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Mechanical properties of the premature lung

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Abstract & Motivation

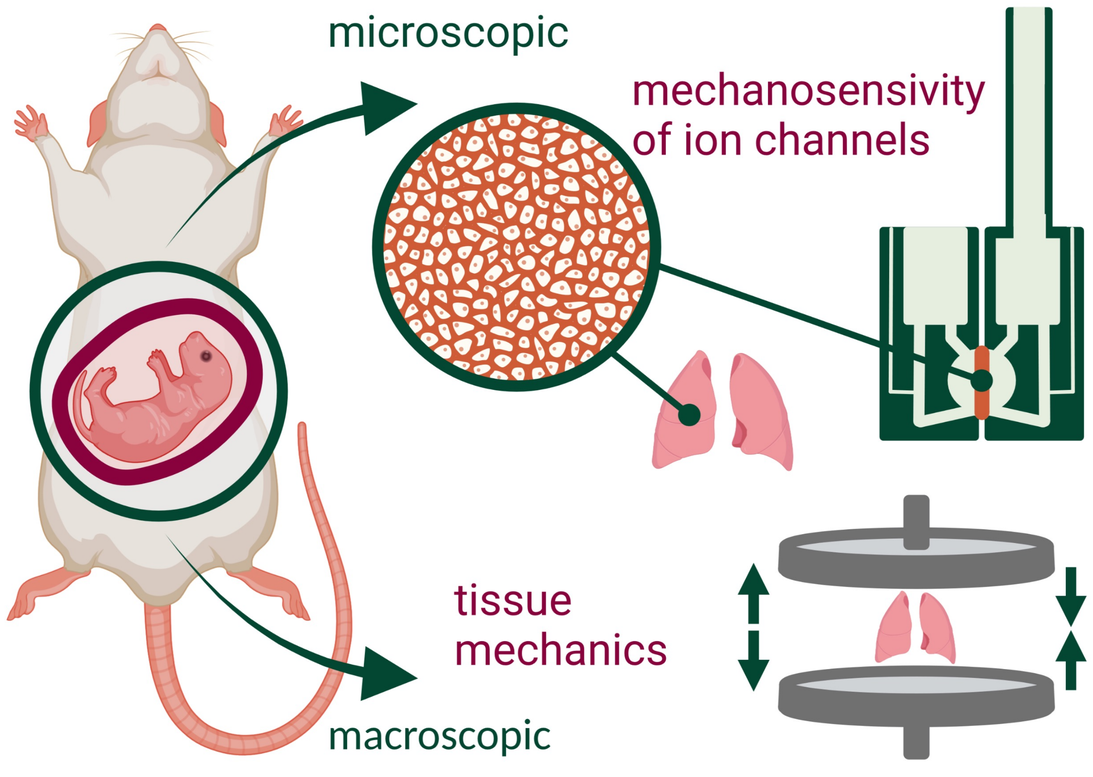

Figure 1. Lungs of premature rats were used as primary fetal distal lung epithelial (FDLE) cells for electrophysiology experiments with different hydrostatic pressure gradients (top) and for rheology tests in compression and tension at different deformation velocities to study the effect of mechanical stress on the immature lung (bottom).

- Why can **inflation** of the lung during **mechanical ventilation cause respiratory damage** – especially in preterm infants?[1-3]
- **Mechanical properties** of the vulnerable lung of pre-term infants are almost **unknown** compared to adult lungs[4-11]
- **Mechanical ventilation** is a life-saving therapy for premature infants suffering from respiratory distress syndrome (RDS)
- Prolonged ventilation and related mechanical load may cause **subsequent pulmonary diseases** such as bronchopulmonary dysplaisa

