

Lung U/S Correlates to Chest X-ray and Other Changes in a Swine Model of ARDS/Septic Shock

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Introduction

► **Acute respiratory distress syndrome (ARDS)** is a severe form of acute lung injury that contributes to 10-15% of all critical care admissions, causing significant morbidity and mortality (40%). Early diagnosis is critical for improving ARDS prognosis by employing therapeutic measures, thus an easy to use and highly accessible diagnostic method is needed to aid in this goal.

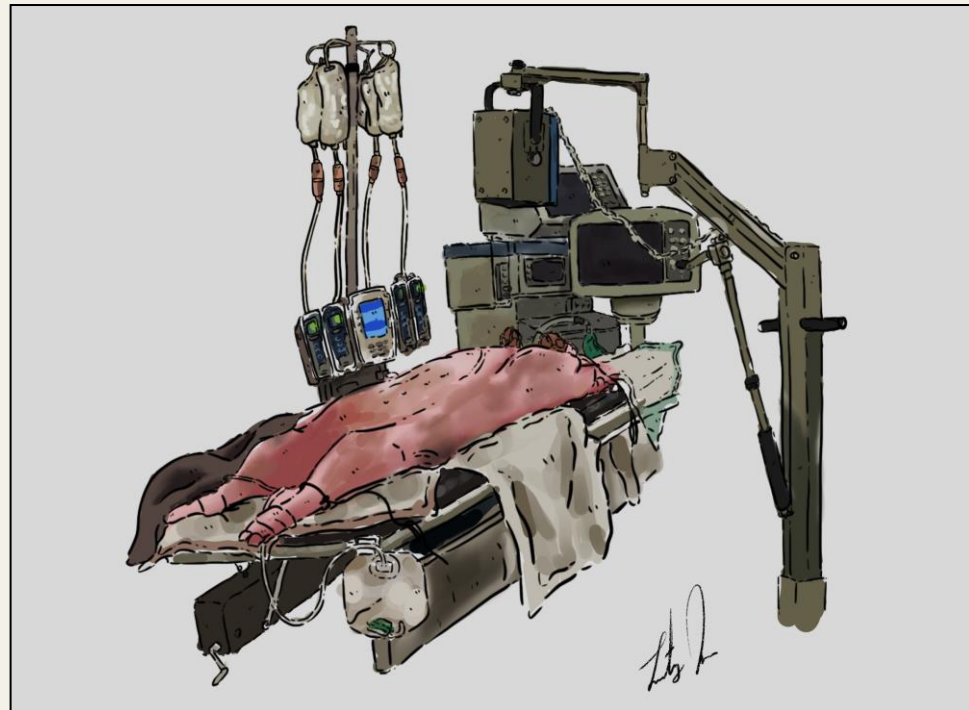
► **Chest x ray** and CT have been used as the predominant method of imaging in ARDS, however their use is not without problems or compromise.

► **Bedside lung ultrasound (LUS)** has emerged as a viable and valuable imaging technique for the diagnosis and evaluation for ARDS as it decreases radiation exposure, allows for bedside imaging without the need to leave the ICU, allows for dynamic imaging, and potentially has increased sensitivity/specificity when compared with CXR.

► We developed a relevant **48 hr Swine ARDS/Septic Shock Model** to help assess ARDS disease progression via LUS vs. CXR, and optimize scoring methodology for improved ability to diagnose and track disease worsening or improvement.

Methods

► **ARDS swine model (triple hit):** Yorkshire swine, **bacterial sepsis, aspiration and ventilator-induced lung injury (VILI)**. Sedated/intubated swine (n=3) given 1hr IV infusion of cecal slurry (8×10^7 CFU; from donor pig), followed by autologous gastric fluid pulmonary administration into the **right lower lobe** (30ml) and **left lower lobe** (30ml) lobes via bronchoscopy, and VILI induction started with $V_T > 15 \text{ ml/kg}$ to achieve PIP of 35-45cm H_2O until compliance was $< 30 \text{ ml/cmH}_2\text{O}$, then by lung protective ventilation.



