Mechanics and histology of lung tissue from ARDS animal models

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Abstract

Introduction: Acute respiratory distress syndrome (ARDS) is a severe condition that affects lung parenchyma, often necessitating mechanical ventilation to ensure adequate oxygenation. Clinicians typically observe reduced lung compliance in ARDS patients, indicating a greater difficulty in lung inflation. This observation qualitatively suggests alterations in the mechanical properties of lung tissue affected by ARDS. However, to our knowledge, this change in mechanical properties has not been quantitatively assessed nor correlated with changes in tissue composition (e.g., cellular content, elastin, collagen).
Materials & Methods: To address this gap, tensile tests were conducted on tissue samples collected from ovine models with ARDS. Samples were excised within 8 hours post-euthanasia, with six samples taken per animal on 6 animals from the top, middle, and bottom regions of each lung, reflecting varying degrees of pathology. Cyclic loading tests were applied to the samples, consisting of 10 cycles to 20% strain followed by 10 cycles to 40% strain at a strain rate of 5% per second to approximate physiological conditions. The stress-strain curves for each sample were characterized by measuring maximum stress, tangents at 15% and 35% strain, and strain energy. Additionally, biopsies adjacent to the tensile test samples site were collected for histological analysis using four types of staining-Hematoxylin and Eosin, Masson's trichrome, Reticulin, and Orcein-to reveal different structural components: cellular content, type I and type III collagen fibers and elastin respectively.

Results: The stress-strain curves align with those reported in previous studies in the literature (1) (2). The tensile test results indicate minimal viscoelasticity, consistent with recent findings from lung biaxial testing (3). Qualitative observations of histological images show that the uppermost samples look more oxygenated than samples retrieved from the bottom parts of both lungs. Preliminary findings indicate that samples from the least oxygenated lung regions exhibit lower stiffness than tissue from healthier areas. Specifically, samples from poorly oxygenated regions show lower tangents (0.32 vs. 0.45 MPa at 20% strain), maximum stresses (5.3 vs. 7.0 kPa at 20% strain), and strain energies (0.13 vs. 0.20 MPa.% at 20% strain), correlating with histological observations of reduced oxygenation .

Discussion & Conclusion: These preliminary results appear paradoxical when compared to clinical observations, as intensivists report that these poorly oxygenated regions are the

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most challenging to inflate. A potential explanation is that in the early stages of ARDS, the resistance to alveolar inflation may stem not from intrinsic tissue stiffness but from increased surface tension due to fluid accumulation, potentially impairing the surfactant's function in reducing surface tension. However, given the limited sample size and current reproducibility of our experiments, these findings require further validation through additional studies.

(1) J. B. Karlinsky, "Stress-strain characteristics of normal and emphysematous hamster lung strips," Respiration Physiology, vol. 90, pp. 251-260, 1992.

(2) S. R. Polio, A. N. Kundu, C. E. Dougan, N. P. Birch, D. E. Aurian-Blajeni, J. D. Schiffman, A. J. Crosby et S. R. Peyton, "Cross-platform mechanical characterization of lung tissue," PLOS ONE, vol. 13, October 2018.

(3) T. M. Nelson, K. A. M. Quiros, E. C. Dominguez, A. Ulu, T. M. Nordgren, M. G. Nair et M. Eskandari, "Healthy and diseased tensile mechanics of mouse lung parenchyma," Results in Engineering, vol. 22, p. 102169, 2024.