Department of Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

Neonatal 22-23-Week Premature Infant Simulation Mannequin

02/24/2023

Advisor: Dr. Kristyn Masters

Client: Dr. Timothy Elgin

The Team

Leader: Loukia Agoudemos

Communicator: Sophia Finn

BWIG: Charlie Fisher

BSAC: Abbie Schaefer

BPAG: Tanishka Sheth

Figure 1: Team photo
From left to right:
Charlie, Abbie, Loukia, Sophia
Not pictured: Tanishka

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Client Information

- Dr. Timothy Elgin, DO
- Currently works in the department of neonatology and Newborn Nursery at the UW Department of Pediatrics.

Figure 2: Image of the client

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Problem Statement

- There are currently no 22-23 week neonatal simulation mannequins on the market, though it is vital for medical professionals to practice the skills needed to resuscitate an infant at this age.
- Must be able to be intubated, support central umbilical line placement, and include IV access.
- Including a chest cavity and rib structure that allows for additional training in thoracentesis and pericardiocentesis would be ideal.

Figure 3: Infant born at 23 Weeks [1]

Background & Prior Work

- 22-23 Week Premature Infants
  - Approximately 8 inches long
  - Weigh between 0.9-1.1 lbs
  - Skin is gelatinous, sticky, and can tear easily
  - The survival rate of infants at this stage is extremely variable [2]
- Last Semester's Model
  - PDMS used for skin model did not fully cure when casted into the mold
  - Needs a more robust chest cavity and airway for accurate intubation and structure
  - Needs limbs

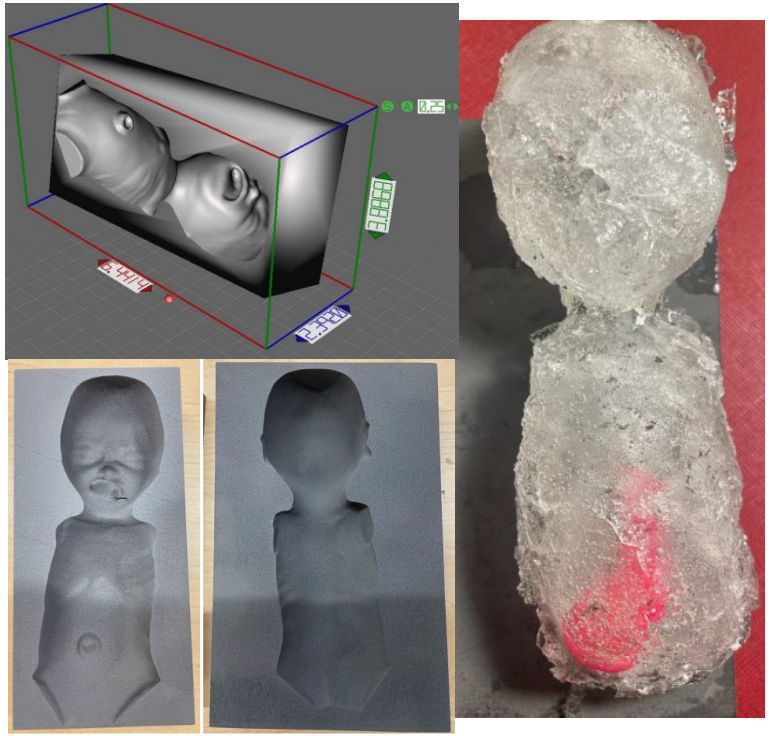

Figure 4: Last Semester's Model and Mold

Competing Designs

- Trucorp TruBaby X [3]
  - 5 month old infant mannequin
  - Notable feature:
    - Fluid system
- Universal Medical C.H.A.R.L.I.E. [4]
  - Resembles an infant at birth
  - Notable feature:
    - Electronics
- Laerdal Premature Anne
  - 25-week premature infant mannequin
  - Closest to the goal of our project
  - Improvements to be made:
    - Size
    - Skin

Figure 5: Premature Anne [5]

Summary of PDS

Client Requirements:

