Flow Limitation

Progress Report #9

Date: 11/06/2026
Client: Dr. Chris Green
Advisor: Dr. Mehmet Orman
Team: "Flow State"

Lakshika Nanda Kumar Reddy: Co-Leader
Julia Shefchik: Co-Leader
Caroline Blust: Communications
Eliza Kubicek: BSAC
Brady Mayer: BPAG
Jillian Seibert: BWIG

Problem statement:

Flow limitation is the phenomenon in which increasing respiratory effort no longer increases airflow beyond a certain point during forced exhalation, because the airway itself becomes the limiting factor rather than muscles driving expiration [1, 2]. During forced expiration, intrathoracic pressure rises sharply and can exceed the pressure inside the airway, resulting in the airway walls, specifically the bronchi, to narrow and eventually reach a choke point past which further effort in exhalation cannot increase flow [3]. This mechanism is central to interpreting spirometry, since flow-volume curves reflect the mechanical properties of airways rather than respiratory muscle effort alone [4, 5]. It is most relevant to obstructive diseases such as asthma, cystic fibrosis, and COPD, where airway walls are more prone to premature collapse or are already narrowed by inflammation, mucus, or loss of elastic recoil. This leads to prominent flow limitation occurring during forced exhalation [6]. This device will model the branching anatomy of the airway and use flexible materials to replicate the compression and collapse that occurs in the affected patient population. This will allow the users to visualize the equal pressure point (EPP) and the resulting choke point as it moves distally through the airway. The device is intended to physically demonstrate flow limitation during forced expiration for use in an educational teaching video. The final video will be used to teach medical fellows and students how these airway mechanics underlie clinical measures such as spirometry, and how they explain and monitor these obstructive conditions that experience flow limitation.

Brief status update:

This week the team modified the SolidWorks model with insight from the previously printed model. The team printed more samples and received advice on MTS testing. Testing will proceed next week along with refinement of the airway model and its dimensions.

Difficulties/advice requests:

None at this time.

Current design:

The box from last year's group project will be used in our current design.

Major team goals for the next week:

- Print the new modified dimensions airway model
- Try new support removal methods on the printed airway model
- Complete MTS testing on sample materials, and compare values obtained by testing 50A and 80A
- Begin pressure testing

Next week's individual goals:

Lakshika Nanda Kumar Reddy

- Finish up arduino code for testing
- Troubleshoot circuit/arduino set up
- Assist in MTS testing

Julia Shefchik

- Help with pressure testing or MTS testing
- Continue research into modeling fluid dynamics in SolidWorks

Caroline Blust

- Complete MTS testing on sample materials
- Print a new prototype for the airway with thicker walls

Eliza Kubicek

- Finish setting up instrumentation for both phases of pressure testing
- Conduct phase 1 balloon testing
- Help with 3D printing a new prototype for the airway

Brady Mayer

- Work on prototyping the airway

- MTS testing on materials
- Research as needed

Jillian Seibert
- Help with MTS testing
- Do any more 3D printing needed

Previous week's goals and accomplishments:

Lakshika Nanda Kumar Reddy
- Continued circuit debugging
- Assisted with researching MTS methods

Julia Shefchik
- Researched into SolidWorks fluids
- Created a new SolidWorks model with dimensions

Caroline Blust
- Researched MTS testing standards and wrote protocol
- Printed all sample materials needed for MTS testing
- Communicated with faculty to gain MTS access and develop plan for grips

Eliza Kubicek
- Assisted with 3D printing for MTS testing and options for airway printing
- Learned how to modify the SolidWorks airway file for changing dimensions for prototyping

Brady Mayer
- Continue prototyping when I arrive back and get up to speed on the teams progress
- Assist with testing and design improvements
- Research necessary information

Jillian Seibert
- Went and helped with 3D printing for the MTS testing
- Went and learned about how we got our SolidWorks for our next design

