Neonatal Intubation Simulation with Virtual Reality and Haptic Feedback

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Abstract

Respiratory distress syndrome (RDS) is a common breathing disorder among premature neonates. Endotracheal intubation is often required to establish a secure airway in these critically ill neonates. Successful intubation, which is an extremely difficult procedure to perform, requires significant practice and skill. Due to limited clinical opportunities to intubate neonates and ineffective simulation training methods (e.g., intubation performed on plastic mannequins), better training strategies are needed to learn intubation skills. Current training methods on mannequins fail to emulate the high-stress delivery room environment and the precision required to intubate neonates. Thus, a more realistic training strategy would likely increase physician competency and potentially improve clinical outcomes. Virtual reality (VR), an innovative tool now being used in medicine, provides a realistic method to visually immerse trainees in a non-physical, yet responsive environment. Incorporation of haptic feedback devices allows somatosensory feedback to provide life-like physical sensations. We speculate that medical VR simulations with haptic feedback represent the future of medical training. Integration of a well-designed virtual environment with haptic devices that mimic the neonatal intubation procedure will provide a cost-effective, superior training experience that may improve patient outcomes.

Problem Motivation

- About 12% (~500,000) babies born preterm in the United States [1]
- ~10% of premature babies are born with respiratory distress syndrome each year [3-6], a risk that rises with increasing prematurity
- Babies born <29 weeks' gestation have a 60 % chance of developing RDS [5,6]
- Babies with RDS often require endotracheal tube intubation to establish a secure airway and to deliver surfactant
- 30-70% of intubation attempts are unsuccessful, partially due to inadequate training methods [6-8]
- Intubations must be done gently, quickly, and precisely [9]
- Current training methods include video instruction and intubation of neonatal mannequins [10,11]
- Mannequins fail to accurately mimic neonate anatomy and other physical properties [11]
  - Unnatural texture and movements
  - Vocal cords are unrealistically easy to identify
- While video instruction is informative, practicing intubation first-hand seems necessary for success under stress [10]

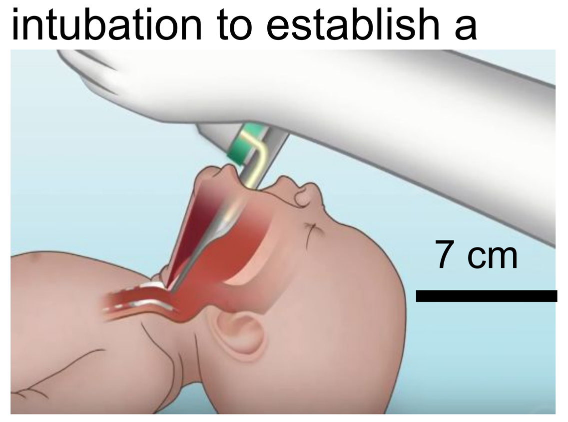


Figure 1: The laryngoscope is inserted into the mouth to sweep aside the tongue and lift the epiglottis, revealing the vocal cords [9]

Figure 2: "Gold standard" intubation models fail to accurately emulate the complex physical properties of the respiratory tract [12]

Current Design

- Semester objectives included creating a highly accurate, virtual neonate model and programming the haptic device to provide object-dependent forces