► **ICU Care; 48hrs continuous** intubation, mechanical ventilation (PEEP 5-18, V_T – 6-8 ml/kg, FiO_2 21-100%), general anesthesia (propofol, fentanyl, precedex, versed CRI via CVC), IV fluids (D5/NS) with total fluids at 2ml/kg/hr, blankets/warmer, vasopressors as needed (norepinephrine, epinephrine, vasopressin), NS/LR fluid boluses as needed, antibiotics (Unasyn and Metronidazole, IV) from 3 hrs post cecal slurry then q6, steroid (methylprednisone, IV 60mg/dose) when 3rd pressor is started then q6, airway suctioning q1 hr, and ARDSNet PEEP titration protocol. For hyperkalemia (pm): Calcium gluconate, insulin with D50 infusion. Amiodarone and Lidocaine (pm) for arrhythmia.

OLD LUS SCORING METHOD	
Lung U/S Score	Definition
0	A lines only, or <2 B lines, plus regular sliding
1	3 or more B-lines
2	Coalescing B-lines
3	Hepatization / consolidation

- NEW LUS SCORING METHOD -					
*** The Harral Method ***					
B-lines Score		Consolidation Score	Pleural Effusion Sum of the areas of effusion (height x width) in cm ²		
0	None	0	No consolidation	0	None
1	1 - 3 B-lines; No coalescence	1	Minimal Consolidation; < 25% of field	1	Minimal Effusion; < 0.3 cm ³
2	>3 B-lines; Possible coalescence in < 50% of field	2	Mild Consolidation; > 25 but < 50% of field	2	Mild Effusion; ≥ 0.3 but < 1.0 cm ³
3	>3 B-lines; Coalescence is present in > 50% of field	3	Moderate Consolidation; >50 but < 75% of field	3	Moderate Effusion; ≥ 1.0 but < 2.0 cm ³
4	>3 B-lines; Coalescence is present – flashlight pattern (>50% of field)	4	Full Consolidation; >75 – 100% of field	4	Minimal Effusion; ≥ 2.0 cm ³
***Report on the worst condition seen within the cine-loop					
***Score all 12 regions separately					
*** Lung Slide evaluated separately as Yes/No, and is not a part of the scoring system					

Figure 1. Old and New lung ultrasound scoring methods to evaluate severity of acute lung pathology

► **Vitals (pOx, HR, temp, EtCO₂, BP)** were continuously monitored with invasive blood pressure monitoring via a femoral arterial line. **Urine Output** was measured hourly via Foley catheter. Blood draws (for ABG, CBC, CMP) were conducted q1-3 hours pre and post ARDS induction. Pulmonary function was recorded every 15 minutes off the Drager Evita 2 ventilator (Compliance, Resistance).

► **Lung Ultrasound (LUS)** was performed at 12 regions (see **Figure 3**) via Phillips U/S, and chest x-rays were taken every 6 hours following ARDS induction, and scored via RALE scoring system.

► **Euthanasia/Necropsy:** at 48 hours or earlier. Bronchoscopy with BAL from all lobes, ABG, CMP, CBC, blood culture, LUS, CXR, full organ procurement for freezing and 4% PFA fixation - histopathology.

