



Department of
Biomedical Engineering
UNIVERSITY OF WISCONSIN-MADISON

Flow Limitation During Forced Expiration in an Airway Model

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Client: Dr. Chris Green

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Overview

- Problem Statement
- Background Information
- Previous Work
- Product Design Specifications
- Material Design
- Alveoli Design
- Airway Design
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- Final Design
- Acknowledgments
- References



Problem Statement

- High chest pressure causes choke point
- EPP
- Asthma, chronic obstructive pulmonary disease (COPD), cystic fibrosis
- Premature collapse
- Replicating branching airway
- Educational video

Flow Limitation

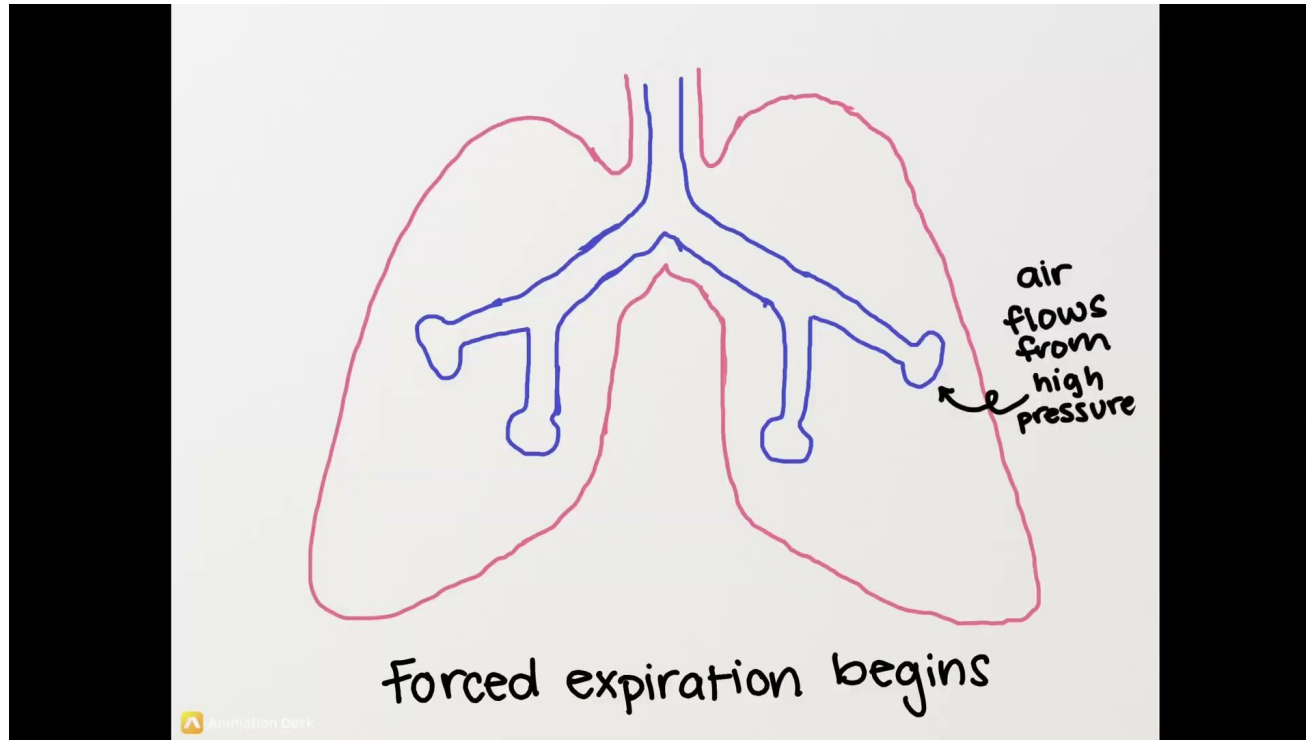


Figure 1: Stop Motion of a simplified airway system undergoing flow limitation

Background

- Client: Dr. Chris Green
 - Pediatric Doctor at UW Health
 - Division of Pulmonology and Sleep Medicine [1]
- Previous BME 400 Project in Fall 2025 and Spring 2026
 - Unable to visibly view flow limitation in previous model
- Competing Models
 - Polak and Yutchen Computation Model
 - Model built by the department of Mechanical Engineering at Yamaguchi University



Figure 2. Dr. Chris Green [1]

Product Design Specifications

- Visibly demonstrate flow limitation during forced expiration
- 3D-printed model that stays in ECB
- Final 6 - 10 second teaching video
- Two/Four Compartment Model
- Branch material thinner and more flexible
- Reuse last year's box
- Budget < \$1000

