Neonatal 22-23 Week Premature Infant Simulation Manikin

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Claire Kramar, Jodi Lawson, Emma Lu, Maya Nornberg, Jensen Weik, Molly Wilhelmson

Client: Dr. Timothy Elgin, DO Advisor: Dr. Pamela Kreeger

College of Engineering
University of Wisconsin–Madison

Motivation

- 11% of all births are preterm, and 5% of these births are infants born before 28 weeks of gestation [1]
  - Medical professionals are unable to practice resuscitation before a real-life scenario
- Survival rates [2]
  - 23 weeks gestation: 1% - 64%
  - 22 weeks gestation: < 10%
- Low survival rates and risk of disability later in life impact physicians' decisions to attempt resuscitation of extremely premature infants (EPIs) [2]

Problem Statement

- Currently no affordable manikins on the market made to model neonates born at 22-23 weeks of gestation
- Vital for professionals to practice resuscitation techniques on a model accurately representing an infant of this size prior to a real-life scenario
- Goal is to soften the learning curve for physicians resuscitating EPIs

Design Criteria

- Manikin specifications:
  - No more than 30.5 cm in length [3]
  - Weigh between 400 g - 500 g [3]
  - Wet, gelatinous, sticky skin
  - Ability to be intubated
  - Intravenous (IV) access points
  - Support central umbilical line placement
  - A chest cavity that rises and falls
- This semester focused on adding limbs and realistic skin

Background

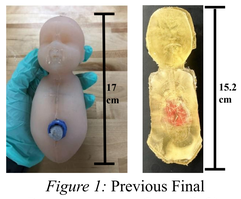

Figure 1: Previous Final Prototypes: Iowa Group (left), BME Design Spring 2023 (right)

- Lacks limbs
- Inaccurate skin texture
- Chest cavities not functional

Figure 2: Lifecast Simulation's Micro-Preemie Manikin [4]

- 22-23 weeks gestation
- No IV access
- Price unknown
- Skin texture unknown

Figure 3: Laerdal Medical's Premature Anne [5]

- 25 weeks gestation
- Inaccurate skin texture
- $2,999 - $6,899

Final Design

Final Prototype

Fabrication
- EcoFlex 00-30 and silicone pigment mixture
- Poured into 3D-printed molds
- Cure for 24 hours on tabletop

Specifications
- Length (head to toe): 24 cm
- Weight: 362.55 g

PDMS Skin Material

Fabrication
- Sylgard 184 and Sylgard 527 PDMS mixture
- Coated limb in PDMS
- Heated at 65℃ for 12 hours

Characteristics
- Glossy appearance
- Wet and sticky to touch

Figure 4: Final Prototype

Figure 5: Body Mold Cavities

Figure 6: Leg Coated in PDMS Skin Material

Testing

- Tensile Testing
  - Performed on EcoFlex 00-30 to confirm that it does not accurately represent the elasticity of an EPI's skin
- Usability Testing
  - Manikin is picked up and handled using proper standard care of a true neonate 10 times to determine the effectiveness of the limb attachment and prototype durability
- Band-Aid Tear Testing
  - Band-Aids are placed on PDMS skin samples and lifted off to test fragility of skin – tearing is expected and desired to ensure accuracy of skin
- Blind Skin Touch Testing
  - A survey was created for neonatal physicians and nurses to fill out for different skin samples – unable to be completed due to supply chain delays

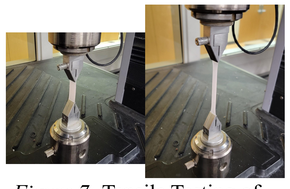

Figure 7: Tensile Testing of EcoFlex 00-30 Material

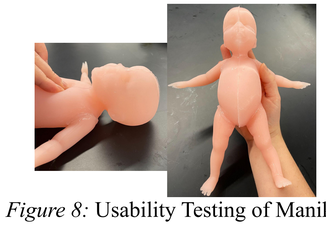

Figure 8: Usability Testing of Manikin

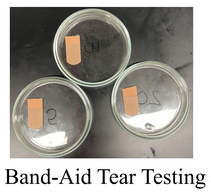

Figure 9: Band-Aid Tear Testing of Skin Samples

Results

- Tensile testing of the EcoFlex 00-30 confirmed the Young's Modulus was below that of a neonatal infant
  - Human Skin Young's Modulus: 4.6 MPa - 20 MPa [6]
  - EcoFlex 00-30 Young's Modulus: 0.43 MPa
- Band-Aid Tear Testing
  - 100% of skin material samples tore when adhesive was applied and removed

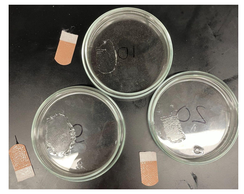

Figure 10: Torn Band-Aid Samples

Discussion

- Little literature exists on the resuscitation of EPIs, making it difficult to determine accuracy of the manikin
- The weight of the prototype was under the specified weight of 400 g - 500 g
  - Will fall within range with addition of internal physiology and electronics
- Long curing time of EcoFlex 00-30 made limb attachment difficult
  - Applying heat decreased curing time
- PDMS was chosen as the skin material because of its sticky, gelatinous texture
  - Literature-reported Young's Moduli of PDMS tested included 5 kPa, 10 kPa, and 20 kPa [7]

Future Work

- Finalize skin material
  - Perform blind skin touch testing
  - Attach skin material to manikin
  - Create patches that could replace tears in the skin
- Future semesters can focus on internal physiology and anatomy
  - Ventilation, IV access, respiration and resuscitation, internal organs
  - Add electronic components (i.e. resuscitation simulation)
  - Improve fabrication by increasing efficiency in creating the model

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References

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[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] T. Elgin, Client Meeting, September, 2023.

[4] "Lifecast Body Simulation | Surgical Manikin." https://www.lifecastbodysim.com/micro-preemie-manikin (accessed Sep. 20, 2023).

[5] "Premature Anne," Laerdal Medical. https://laerdal.com/us/products/simulation-training/obstetrics-pediatrics/premature-anne/ (accessed Sep. 20, 2023).

[6] M. Pawlaczyk, M. Lelonkiewicz, and M. Wieczorowski, "Age-dependent biomechanical properties of the skin," *Postepy Dermatol Alergol*, vol. 30, no. 5, pp. 302–306, Oct. 2013, doi: 10.5114/pdia.2013.38359.

[7] R. N. Palchesko, L. Zhang, Y. Sun, and A. W. Feinberg, "Development of Polydimethylsiloxane Substrates with Tunable Elastic Modulus to Study Cell Mechanobiology in Muscle and Nerve," PLoS ONE, vol. 7, no. 12, p. e51499, Dec. 2012, doi: 10.1371/journal.pone.0051499.