Results

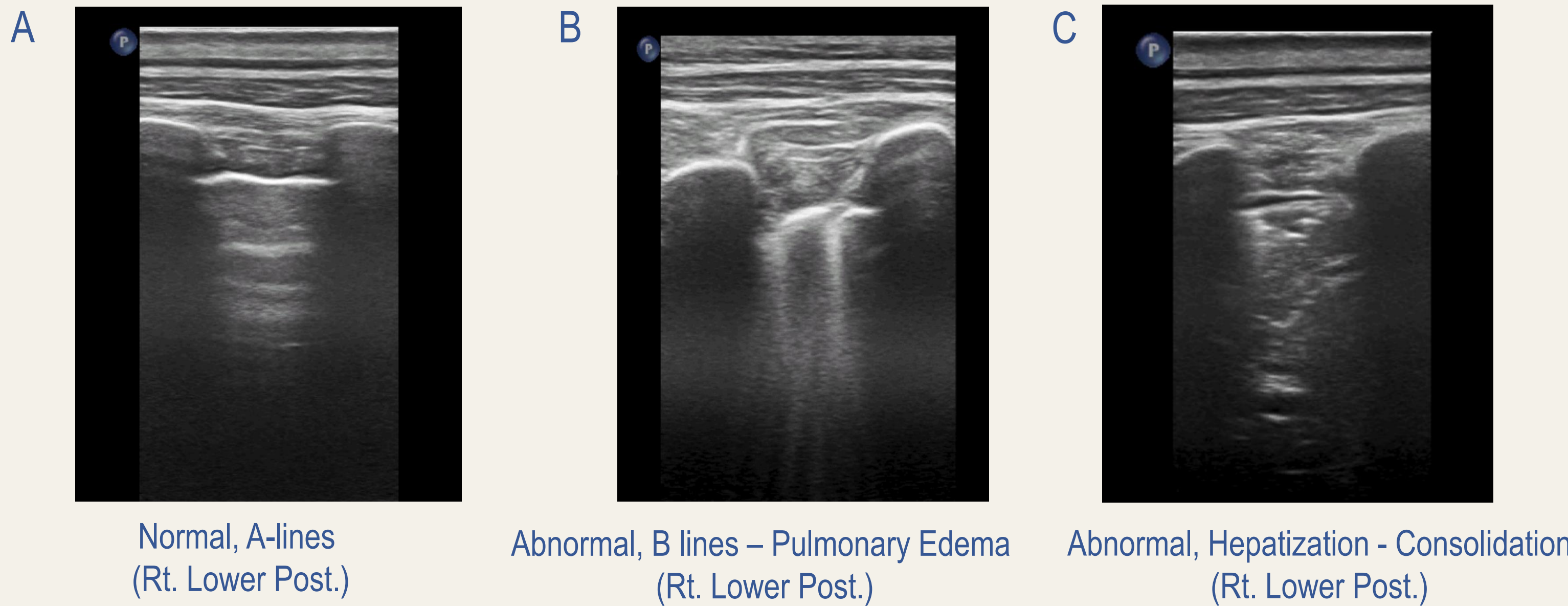


Figure 2. Lung Ultrasound pictures of Normal A=lines (A), and Abnormal numerous B lines (B) and lung hepatization (C).

