe_attachments/575/4161-Critical appraisal_Cuevas-Gomez 2020_23.06.21.pdf)

Cuevas-Gomez et al. (2021) Ireland

Title:	Association between clinical respiratory signs, lung lesions detected by thoracic ultrasonography and growth performance in pre-weaned dairy calves
Patient group:	53 male dairy-bred calves (28 Holstein Friesian-Aberdeen Angus cross, on average 24 days old and 25 Holstein Friesians, on average 21 days old) purchased from 13 different farms and hosted at Teagasc, Ireland.
Study Type:	Although the authors state the study design that was used (retrospective cohort study), it is unclear to the BET authors which study design has been used as there are elements of a prospective study reported. Therefore, the diagnostic test critical appraisal sheet was used to assess the sources relevant to the aim of the BET. The second primary aim of the study was the same as for our BET.

- **Mulitple TUS & CRS case definitions were used:**

- Wisconsin clinical respiratory score (CRS) status - measured rectal temperature, presence of cough, ocular and nasal discharge and ear position, with each aspect scored 0 (normal) to 3 (very abnormal) at day 0, 7 and 14. cBRD positive status: fever >39.6 or CRS total score ≥5; cBRD negative status: CRS total score less than 5 or no fever
- Thoracic ultrasonography (TUS) status (from any scanning site) - TUS score 1: normal lung/comet tails; TUS score 2: lung lesion <2cm^2; TUS score 3: lung lesion ≥2cm^2; TUS score 4: consolidated lung lobe/emphysema. TUS performed at day 0, 7, 14 in all calves and between day 14 and 30 in 33/53 calves.

Outcomes:

- **The following main outcomes were estimated/calculated based upon the above case definitions:**

- Distribution of cumulative CRS status and TUS scores recorded from day 0 to day 14 and day 14 to day 30. Frequencies of different TUS scores and of the 5 CRS clinical signs recorded at day 0, 7 and 14.
- Spearman rank correlation performed between each CRS clinical sign and TUS score at day 0, 7 and 14.
- Average daily gain (ADG) - calves were weighed at day 0 and every 14 days following (until weaning, day 53). Estimates for ADG for each TUS score from day 0 to day 30, estimates for ADG for each breed (Holstein Fresian {HF} vs HF x Aberdeen Angus {AA}) and estimates for ADG for different housing type (fan ventilated vs naturally ventilated) were performed in a multivariate linear regression model.

Key Results:

- At 0 - 30 days post arrival, 64% (34/53) calves had lung lesions detected by TUS.
- 44% (15/34) of these calves were not detected by CRS.
- 28% (15/53) of all calves with sub-clinical pneumonia were undetected by CRS alone.
- Weak to moderate correlation between the individual clinical signs of pneumonia and TUS.

Study Weaknesses:

- The number of animals involved in the current study was based on a power calculation for a different study looking at a different outcome (microbiome study), therefore the BET authors are uncertain as to their equivalence.
- It is also unknown how representative these animals might be of all farms in Ireland.
- Assessments for the first 14 days of the trial were stated to have been performed by the same parties and therefore, unlikely to be independent or blinded. In assessments following this point, it is unclear.
- All calves were assessed by both CRS and TUS at day 0, 7 and 14. However, 33 of the 53 calves were then assessed again by TUS during an evaluation between day 14 and 30 with no explanation provided by the authors as to why.
- There is not an accepted validated way of scoring TUS, and therefore although referenced from another study, the TUS method of classification used here could be impacting on the results obtained.
- Individual clinical signs used in the CRS system, not overall CRS scores, were used to compare CRS and TUS for some of the data analysis. This was apparent in Spearman rank correlations performed between each CRS clinical sign and TUS score at day 0, 7 and 14. Assessing clinical signs individually is not a previously validated system that is proven to be correlated to pneumonia and hence the two assessment methods (CRS and TUS) have not been directly compared in this analysis.

- Limitations of the study were not discussed by the authors.

Attachment:

Evidence appraisal (/soe_attachments/575/4162-Critical appraisal_Cuevas-Gomez 2021_23.06.21.pdf)

Comments

It should be acknowledged that not all studies appraised assessed the pre-weaned age group (Cuevas-Gomez et al., 2020) and hence performance of TUS and CRS/CRSC in these animals may not be directly comparable to performance of these tests in the chosen age group of risk in the BET scenario. The scenario is based upon a common circumstance of purchasing and rearing young pre-weaned calves of mixed breed (although pneumonia develops commonly in the weaned calf and fattening stock); the pneumonia risks associated with the pre-weaned calf are often related to stress after transport and mixing, poor environmental management, alongside lesser immunity from poor colostrum management on the farm of origin. The original PICO question was formulated to investigate performance of these tests in calves of all age groups. However, following completing this BET, it has become apparent that it is possible that TUS and CRS/CRSC characteristics may be different between younger and older patient groups due to obvious differences in size and resultant TUS scanning technique practicalities (such as an inability to scan the cranial lung lobes in older calves, as in Cuevas-Gomez et al., 2020). Further work to investigate this would be beneficial.

Methods of diagnostic testing used across studies were often not explicit. It is also worth noting that there is no universally recognised, TUS scoring system as there is for the Wisconsin calf scoring system. Although every study appraised referenced the practical TUS approach used, there is no standardisation between studies concerning technique used (*i.e.* location and method of TUS) or classification of a ‘positive’ lesion. The studies found were based in North America and Ireland; differences may exist between TUS techniques used in different countries. Therefore, extrapolation of outcomes to clinical practice in other countries may be challenging.

Aetiology of calf pneumonia was not investigated in any of the studies critically assessed here. It is possible that different aetiologies may lead to differing thoracic lesion sites and features, therefore impacting performance of TUS in studies where only a restricted site of the thorax was scanned. Aetiology may also differ between countries, again making extrapolation of outcomes more challenging. Additionally, the relationship between TUS and CRS/CRSC does not seem to be well correlated. One explanation may be TUS is more efficient at detecting disease, or that clinical signs are associated with early respiratory disease and conversley that TUS is associated with later stage respiratory disease. Cost of procedures will also play a role and therefore cost analysis would be useful to undertake.

Finally, it is apparent in most of the studies that the prevalence of pneumonia in the study population was low, with no tangible power calculations to support sample size in any of the studies. This ultimately does make it more difficult to draw definitive conclusions from this work.

Bottom line

There is some evidence to suggest that TUS could be more accurate generally for detection of pneumonia in calves, however due to different study design issues across all papers and the points listed above, this is difficult to definitively conclude from this BET.

Although not the focus of this BET, there may be value in

investigating the combined use of TUS and CRS in specific circumstances to maximise identification of cases, but would require further investigation.

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