I&E Summer Scholar Research Program

Image Boundary and Geometry Algorithm to Determine Surface Tension

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STEVENS INSTITUTE of TECHNOLOGY
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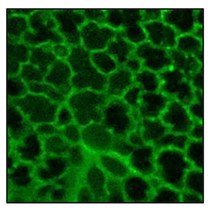
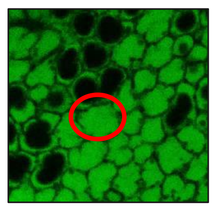
I&E Summer Scholar Poster Conference

Pulmonary Edema and ARDS



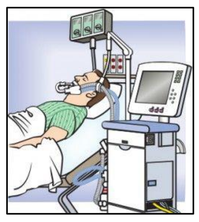
Normal Lung

Injury and Inflammation → Leaky capillaries



Edematous Lung (ARDS)

Alveoli are flooded, ST ↑ → Hard to breathe



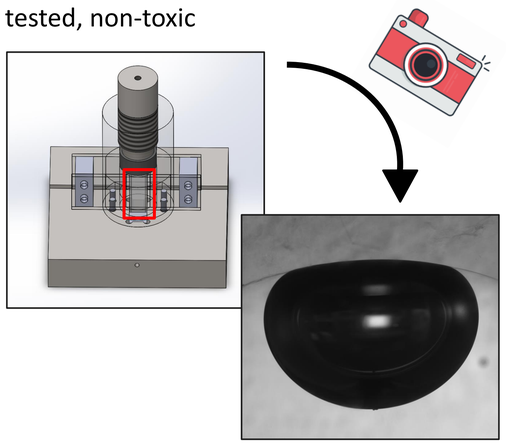
Mechanical Ventilation

- Pulmonary edema has many causes, such as:
  - heart disease
  - infections
  - drug reactions
  - direct lung injury
- Advanced stage is ARDS with **~200,000 patients in the US per year and a >35% mortality rate**
- Traditionally treated with mechanical ventilation
  - Over distends lungs
  - Further injury, proportional to raising of surface tension
- **How can we lower surface tension as an alternative therapy?**

SRB and Surface Tension

Sulforhodamine B (SRB)

- **Sulforhodamine B (SRB) has been shown to lower surface tension in animal models**
- Improves efficacy of native lung surfactant, which normalizes surface tension in healthy lungs
- Heavily tested, non-toxic
- **How does SRB interact with native surfactant?**
- Captive bubble surfactometer (CBS) is used to model a single alveoli
  - Air bubble inserted
  - Different surfactant compounds with SRB inserted
  - Picture taken to see effect on surface tension component by component

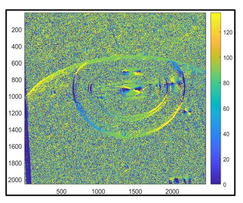


Quantifying Surface Tension Through Image Analysis

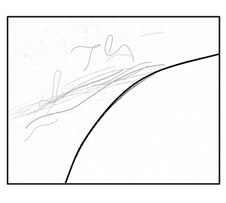
Phase 1: Edge Detection

1. 

Blurring filter is applied to reduce background noise

2. 

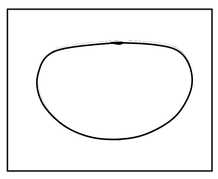
Gradient magnitude and direction identified to find biggest changes in color intensity

3. 

Non-maximum suppression to preserve darker possible edge points only

4. High Threshold ≥ 90% of darkest pixel
   Low Threshold = High Threshold/2
   Edge ≥ High Threshold

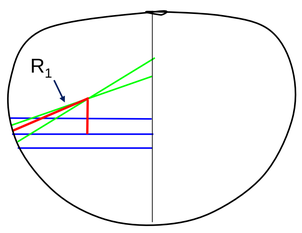
Intensity thresholding to further isolate dark edge points

5. 

Blob analysis to binarize image and produce a black boundary

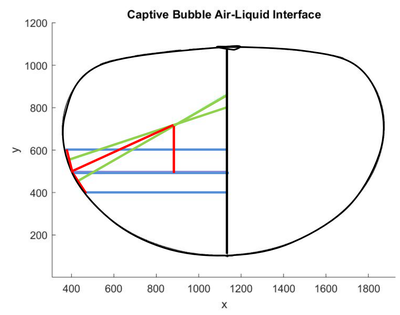
Phase 2: The Laplace Relation

Laplace Relation: $\Delta P = P_{air} - P_{liquid} = T(1/R_1 + 1/R_2)$



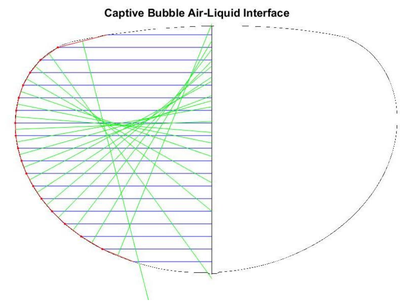
- Laplace Relation applied to find surface tension using 2 radii
  - R1 found from image
  - R2 found from system of equations derived from Laplace Relation
- Solve for T, **see if surface tension is lowered in surfactant component - SRB interaction**

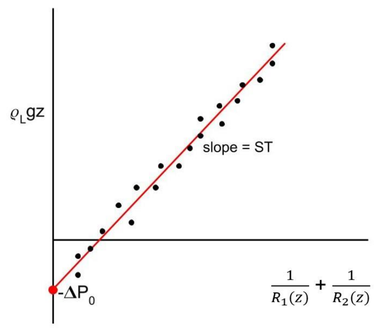
Progress and Next Steps



Step 1: Done
Create an algorithm in MATLAB to automatically detect the boundary of a captive bubble image and find R1 and R2 at one point on the boundary/air-liquid interface.

Step 2: In Progress
Modify this algorithm to find R1 and R2 at every point on the boundary. R1 still needs to be found, which will then produce the geometric relations needed to find R2.





*Expected line plot, not actual data

Step 3: Next Step

$$\boldsymbol{\rho_L g z = -\Delta P_0 + T\left(\frac{1}{R_1(z)} + \frac{1}{R_2(z)}\right)}$$

Plot a regressive equation of the surface tension at every n^{th} point on the interface and study the relationship between the Laplace Relation variables.

Market and Potential Applications

- Once we know how SRB improves the efficacy of native surfactant, it can be made into an **intravenous drug for clinical applications**
- The pulmonary drug delivery market is projected to be worth **50.3 billion by 2023**

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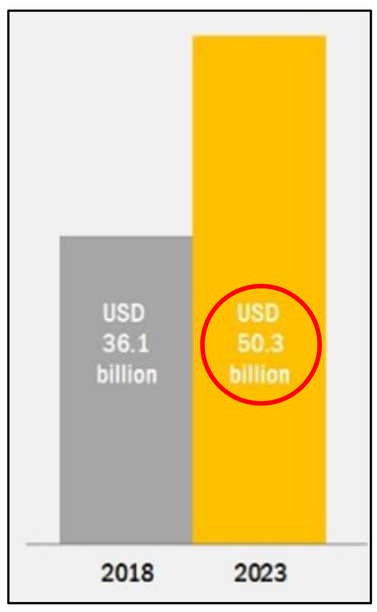

IP and Patent Potential

- CBS designs are modifications to existing patents
- Surface tension determination methods are modifications to, and optimizations of, existing patents
- **Potential to patent or trademark this overall process, or a resulting drug/treatment method**