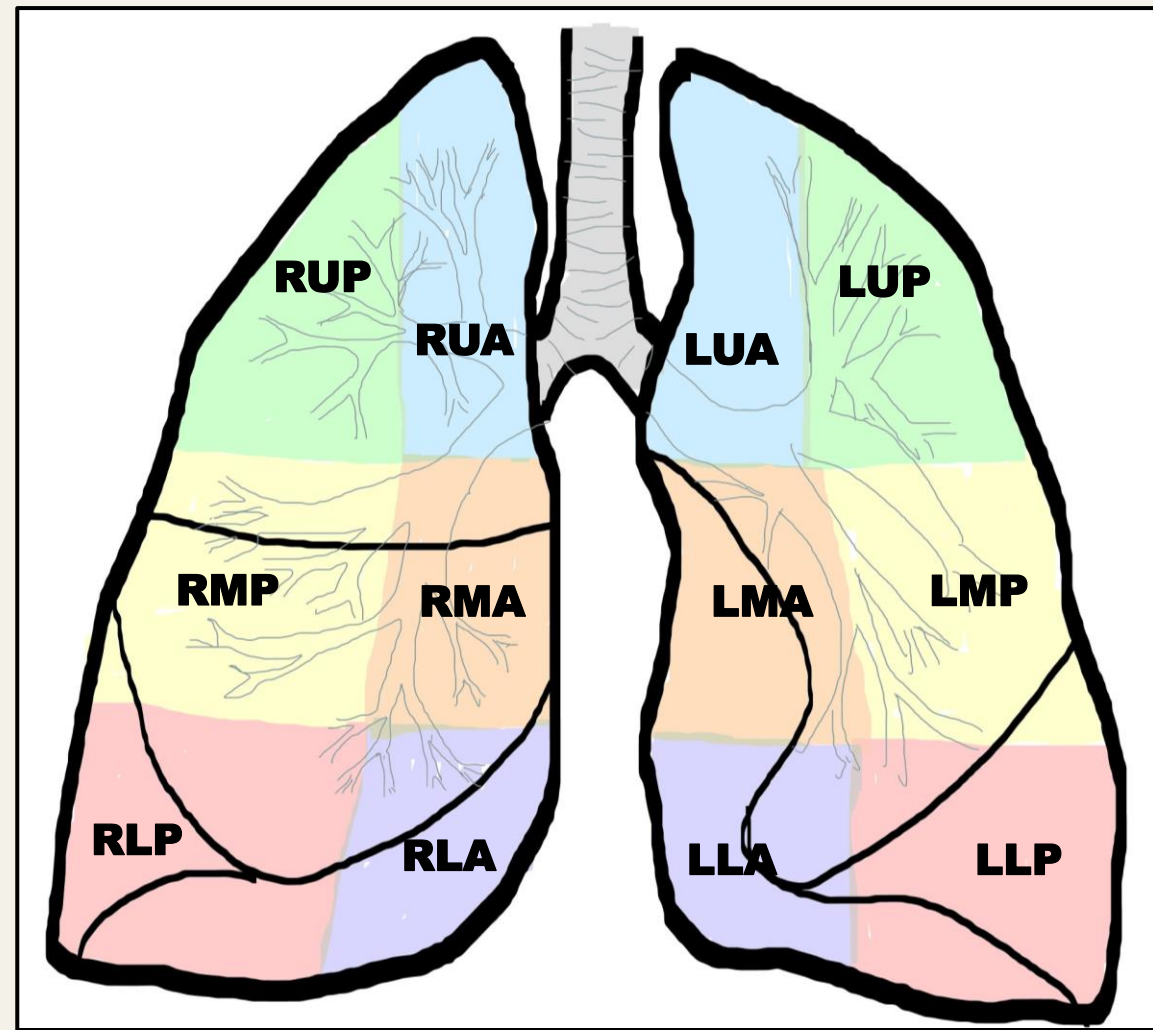


Figure 3. LUS location lung diagram. R=right/ L=left. U=upper/M=middle/L=lower. A=anterior/P=Posterior