1. Length < 30.5 cm
2. Ability to practice medical procedures
3. Weight around 400-500 grams
4. Expandable lungs

Design Requirements:

1. Life in service : 3-5 years
2. Features must resemble that of a 22-23 week premature infant
3. Needs to be reproducible (both in products used and cost)
4. No discomfort to the person using the mannequin

PDS

Focus Areas of the Project

01 The Inner Workings

- Create the intubation system and thoracic cavity
- Create the structural skeleton of the model
- Ensure that there are adequate IV access points

02 Model Materials

- Ensure mechanical accuracy and robustness of materials used in the inner workings and skin
- Ensure materials used are chemically/physically compatible
- Achieve life-likeness of skin texture

03 **The Model's Mold**

- How we will cast the model.
- Ensure enough room for inner workings and poured material.
- Plan fabrication process and steps involved.
-

The Inner Workings Ideas

1. Intubation and Shell Model

- PLA printed chest and belly cavity
- Infant-sized cpr bag for “lungs”
- Trachea model with silicone mouth & esophagus
- Previously used by First Breath & Micro Mike teams

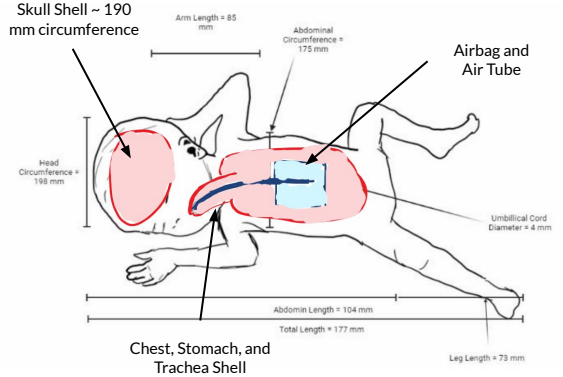

Figure 6: Intubation and Shell Model

2. Balloon Lungs

- Breathing tube with a T-connector to mimic airways
- Two balloons serving as lungs
- Absence mannequin’s “skeleton”

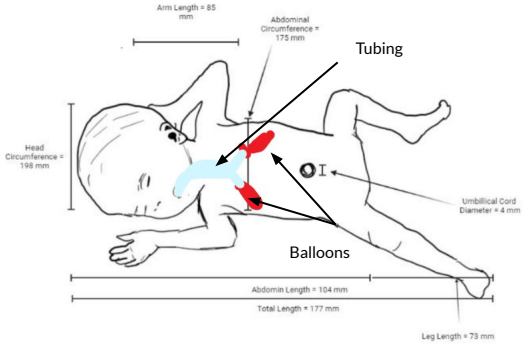

Figure 7: Balloon Lungs

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3. Mock Airway and Mock Skeleton

- Includes a 3D printed skull and skeleton as the interior structure
  - Made of an elastic plastic– ie polyurethane
- Accurately sized lung-air bags for rise and fall of lungs

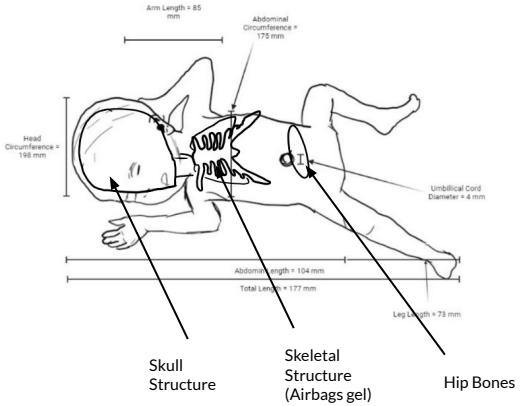

Figure 8: Mock Airway and Mock Skeleton

Design Matrix of the Inner Workings

	Design 1: Intubation and Shell	Design 2: Balloon Lungs	Design 3: Mock airway and skeleton
Feedback Mechanism/ Realism (25)	4/5 (20)	4/5 (20)	5/5 (25)
Usability(25)	4/5 (20)	4/5 (20)	5/5 (25)
Cost (20)	3/5 (12)	5/5 (20)	2/5 (8)
Durability (15)	3/5 (9)	3/5 (9)	4/5 (12)
Feasibility/ Reproducibility (15)	3/5 (9)	5/5 (15)	2/5 (6)
Total (100)	70	84	76