ACTIVITIES

Name	Date	Activity	Time (h)	Week Total (h)	Sem. Total (h)
Lakshika Nanda Kumar Reddy	9/7/2026	Review previous team's final report	1	2.5	36
	9/7/2026	Brainstorm questions for the	0.5		

		client meeting			
	9/10/2026	Conducted research on flow limitation and took notes	1		
	9/15/2026	Worked on PDS	1	5.5	
	9/15/2026	Researched FV curves, obstructive diseases, and flow limitation for PDS	2		
	9/16/2026	Edited PDS	1.5		
	9/16/2026	Researched materials for design ideas	1		
	9/21/2026	Started preliminary research on material ideas for 3D printing and alveoli	1	7.5	
	9/22/2026	Caroline/Eliza meeting for materials	1.5		
	9/23/2026	Conducted intensive research on 3D printing materials and alveoli materials	2		
	9/23/2026	Wrote the assigned sections of the design matrix	1		
	9/24/2026	Edited and reformatted all three design matrices to have cohesiveness through the documents	2		
	9/28/2026	Created Preliminary Presentation Slides	0.5	3.5	
	9/28/2026	Created initial flow limitation animation	1		
	9/28/2026	Met with Simon Nam to figure out applying compressed air and vacuum air to box	0.5		
	9/30/2026	Team Practice for Preliminary presentation	0.5		
	10/1/2026	Created final flow limitation animation	1		
	10/3/2026	Wrote sections of preliminary report	2	8.5	

	10/4/2026	Provided feedback on sections of the preliminary report	0.5		
	10/4/2026	Met with team to go over comments in prelim report	1		
	10/4/2026	Created protocol for pressure testing phase 1 and wrote protocol in report	2		
	10/8/2026	Met with Makerspace Staff for fabrication protocol of airway with Caroline	0.5		
	10/8/2026	Completed Airway fabrication protocol and started working on pressure testing phase 2 protocol with Caroline	1.5		
	10/8/2026	Created draft of pressure testing phase 2 protocol	1		
	10/12/2026	Researched I2C Architecture	1	2	
	10/13/2026	Met with Dr. Green	0.5		
	10/13/2026	BPAG Sheet	0.5		
	10/18/2026	MatLAB mathematical model + research	2	5	
	10/21/2026	Grab Materials from University Hospital	1		
	10/22/2026	Started Base pressure sensor testing	2		
	10/26/2026	Meeting with Caroline to print 2 airways: 1 whole and 1 split	1.5	4.5	
	10/26/2026	Worked with Eliza to work on testing digital gauge pressure sensor from last year	1		
	10/28/2026	Worked on running both BMP sensor and digital gauge pressure sensor together	2		
	11/4/2026	Worked on debugging	1	2	
	11/5/2026	MTS research	1		
Julia Shefchik	9/7/2026	Review previous team's deliverables (final report, PDS, final poster)	1	4	40

	9/7/2026	Brainstorm questions for the client meeting	0.5		
	9/9/2026	Annotated and read a review article on Expiratory Flow Limitation	1.5		
	9/9/2026	Researched mechanical properties of the Airway Tree	1		
	9/13/2026	Worked on PDS	1	4	
	9/14/2026	Research standards and worked on PDS	2		
	9/16/2026	Edited PDS	1		
	9/21/2026	Preliminary research to support design ideas	1	7.5	
	9/22/2026	Research on physiological airway models and balloon materials	2		
	9/23/2026	Work on design matrices	3		
	9/24/2026	Edit design matrices	1.5		
	9/28/2026	Worked on preliminary design presentation slides and drawings	1	4	
	9/28/2026	Met with Simon Nam to learn about vacuum system	0.5		
	9/30/2026	Team practice for presentation	0.5		
	9/30/2026	Brainstorm testing ideas and draft sections of preliminary report	2		
	10/1/2026	Individual practice for design presentation	0.5		
	10/2/2026	Worked on sections of preliminary design report	2	6.5	
	10/3/2026	Edited preliminary design report	1		
	10/4/2026	Research on testing for preliminary design report	1		
	10/4/2026	Met with the team to discuss edits	1		