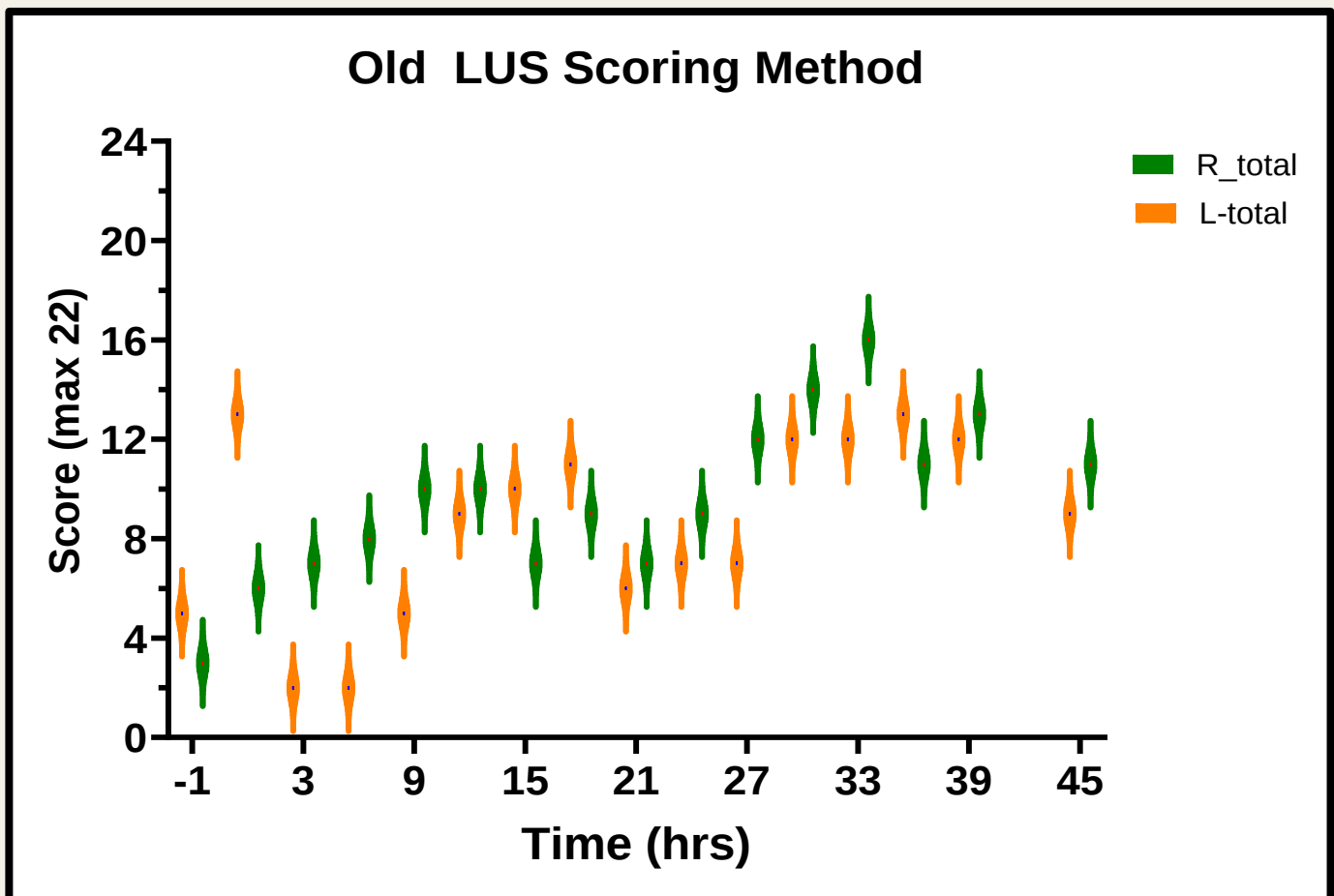


Figure 4. Old LUS Scoring Method (Total). Total LUS score of 12 regions for one representative ARDS animal over 45 hours.