Methods

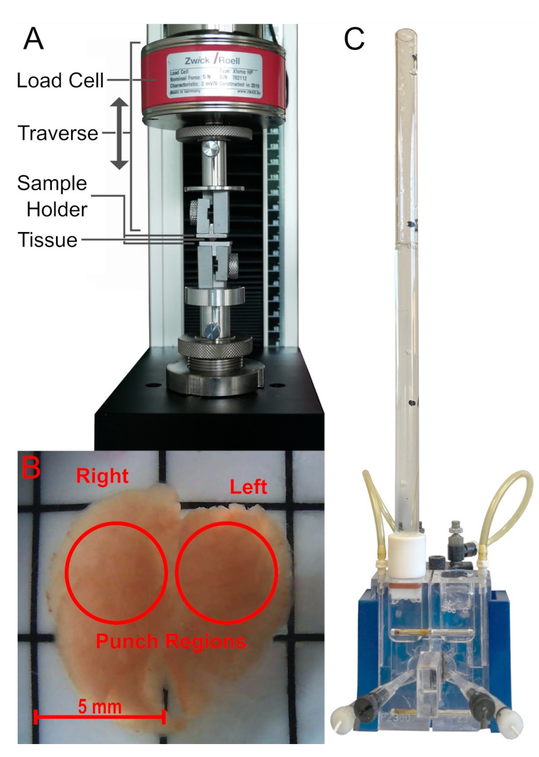

Figure 2. Images of the mechanical testing machine including load cell, as well as the self-designed sample holders (A), the fetal rat lung after harvest (B) and the Ussing chamber with the applied fluid columns (C).

Rheology of Fetal and Adult Lungs

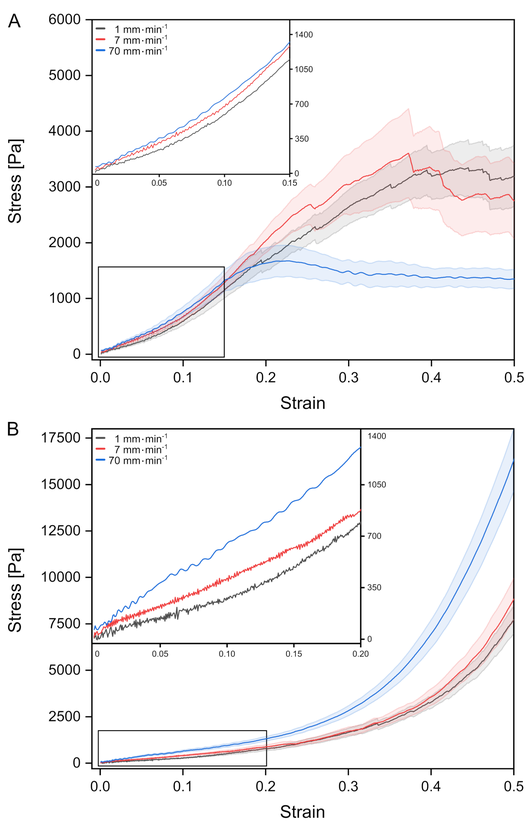

Figure 3. Stress-strain behaviour of fetal rat lung tissue samples under tension (A) and compression (B).

- Linear behavior into nonlinear overbending (**hyperelastic**)
- Young's moduli by **linear regression** or **van der Waals model**
- Deformation-rate dependence in compression (**viscoelasticity**)
- Impact of surfactant with rinsed adult lungs
- **Fetal lungs stiffer than adult lungs**

Fetal lungs are much **more vulnerable during inflation by mechanical ventilation** compared to normal inspiration.