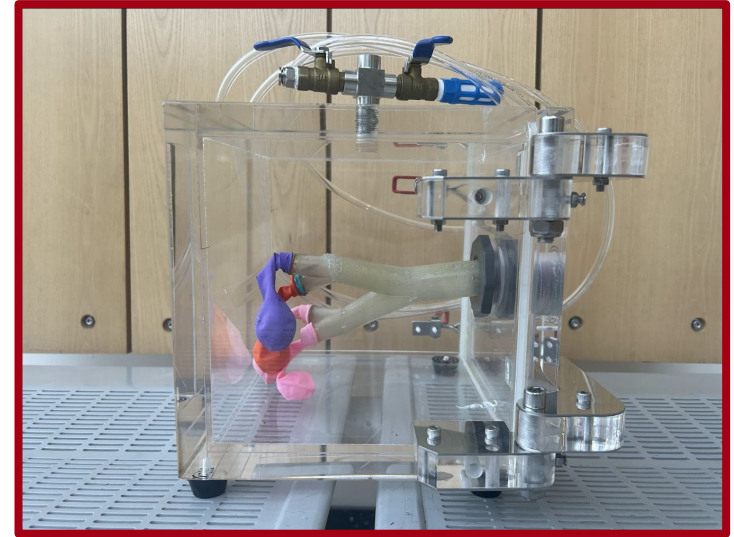


Figure 3: Current Prototype

Material Design Options

Design 1: Flexible 80A Resin



Figure 4: Flexible 80A [2]

- Shore hardness: 80A
- Tensile strength: 8.9 MPa
- Material used in previous project

Design 2: Flexible 50A Resin



Figure 5: Flexible 50A [3]

- Shore hardness: 50A
- Tensile strength: 3.4 MPa
- Better elasticity

Design 3: MoldStar 31T Silicone



Figure 6: Mold Star 31T Silicone [4]

- Shore hardness: 30A
- Tensile strength: 2.9 MPa
- Challenging fabrication

Material Design Matrix

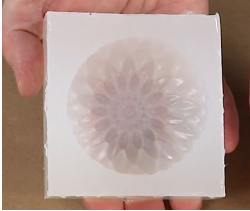
		Design 1: FormLabs Flexible 80A		Design 2: FormLabs Flexible 50A		Design 3: Smooth-On Mold Star 31T Silicone	
							
Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Flexibility	35	3/5	21	4/5	28	5/5	35
Ease of Fabrication	30	4/5	24	4/5	24	2/5	12
Strength and Durability	15	5/5	15	4/5	12	3/5	9
Size Restriction	10	2/5	4	2/5	4	3/5	6
Price	5	3/5	3	3/5	3	2/5	2
Transparency	5	4/5	4	3/5	3	2/5	2
Total	100	71		74		66	

Figure 7: Materials Design Matrix

Alveoli Design Options

Design 1: Water Balloons



Figure 8: Water Balloons [5]

- Small, affordable, reasonably high elasticity
- Lower durability

Design 2: Latex Balloons



Figure 9: Latex Balloons [6]

- Durable, affordable
- Low elasticity, difficult to connect to model

Design 3: Medical-Grade Balloon

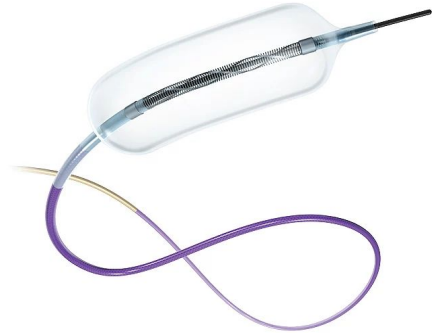


Figure 10: Medical-Grade Balloon [7]

- Stryker Transform Occlusion Balloon Catheter, Super Compliant
- High elasticity, easy to connect to model
- Expensive, low durability

Alveoli Design Matrix

		Design 1: Water Balloons		Design 2: Latex Balloons		Design 3: Stryker Transform Occlusion Balloon Catheter, Super Compliant	
							
Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Connection Points	30	4/5	24	2/5	12	5/5	30
Elasticity	25	4/5	20	2/5	10	5/5	25
Durability	25	3/5	15	4/5	20	2/5	10
Price	15	5/5	15	4/5	12	1/5	3
Size	5	5/5	5	3/5	3	4/5	4
Total	100	79		57		72	

Figure 11: Alveoli Design Matrix

Airway Design Options

Design 1: Symmetric Model

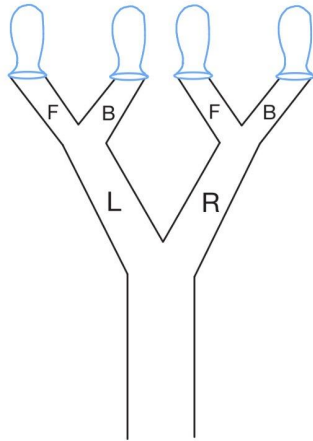


Figure 12: Symmetric Model

- Identical mirror-image branching (Weibel model)
- Simplest to fabricate; lacks anatomical realism