NEW HARRAL LUS SCORING METHOD

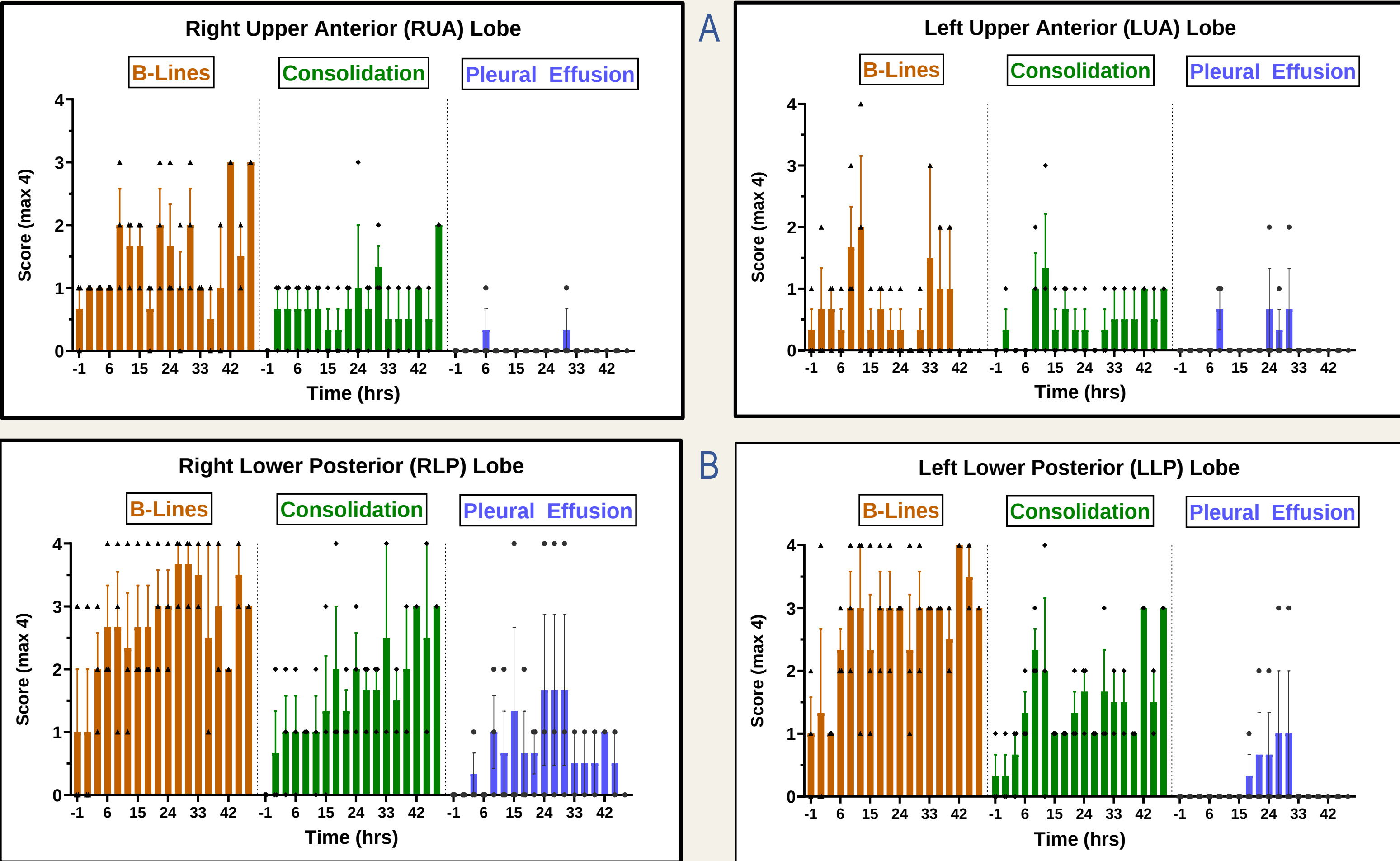


Figure 5. New Harral LUS Scoring Method with Sub-scores for B-lines, Consolidation and Pleural Effusions. (A) Right and Left Upper Anterior lobes (no direct gastric fluid). (B) Right and Left Lower Posterior lobes (direct gastric fluid administered). Mean + SEM. N=3