Table 1: Design Matrix showing the three intubation options that can be used in the final design. Green highlighting shows the winner in each category

Model Materials

1. **PDMS Coating on Ballistics Gel**

- Base skin layer made of thicker ballistics gel
- Layer of PDMS cured on top for more realistic skin texture
- Allows for stiffer chest area but also ideal skin texture

2. **PDMS Only**

- PDMS cured in layers on top of each other
- Material left in cavities that can be easily removed after curing process

3. **Sleeve Coating**

- Base of baby made of a harder material
- Areas necessary for different procedures can have an interchangable sleeve made of a softer skin like material

Criteria (Weight):

- Texture(25)
- Usability(25)
- Cost(25)
- Durability(15)
- Realism(5)
- Feasibility/Reproducibility (5)

Design Matrix of the Model's Materials

	Design 1: PDMS Coating on Ballistics Gel	Design 2: PDMS Only	Design 3: Sleeve Coating -Thicker silicone sleeve on top of hard plastic body
Texture(25)	5/5 (25)	3/5 (15)	4/5 (20)
Usability(25)	5/5 (25)	3/5 (15)	4/5 (20)
Cost(25)	4/5 (20)	5/5 (25)	2/5 (10)
Durability(15)	4/5 (12)	2/5 (6)	3/5 (9)
Realism(5)	4/5 (4)	2/5 (2)	5/5 (5)
Feasibility/ Reproducibility (5)	4/5 (4)	5/5 (5)	2/5 (2)
Total (100)	90	68	66

Table 2: Design Matrix showing the three skin materials that can be used in the final design. Green highlighting shows the winner in each category.

The Model's Mold Design Ideas

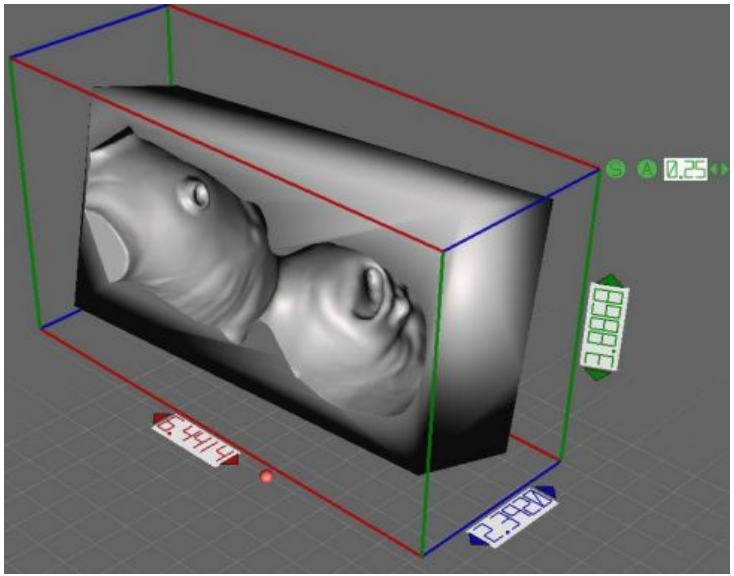

Figure 9: 3D model of mold

1. **PVA Casted Mold**
2. **Tough PLA**
3. **Nylon Mold**

Criteria (Weight):

- Heat Resistance (25)
- Cost (20)
- Durability (20)
- Detail Capturing (20)
- Feasibility (10)
- Ease of Use (5)

Design Matrix of The Model's Mold

	Design 1: PVA Casted Mold	Design 2: Tough PLA	Design 3: Nylon Mold
Heat Resistance (25)	3/5 (15)	4/5 (20)	5/5 (25)
Cost (20)	2/5 (8)	5/5 (20)	4/5 (16)
Durability (20)	4/5 (16)	5/5 (20)	4/5 (16)
Detail Capturing (20)	4/5 (16)	5/5 (20)	4/5 (16)
Feasibility (10)	3/5 (6)	4/5 (8)	1/5 (2)
Ease of Use (5)	3/5 (3)	4/5 (4)	1/5 (1)
Total (100)	64	92	76

Table 3: Design Matrix showing the three materials that can be used in the final design. Green highlighting shows the winner in each category.