Design 2: Asymmetric Model

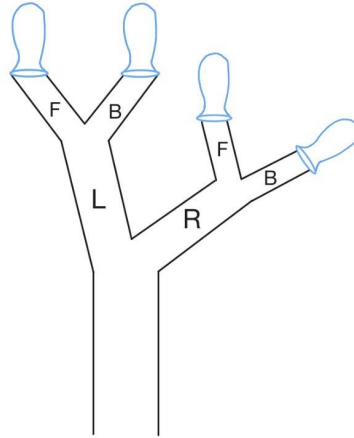


Figure 13: Asymmetric Model

- Differentiates left and right bronchial trees
- Improves realism; limited deep-generation data

Design 3: Stochastic Model

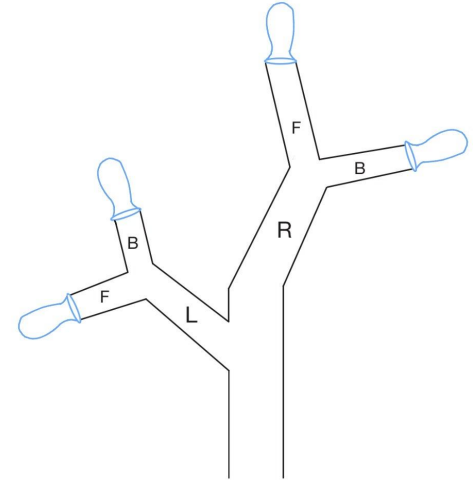


Figure 14: Stochastic Model

- Randomized dimensions and branching angles
- Highest physiological accuracy; complex to fabricate

Airway Design Matrix

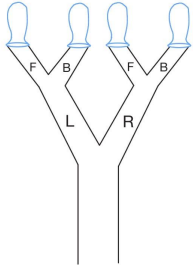
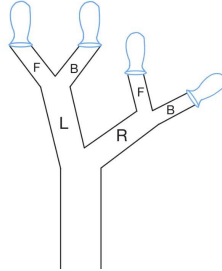
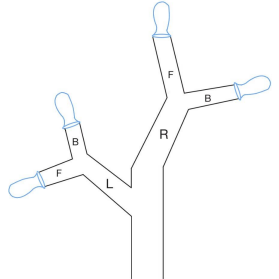
		Design 1: Symmetric Model		Design 2: Asymmetric Model		Design 3: Stochastic	
							
Criteria	Weight	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Physiologically Accurate	30	2/5	12	4/5	24	5/5	30
Manufacturing Feasibility	20	5/5	20	4/5	16	3/5	12
Modeling Feasibility	20	5/5	20	4/5	16	3/5	12
Supported Literature	15	1/5	3	2/5	6	5/5	15
Pathological Adaptability	10	3/5	6	3/5	6	4/5	8
Durability	5	5/5	5	3/5	3	3/5	3
Total	100	66		71		80	

Figure 15: Airway Design Matrix

Final Design



Figure 16: Vacuum Desiccator

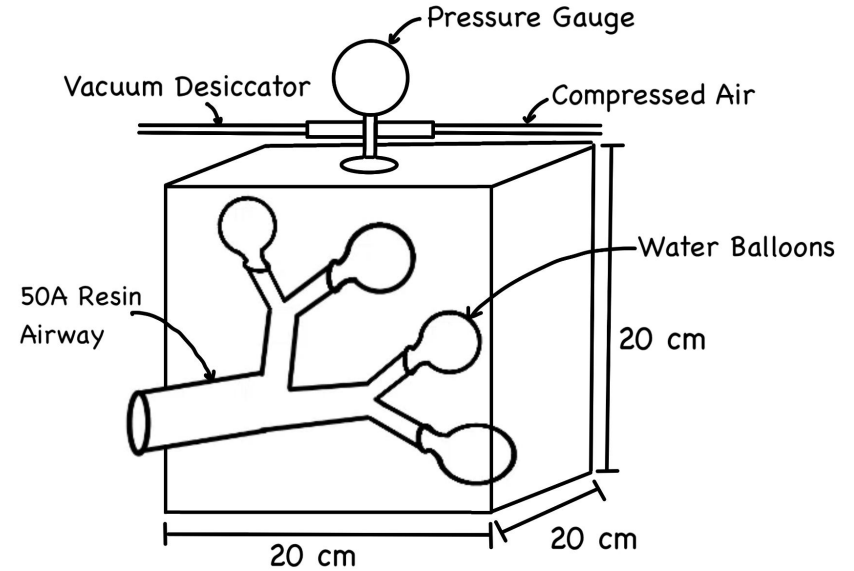


Figure 17: Final Design Depiction

Future Work

- Testing the pressure box
- SolidWorks modeling
- Model fabrication
- Testing protocols and testing
- Modeling different airways and diseases





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References

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Questions?