Results

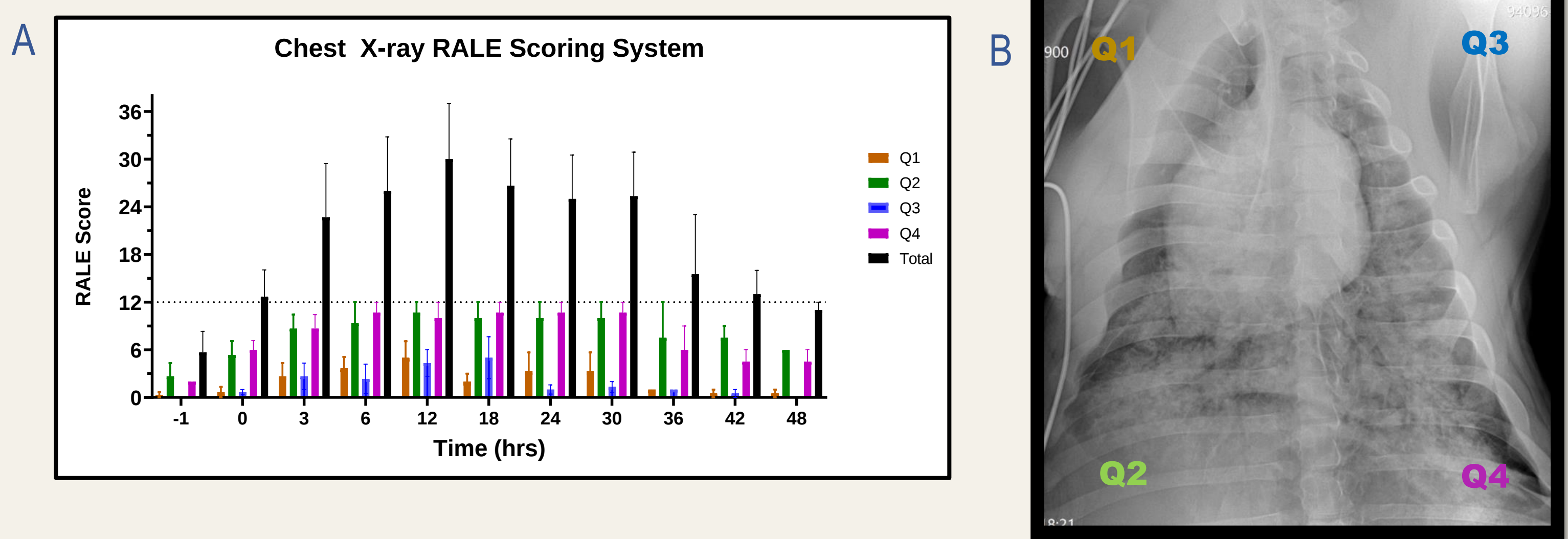


Figure 6. RALE scoring system on pig ARDS CXR every 6 hours after induction (A). ARDS CXR from 24hrs (B) shows each quadrant (Q1, Q2, Q3, Q4) scored over time.