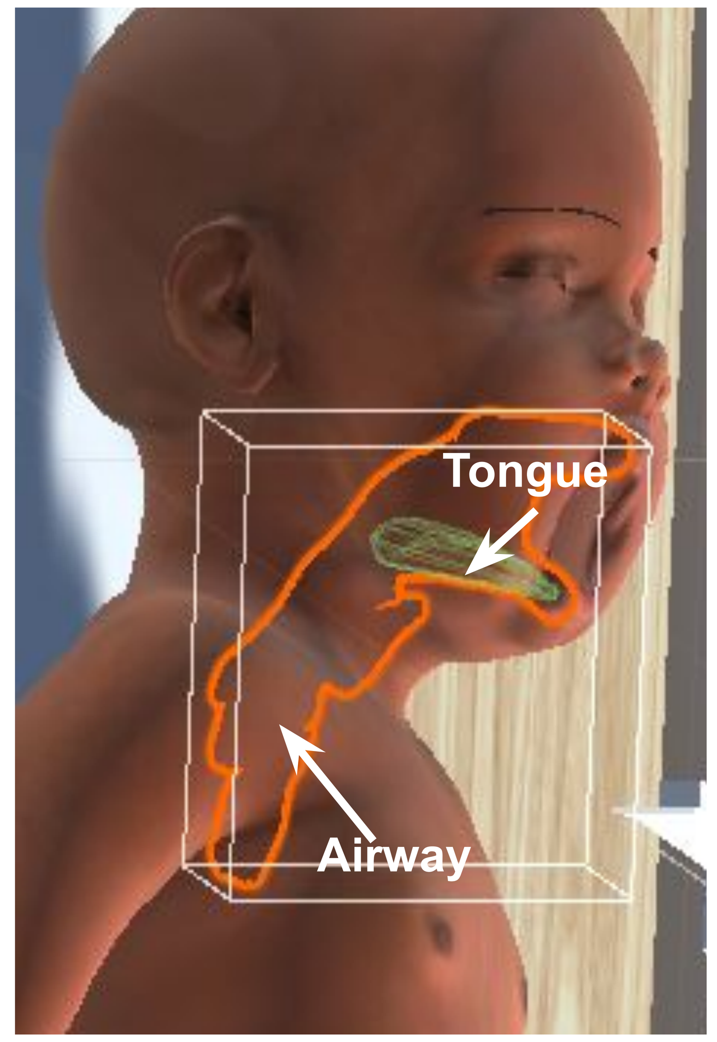
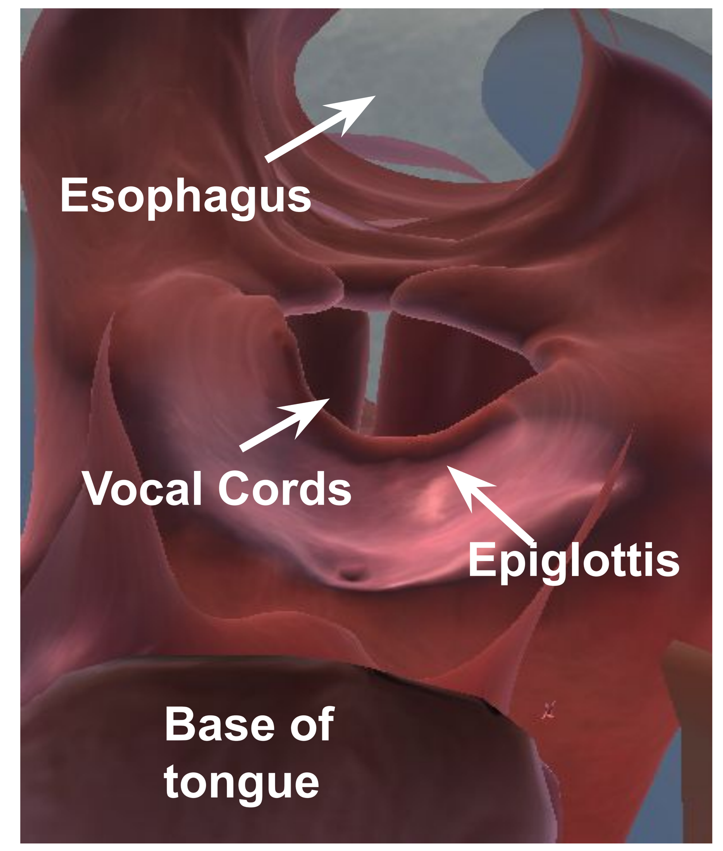


Figure 3 (Left): Cross-section of a throat model joined to a downloaded mouth model in Blender

Figure 4 (Below): A human infant CT scan was reconstructed and rendered in Blender to create an anatomically accurate physical model of the inner anatomy of the throat



