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, an extremely difficult procedure to perform, requires significant practice and skill. Due to limited clinical opportunities to intubate neonates and ineffective simulation training methods, including video instruction and 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 than may improve patient outcomes.

Problem Motivation

- About 12% (~500,000) babies born preterm in the United States(1)
- ~10% of premature babies respiratory distress syndrome each year (2), a risk that rises with increasing prematurity
- Babies born <29 weeks' gestation have a 60 % chance of developing RDS (3)
- 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 [3-5]
- Intubations must be done gently, quickly, and precisely [6]
- Current training methods include video instruction and intubation of neonatal mannequins [7,8]
- Mannequins fail to accurately mimic neonate anatomy and other physical properties [8]
  - 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 [7]

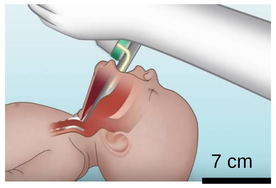


Figure 1: The laryngoscope is inserted into the mouth to sweep aside the tongue and lift the epiglottis, revealing the vocal cords [6]

Figure 2: "Gold standard" intubation models fail to accurately emulate the complex physical properties of the respiratory tract [9]

Current Design

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

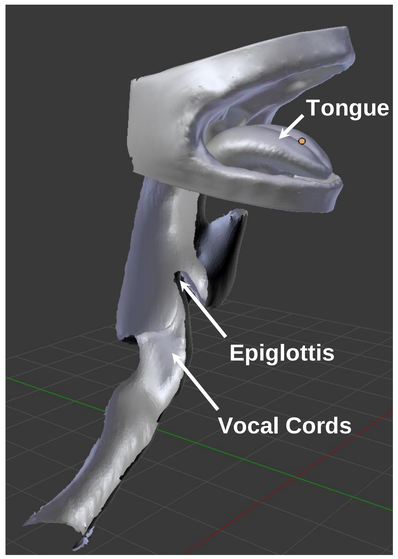


Figure 3 (Left): Cross-section of a throat model joined to a downloaded mouth model in Blender

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

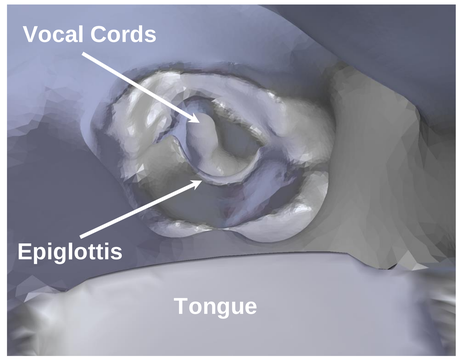
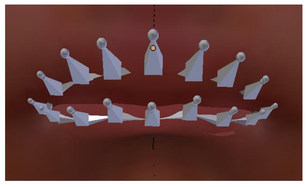
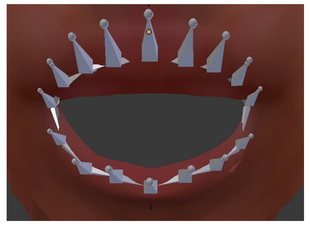


Figure 5 (Left): A neonatal 3D model was downloaded online, and modified in Blender



Figures 6a and 6b (Right): Using a built-in Blender 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 is currently modelled in Unity as a single point in space, but a point cloud will be necessary to provide lifelike somatosensory responses (Figure 7)

Figure 7: Points covering the surface of the laryngoscope will be used with a collider, producing linear forces and torque around a central axis

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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 [10]
  - Haptic feedback devices provide force feedback, allowing users to 'feel' virtual objects [11]
  - The simulation should have a resolution of 0.02mm to compete with current haptic simulation systems [12]

Figure 8: 3D Systems Touch haptic feedback device is an affordable, effective tool for somatosensory feedback [12]

Figure 9: A 3D Systems haptic device simulating a virtual surgery [13]

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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