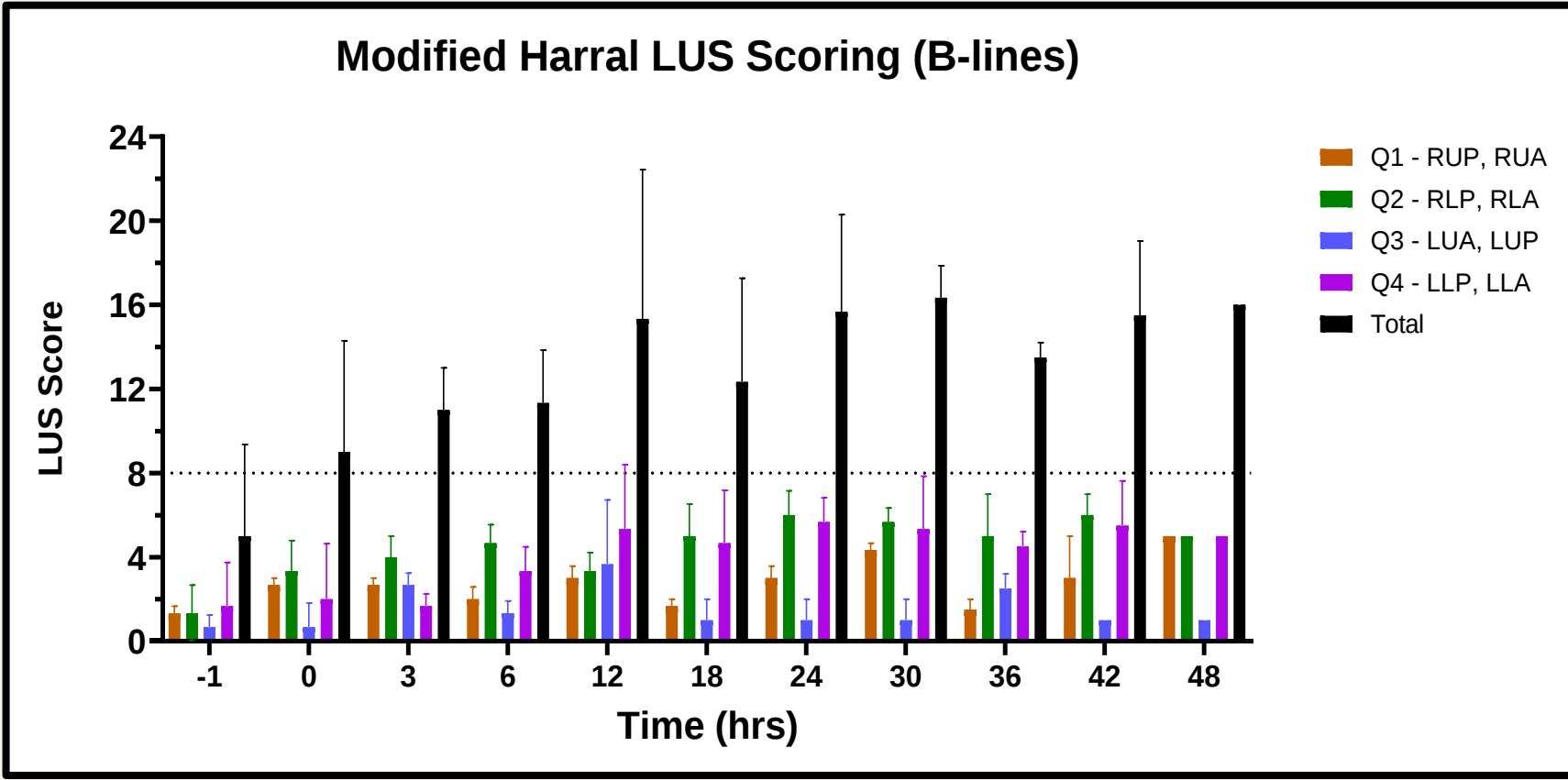


Figure 7. Modified Harral LUS scoring in ARDS pig, correlated with B-lines. The correlation coefficient for Total Harral LUS B-score vs. Total RALE CXR score is $r=0.4580$.

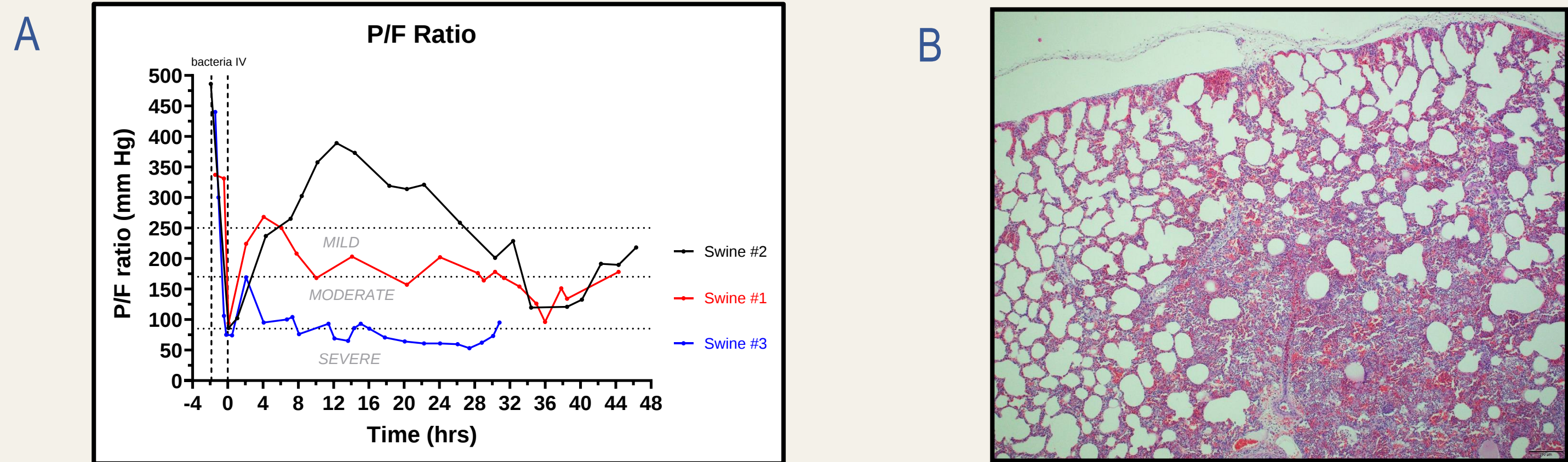


Figure 8. ARDS swine model P/F ratio over time (A), and Histopathology (B) of ARDS lungs at 45 hrs.

Conclusion

- Progressive ARDS development in this swine model was easily tracked with bedside LUS, and showed the most severe changes in the posterior lower lobes (where gastric fluid was instilled).
- The New Harral LUS Scoring method differentiates pleural effusions, B-lines and consolidations in great detail.
- Chest X-ray RALE scores track with Modified Harral LUS Scores the best.
- P/F changes worsened over time in all swine, as well as ARDS lung histology.

Contact

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