Ussing Chamber

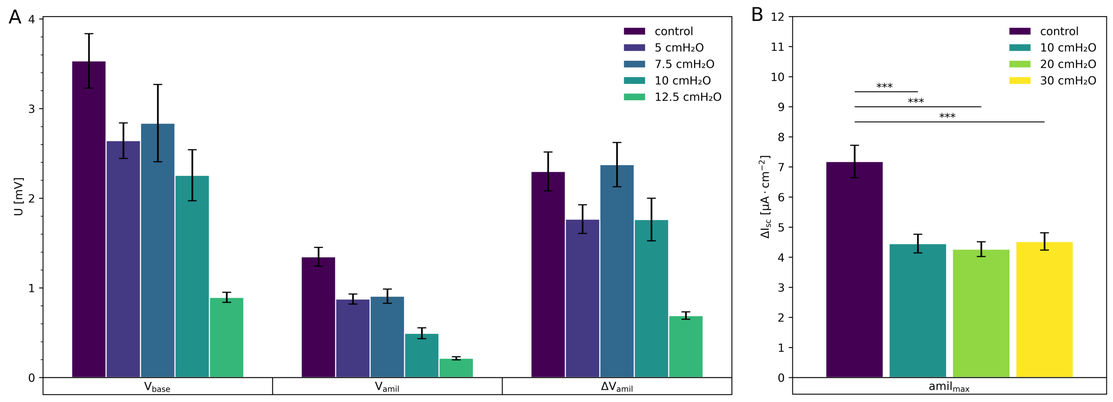

Figure 5. Data obtained from Ussing chamber experiments of FDLE cells with increased hydrostatic pressure. Column diagram of (A) amiloride inhibition with basolateral fluid columns, (B) amiloride inhibition ($amil_{max}$) with apical fluid columns. *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$

- Effect of **hydrostatic pressure** gradients on cellular function and vectorial **Na^+ transport** via ENaC and Na,K-ATPase
- Hydrostatic pressure affects **epithelial integrity** (reduced R_{te})

Positive pressure might **impair ion channel activity** and affect fluid regulation being detrimental for preterm lung function

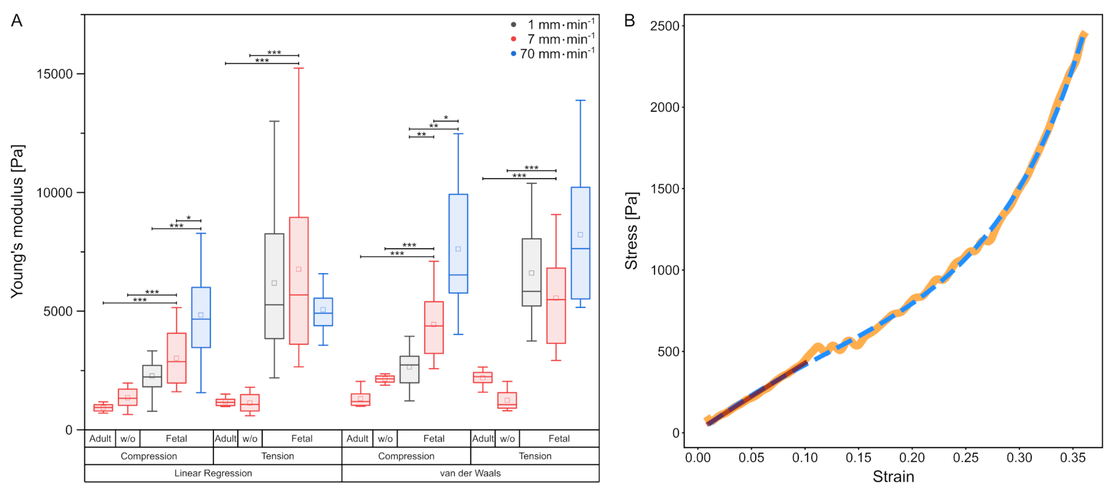

Figure 4. (A) Boxplot of Young's moduli determined by linear regression, as well as the van der Waals model. Underlying data were obtained from compression and tension tests of fetal and rinsed (w/o) and unrinsed adult rat lung. (B) Comparison of linear regression (red) with the van der Waals model (blue dashed) on experimental data (orange). *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$

Conclusion

- Lungs of early neonates have an **increased risk of damage** and ventilation-induced injury
- Future studies on structural differences of fetal vs. adult **ECM components**
- Development of new strategies for **safe respiratory support** in preterm infants[12]

References

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DFG Deutsche Forschungsgemeinschaft

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