	10/4/2026	Editing and refining sections of the preliminary report	1.5		
	10/13/2026	Review team client meeting notes and material choices	0.5	2	
	10/15/2026	Work on SolidWorks testing tubes and begin work on airway model	1.5		
	10/20/2026	SolidWorks airway research and stochastic model	1	5	
	10/21/2026	SolidWorks modeling	4		
	10/24/2026	Rebuild SolidWorks model for printing and easy refinement	2	3.5	
	10/28/2026	Write and prepare for show and tell	0.5		
	10/29/2026	Try to find new potential measurements for airway	1		
	11/4/2026	SolidWorks update model	1.5	3.5	
	11/4/2026	LabArchives update	1		
	11/4/2026	Flow modeling research	1		
Caroline Blust	9/7/2026	Brainstorm questions and review past project	0.5	1	37.5
	9/7/2026	Add research entry to LabArchives	0.5		
	9/11/2026	Researched project concepts and summarized client article	1.5	6	
	9/15/2026	Worked on PDS	3		
	9/15/2026	Further research	1		
	9/16/2026	PDS edits	0.5		
	9/21/2026	Materials research and design matrix initial brainstorming	1	8.5	
	9/22/2026	Lakshika/Eliza materials matrix meeting	1.5		
	9/23/2026	Materials matrix research and writing	3		

	9/24/2026	Materials/alveoli matrix work	2		
	9/24/2026	Final edits on matrices	1		
	9/28/2026	Worked on preliminary presentation	1	3	
	9/29/2026	Met with Simon Nam to learn how to use vacuum pump	0.5		
	9/30/2026	Presentation edits/practice	1		
	10/01/2026	Final edits/citations	0.5		
	10/03/2026	Preliminary report edits and feedback	1	6	
	10/05/2026	Worked on preliminary report	0.5		
	10/07/2026	Feedback fruits	0.5		
	10/08/2026	Preliminary report final edits/citations and additional research for pressure testing	4		
	10/11/2026	Feedback fruits	0.5	2.5	
	10/12/2026	Communicated with contacts about ordering materials	0.5		
	10/12/2026	Confirmed and finalized materials table	0.5		
	10/13/2026	Client meeting and pressure testing protocol discussion	1		
	10/22/2026	Research into MTS testing and tensile test standards	2	4	
	10/22/2026	Solidworks and printing of Die C for MTS testing	2		
	10/26/2026	Finalized two versions of initial airway test print and sent to printer	2	3.5	
	10/28/2026	Picked up airway test print and worked on removing supports	1		
	10/29/2026	Experimented with use of AI in generating model of chokepoint formation	0.5		
	11/2/2026	MTS testing standard and	1.5	3	

		protocol research			
	11/2/2026	Printed new die samples	1		
	11/5/2026	Checked on die samples and started reprinting	0.5		
Eliza Kubicek	9/5/2026	Read through last semester's final report documentation and took notes on previous work and potential starting points in LabArchives	2	6	36.5
	9/7/2026	Brainstormed questions for the client meeting	0.5		
	9/7/2026	Conducted research on flow limitation during forced expiration and took notes in LabArchives	2		
	9/9/2026	Conducted research on tube law and physical properties of human airways for future design use and took notes in LabArchives	1.5		
	9/14/2026	Outlined PDS sections	0.5	4	
	9/15/2026	Conducted research for and wrote PDS sections	2.5		
	9/16/2026	Edited PDS based on feedback	0.5		
	9/16/2026	Updated LabArchives with research findings used in writing the PDS	0.5		
	9/21/2026	Conducted research on possible materials to model the bronchi and alveoli	2	6	
	9/22/2026	Met with Caroline and Lakshika to work on the materials design matrix	1.5		
	9/23/2026	Worked on the materials and alveoli design matrices	1.5		
	9/24/2026	Finalized my assigned parts of the materials and alveoli design matrices	1		
	9/27/2026	Worked on slides for the	1	3.5	

		preliminary presentation			
	9/30/2026	Practiced with the team for the preliminary presentation	0.5		
	10/1/2026	Worked on the discussion section of the preliminary design report	2		
	10/4/2026	Finalized the discussion section of the preliminary report based on feedback	1	2.5	
	10/4/2026	Met with the team to discuss the preliminary report	0.5		
	10/6/2026	Completed Feedback Fruits peer and self assessments	1		
	10/13/2026	Attended the client meeting and discussed testing methods	1	2	
	10/15/2026	Learned basic SolidWorks by walking through the testing airway	0.5		
	10/15/2026	Updated LabArchives with research entries	0.5		
	10/18/2026	Began work on the AI mathematical model for choke point formation and flow limitation	1.5	3	
	10/22/2026	Met with Lakshika to set up the sensor for phase 1 pressure testing	1.5		
	10/23/2026	Researched equations for and began re-developing an AI mathematical model for flow limitation using Gemini	1.5	7.5	
	10/25/2026	Conducted research on the ARD20 digital pressure sensor for use in Phase 2 balloon testing	1		
	10/26/2026	Assisted in 3D printing the complete airway	0.5		
	10/26/2026	Set up the digital pressure sensor to give output readings for pressure in the vacuum box to an Arduino Uno	2.5		

