Lung Surfactant & Acute Respiratory Distress Syndrome

- Lung surfactant (LS): surface active multicomponent mixture of lipids and proteins
- Reduces surface tension in lung, \( y \) \( \rightarrow \) decreases energetic cost of breathing
- Arterial-venous oxygen difference (AVDO2) > 20 mmHg
- \( \dot{V} \) < 10 µm³

DPPC Monolayer Phase Behaviour & Rheology

- Dipalmitoylphosphatidylcholine (DPPC): most abundant lipid in LS
- Monolayer morphology:
  - Low surface density / surface pressure \( \rightarrow \) liquid expanded (LE)
  - High surface density / surface pressure \( \rightarrow \) liquid condensed (LC)
- \( \Pi = 5 \times 10^{-5} \) mN/m

Penetration of DPPC Monolayer by Fibrinogen

Experimental procedure:

1. DPPC monolayer compressed to initial surface pressure \( \Pi_i \)
2. Fibrinogen added to subphase
3. Measure \( \Pi \) and rheology

- Interfacial viscoelastic modulus: \( G', G'' \)
- \( \Pi \) increases immediately, moduli increase after onset time
- Initial monolayer LE or at consistency \( \rightarrow \) 3 orders of magnitude increase in \( G', G'' \) \( \rightarrow \) End state: mixed response \( G' \approx G'' \)
- Initial monolayer LC \( \rightarrow \) Small increase in \( G', G'' \) \( \rightarrow \) End state: viscous response \( G' > G'' \) \( \rightarrow \) Mixed monolayer retains DPPC-like character
- Observe evolution of morphology via fluorescence microscopy

Fibrinogen Adsorption From Solution

- Fibrinogen: serum protein responsible for blood clotting
- Surface active: adsorbs from solution, molecular orientations depend on bulk concentration [5]

Interfacial Microbutton Microheology

- Measure response of amphiphilic, ferromagnetic microbutton probe to sinusoidal magnetic field
- \( t(t) = mB_0 e^{\omega t} \)
- \( \delta(t) = \theta_0 e^{\omega t - \delta} \)
- Complex rotational resistance in high Bocquingy number limit:
  \[ G_S' + iG_S'' = \frac{mB_0}{\theta_0 \omega \tau_\delta^2} \left( \cos \delta + i \sin \delta \right) \]

Conclusions

- More elastic
  - \( G' > G'' \)
- Mixed response
  - \( G' \approx G'' \)
- More viscous
  - \( G' > G'' \)

DPPC \( \rightarrow \) viscous dominated interfacial rheology

Fibrinogen \( \rightarrow \) elastic dominated interfacial rheology

Mixed monolayer response depends on initial surface pressure \( \rightarrow \) fibrinogen preferentially adsorbs to liquid expanded DPPC

Fibrinogen likely a direct cause of lung surfactant inactivation

References