Neonatal 22-23 Week Premature Infant Simulation Manikin

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Motivation

- Underdevelopment of vital organs (like lungs) make resuscitation at this age difficult, but critical for infant survival
  - As more premature babies are being born, there is a greater demand for training manikins specific to 22-23 weeks infants [1]
  - Earliest commercial model represents a neonate born at 25 weeks
- Survival rates [2]
  - 22 weeks of gestation: <10%
  - 23 weeks of gestation: 1%-64%

Problem Statement

- There are no 22-23 neonatal simulation manikins on the market
  - Vital for medical professions to be able to practice resuscitation on an infant of this size
  - Need to develop a manikin in order to practice in a less chaotic environment when the stakes are not so high
- Manikin 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 [3]

Background

Figure 1: Prior Group's Model

Figure 2: Laerdal's Premature Anne [4]

- 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 such as intubation, IV insertion, and resuscitation
- Weight around 400-500 grams
- Reproducible and low cost
- Features must resemble that of a 22-23 week premature infant
- No discomfort to the person using the mannequin
- Must include a resuscitation feedback mechanism, for effective medical training

Final Design

- Final design consists of a ballistics gel manikin, molded in a polylactic acid (PLA), 3D printed mold with a balloon lung-mechanism
  - PLA mold
    - Low cost material
    - Durable over lifetime
  - Ballistics gel manikin
    - Mimics texture and physical properties of skin
      - Retains moisture
      - Similar elastic modulus when formulated at 20% concentration
      - Smooth texture and mostly transparent when solidified
  - Balloon mechanism
    - Includes tubing and balloons attached to a T-connector at the end of a breathing tube
    - Simulates the lungs inflating and deflating when air is blown through the mechanism (intubation)

Figure 3: Final Design

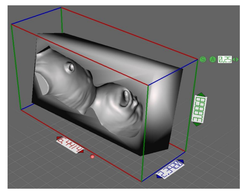

Figure 4: Scaled down mold created using Blender and Meshmixer, units in mm

Testing

- Compression Testing
  - Performed to determine whether the ballistics gel can withstand enough compressive force to be used effectively in future mannequins and prototypes
- Tensile Testing
  - Performed to determine whether the ballistics gel can withstand enough tensile force to be used effectively in future mannequins and prototypes
- Usability Testing
  - Members of the team and our medical student 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
    - Users filled out a survey on their experiences with the mannequin

Figure 5: Image of tensile testing

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Results

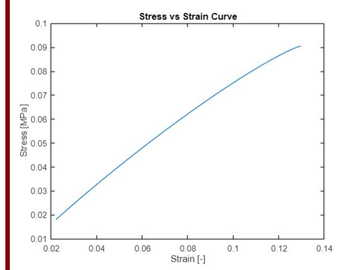

Figure 6: Graph resulting from tensile testing of the ballistics gel

- Young's Modulus calculated: 727.85 kPa

Figure 7: Image from usability testing of the ballistics gel manikin

Discussion

- Ballistics gel should have a Young's Modulus of ~630 kPa for 10-20% gelatin [5]
  - Young's modulus of the skin fluctuates between 0.42 MPa and 0.85 MPa [6]
  - This creates extra stiffness that makes intubation harder about the chest region
  - Next time the gelatin concentration can be reduced
- Usability testing revealed that users appreciated the texture of the manikin but would prefer the addition of limbs and for the chest to be more flexible
  - This can be achieved by adapting the mold to include limbs and using a lower gelatin percentage
  - Additionally creating a larger chest cavity that allows for less dense ballistics gel to be on top of the balloon mechanism
  - Usability testing results mostly focused on realism due to lack of access to a laryngoscope

Future Work

- Improvements to Design
  - PDMS coating to further replicate wet and sticky feel
  - Limbs for more realistic IV insertion points
  - Adding color so the skin is more realistic
  - Zipper for accessibility to inside components
- Perform more usability testing with medical professionals that would be using this manikin
  - Ideally this would include intubation techniques with a laryngoscope

References

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