PROJECT TIMELINE

Task	Sept			October					November				Dec	
	11	18	25	2	9	16	23	30	6	13	20	27	4	11
Project R&D														
Preliminary Research	X	X	X	X										
Detailed Final Design					X									
Testing Plan						X								
Show and Tell								X						
Fabrication							X	X	X					
Testing														
Deliverables														
Progress Reports	X	X	X	X	X	X	X	X	X					
PDS		X												
Design Matrix			X											
Prelim presentation				X										
Preliminary Deliverables					X									
Final Poster														

Final Deliverables														9th
Meetings														
Client		X	X	X		X								
Advisor	X	X	X		X	X	X							
Website														
Update	X	X	X	X	X	X	X	X	X					

Materials and expenses:

Item	Description	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	QTY	Cost Each	Total	Link
Airway Materials										
FormLabs Flexible 50A Resin	Elastic resin used to print on FormLabs SLA printers.	FormLabs	N/A	DI Lab	N/A	TBD	TBD	$0.29/g	TBD	Link
Assorted Water Balloon	Multi-color latex 3” water balloons 100ct	Arcady	N/A	Amazon	N/A	TBD	1	$4.94	$4.94	Link
Loctite Super Glue Ultra Gel Control	Tough silicone gel super glue	Loctite	N/A	Amazon	N/A	TBD	1	$4.49	$4.49	Link
Pressure Testing Materials										
BMP388 Precision Barometric Pressure and Altimeter	Pressure sensor, accurate up to 8 Pascals	N/A	N/A	Amazon	N/A	TBD	1	$16.99	$16.99	Link
STEMMA QT / Qwiic JST SH 4 pin to premium male headers cable	Connector from QT to Male Headers for Arduino	N/A	N/A	Amazon	N/A	TBD	1	$6.70	$6.70	Link
ELEGOO 120pcs Multicolored Dupont Wire M-F, M-M, F-F for Breadboard Jumper	Female-Male Connector Jumpers for Breadboard	N/A	N/A	Amazon	N/A	TBD	1	$6.98	$6.98	Link
Basketball Football Volleyball Water Polo Rugby Exercise Sports Ball Balloon Swim Inflatables	Balloon Pump with extension attachment	N/A	N/A	Amazon	N/A	TBD	1	$6.99	$6.99	Link
D-NYX 6 Rolls E Tape Multi Colored Vinyl	Tape for Electronic Attachments	N/A	N/A	Amazon	N/A	TBD	1	$4.99	$4.99	Link

Electrical Tape 3/5in x 26ft Waterproof Strong Adhesive Indoor Outdoor 6 Colors Durable Easy Wrap Professional Grade Electric Wire Repair 7 Mil										
										TOTAL: $52.08

References

[1] C. Tantucci, “Expiratory Flow Limitation Definition, Mechanisms, Methods, and Significance,” Pulm Med, vol. 2013, p. 749860, 2013, doi: 10.1155/2013/749860.

[2] T. C and G. V, “Flow limitation: an overview,” PubMed, Accessed: Sep. 15, 2026. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/10546481/

[3] Z. Ms, “The physiology of forced expiration,” PubMed, Accessed: Sep. 15, 2026. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/16263442/

[4] “Lung Flow Volume Curve - an overview | ScienceDirect Topics.” Accessed: Sep. 15, 2026. [Online]. Available: https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/lung-flow-volume-curve

[5] “Pulmonary Function Testing - PMC.” Accessed: Sep. 15, 2026. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC7158317/

[6] R. L. Dellacà et al., “Detection of expiratory flow limitation in COPD using the forced oscillation technique,” Feb. 2004, Accessed: Sep. 15, 2026. [Online]. Available: https://publications.ersnet.org/content/erj/23/2/232