Chosen Preliminary Design

- Neonatal Manikin
  - Ballistics gel with a PDMS coating to model the skin tissue
    - The model will include a cavity for the trachea and chest cavity
      - Snowman shape made from PLA will be placed inside during curing and removed at the end
    - The model will also include limbs for IV access
- Mold
  - 3D printed from Ultimaker Tough PLA

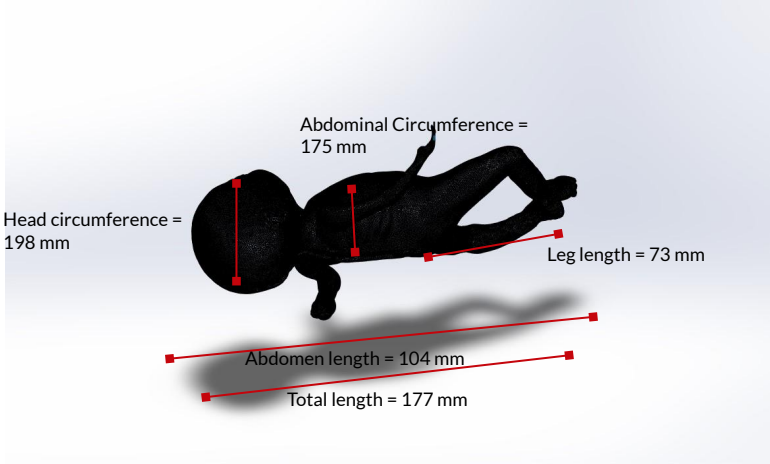

Figure 10: 3D model of the 22-23 week neonatal mannequin

Future Work

This semester:

- Creating new molds using selected material
  - Addition of mold for limbs
- Fabricating intubation materials
- Fabricating a usable prototype
- Embodying Accuracy
- Usability testing

Beyond this semester:

- Creating a High Fidelity Model
  - Vein system
  - Pulse
  - Different thoracic cavity movements
  - Programming software
  - Pressure sensor
  - Lights
  - Fluid system

Acknowledgements

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- BME Department

References

[1] “A miracle preemie: Yishan's story,” *Children's Minnesota*, 25-Nov-2020. [Online]. Available: https://www.childrensmn.org/2020/11/12/extremely-premature-infant-miracle-baby/. [Accessed: 05-Oct-2022].

[2] A. Cavolo, B. Dierckx de Casterlé, G. Naulaers, and C. Gastmans, “Physicians’ Attitudes on Resuscitation of Extremely Premature Infants: A Systematic Review,” Pediatrics, vol. 143, no. 6, p. e20183972, Jun. 2019, doi: 10.1542/peds.2018-3972.

[3] “Trubaby x: Infant CPR manikin: Pediatric manikin,” *Trucorp*, 16-Aug-2022. [Online]. Available: https://trucorp.com/product/trubabyx/. [Accessed: 05-Oct-2022].

[4]“Life/form C.H.A.R.L.I.E. neonatal resuscitation simulator without interactive ECG Simulator,” *Universal Medical*. [Online]. Available: https://www.universalmedicalinc.com/life-form-c-h-a-r-l-i-e-neonatal-resuscitation-simulator-without-interactive-ecg-simulator.html. [Accessed: 05-Oct-2022].

[5] “Premature anne,” *Laerdal Medical*. [Online]. Available: https://laerdal.com/us/products/simulation-training/obstetrics-pediatrics/premature-anne/. [Accessed: 05-Oct-2022].

Questions?