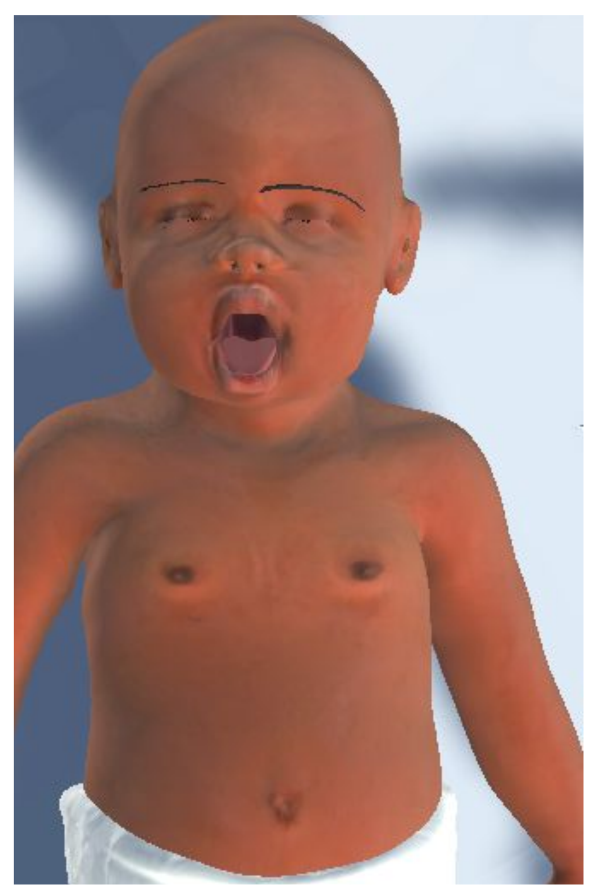


Figure 5 (Top-Right): A model of a Giraffe Infant warmer, one of the most important props within the simulation room, was developed in SolidWorks

Figure 6 (Left): Neonatal 3D model was downloaded online, and modified in Blender

Figures 7 (Bottom-Right): Using a built-in Unity functionality called rigging, 'bones' were added to the neonate to allow for realistic anatomical movement of the mouth and face

- Unity is our development platform of choice, due to its ability to interface with the Touch device
- The laryngoscope can be controlled with the haptic device and has a 3D collider that allows the user to feel when any part of the laryngoscope contacts an object in the virtual space (Figure 7)

Figure 8: The laryngoscope 3D model in Unity.

Acknowledgments

The team would like to extend their appreciation to Dr. Brandon Tomlin, Dr. Ryan McAdams, Dr. Beth Meyerand, Timothy Arment, Dr. Kevin Ponto, Ross Tredinnick, and the BME department for all of their collaboration on this project

Design Overview

- The clients (Dr. McAdams and Dr. Tomlin) want a VR simulation which emulates a neonatal intubation procedure for under $6000
- The system should incorporate a virtual reality headset alongside a haptic feedback device (Figure 8) to create a simulation with somatosensory feedback (Figure 9)
  - VR is an emerging tool in clinical medicine [13]
  - Haptic feedback devices provide force feedback, allowing users to 'feel' virtual objects [14]
  - The simulation should have a resolution of 0.02mm to compete with current haptic simulation systems [15]

Figure 9: 3D Systems Touch haptic feedback device is an affordable, effective tool for somatosensory feedback [15]

Figure 10: A 3D Systems haptic device simulating a virtual surgery [16]

Future Work

Imminent goals:
- Improve neonatal model
- Refine haptics with collision-dependent forces
- Merge completed neonatal model with haptics in Unity

Long-term goals:
- Implement two haptic devices
- Develop soft-tissue models
- Introduce multiple simulation difficulty levels and feedback for performance

Discussion and Conclusion

- Successful implementation of the proposed design will drastically improve training for neonatal intubation
- Accessibility will be limited at first, primarily to advanced facilities that can afford haptic devices
- The final design will incorporate multiple components: VR headset, two haptic feedback devices, computer and external server

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