Neonatal 22-23 Week Premature Infant Simulation Mannequin

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Motivation

- Underdevelopment of vital organs (like lungs) made resuscitation at this age extremely difficult and avoided
  - As more doctors attempt resuscitation, high demand for training mannequins specific to 22-23 weeks infants
  - Earliest commercial model represents a neonate born at 25 weeks
- Survival rates [1]
  - 22 weeks of gestation: <10%
  - 23 weeks of gestation: 1%-64%

Problem Statement

- There are no 22-23 neonatal simulation mannequins on the market
  - Vital for medical professions to be able to practice resuscitation on an infant of this size
  - Need to develop a mannequin in order to practice in a less chaotic environment when the stakes are not so high
- Mannequin needs to be able to be intubated, support central umbilical line placement, and include IV access
  - Ability to put a synthetic breathing tube (2.00-2.50 mm diameter) in the mouth of the mannequin
  - Include realistic gelatinous, sticky skin that tears very easily [2]

Background

Figure 1: Prior Group's Model

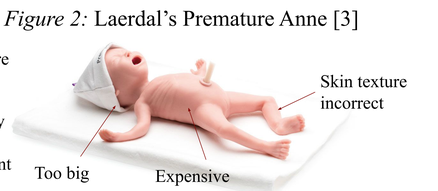

Figure 2: Laerdal's Premature Anne [3]

- Approximately 1 foot long
- Weigh between 0.9-1.1 lbs
- Skin is gelatinous, sticky, and can tear easily
- Previously, doctors did not attempt resuscitation of neonates–more common to resuscitate now with increased viability

Design Criteria

- Length < 30.5 cm
- Ability to practice medical procedures
- Weight around 400-500 grams
- Life in service: 3-5 years
- Reproducible and low cost
- Features must resemble that of a 22-23 week premature infant
- No discomfort to the person using the mannequin

Final Design

- Final design consists of a Sylgard 184 elastomer, molded in a Nylon, 3D printed mold with a balloon mechanism
  - Nylon Mold
    - Heat-resistant – withstands temperatures up to 280° F
    - 6.5in height, 1.5in width
  - Sylgard 184 Elastomer
    - Mimics texture of neonate's skin
      - Retains moisture
      - Gelatinous
      - Elastic
      - Smooth texture when cured
    - Easily Moldable
      - Liquid state until curing agent added
      - Cures quickly at high temperatures (>200° F)
      - We chose to cure the mold in layers, at 280° F for an hour at a time
    - Placed molds on top of first layers to create chambers for intubation, chest cavity
  - Balloon mechanism
    - Includes tubing and a balloon attached to the end
    - Simulates the lungs inflating and deflating when air is blown through the mechanism (intubation)

Figure 3: Final Design

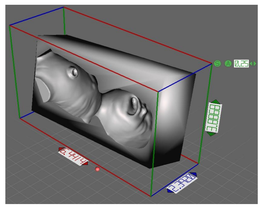

Figure 4: Scaled down Nylon mold created using Blender and Meshmixer, units in mm

Testing

- Compression Testing
  - Performed to determine whether the selected hydrogel (agar) can withstand enough force to be used effectively in future mannequins and prototypes
- Tensile Testing
  - Performed to determine whether the selected elastomer (Sylgard 184) can stretch to a point that shows it can be effectively used in future prototypes and mannequins
- Usability Testing
  - Members of the team attempt to intubate the prototype and determine if it is comfortable and usable enough for professional use
    - Involved handling of the prototype (ie resuscitation compressions) and trying to inflate the balloon mechanism

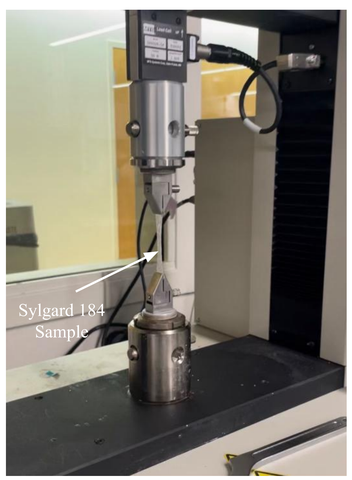

Figure 5: One of three tensile tests on Sylgard 184

Results

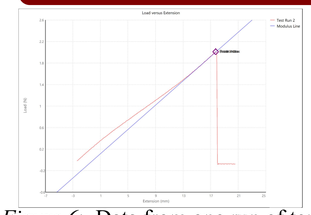

Figure 6: Data from one run of tensile testing of Sylgard 184

- Withstood maximum of 2.0 N
- Young's Modulus of .11 MPa

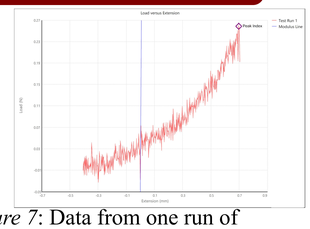

Figure 7: Data from one run of compression testing of Agar Hydrogel

- Withstood maximum of 0.25 N
- Young's Modulus of 360 kPa

Discussion

- Sylgard 184 elastomer should have a Young's modulus of 1.32-2.97 MPa [3]
  - Our value is lower than industry standard, and may be a result of not degassing the sample for long enough
  - Improper degassing causes air bubbles within the material which reduces the amount of force that the material can withstand
  - Next time ensure degassing prior to pouring in the mold
- Agar should have a Young's modulus of ~30 kPa-700 kPa [4]
  - Our value fell within the range of industry standards
  - When including it within the prototype the texture was too slimy and not attaching as desired to the elastomer so it was not used
    - This could've been aided by using reagent grade agar and a chemical acrylation process

Future Work

- Improvements to Design
  - Less moist agar layer between elastomer layers to mimic skin conditions
  - Limbs for more realistic IV insertion points
  - Adding color so the skin is more realistic
  - Zipper for accessibility to inside components
- Perform usability testing with medical professionals that would be using this mannequin

Acknowledgements

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- Dr. Melissa Skala
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References

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