Neonatal Intubation Simulation with Virtual Reality and Haptic Feedback

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Abstract

Respiratory distress syndrome (RDS), a neonatal disease characterized by difficulty breathing, is remarkably common among premature infants. Patient outcomes resulting from RDS are undesirably poor. Unsatisfactory patient outcomes are in part due to ineffective training methods. The high stress environment of the delivery room and the precise nature of the procedure are nearly impossible to emulate using current training methods; including video instruction, and mannequin intubation. Thus, a more realistic training method that better represents both the difficulty of the procedure as well as the tense external environment would improve physician competency and outcomes. Virtual reality (VR) is an innovative tool becoming increasingly used in the medical field, particularly for simulations. VR provides a means by which individuals can be visually immersed in a non-physical, yet responsive, environment. Incorporation of haptic feedback devices incorporates somatosensory feedback into the environment as well. Cutting edge medical VR simulations with haptic feedback already exist and represent the future of medical training. Integration of a well designed virtual environment with haptic devices that imitate a neonatal intubation procedure would provide a more effective means of training. Effective implementation of the proposed system would increase training efficacy, lower healthcare costs, and improve patient outcomes.

Problem Motivation

- 7% of term-newborns undergo respiratory distress [1]
  - Rates increase substantially in premature infants

- 30-70% of intubation attempts are unsuccessful, partially due to inadequate training methods [3-5]

- Procedure must be done gently, quickly, and precisely [6]

- Current training methods include video instruction and Neonatal Mannequins [7,8]

- Mannequins fail to accurately mimic neonate anatomy and other physical properties [8]
  - Unnatural texture and movements
  - Easily identifiable vocal cords

- While useful, without practicing an intubation first-hand, one cannot hope to perform the procedure correctly under stress [7]
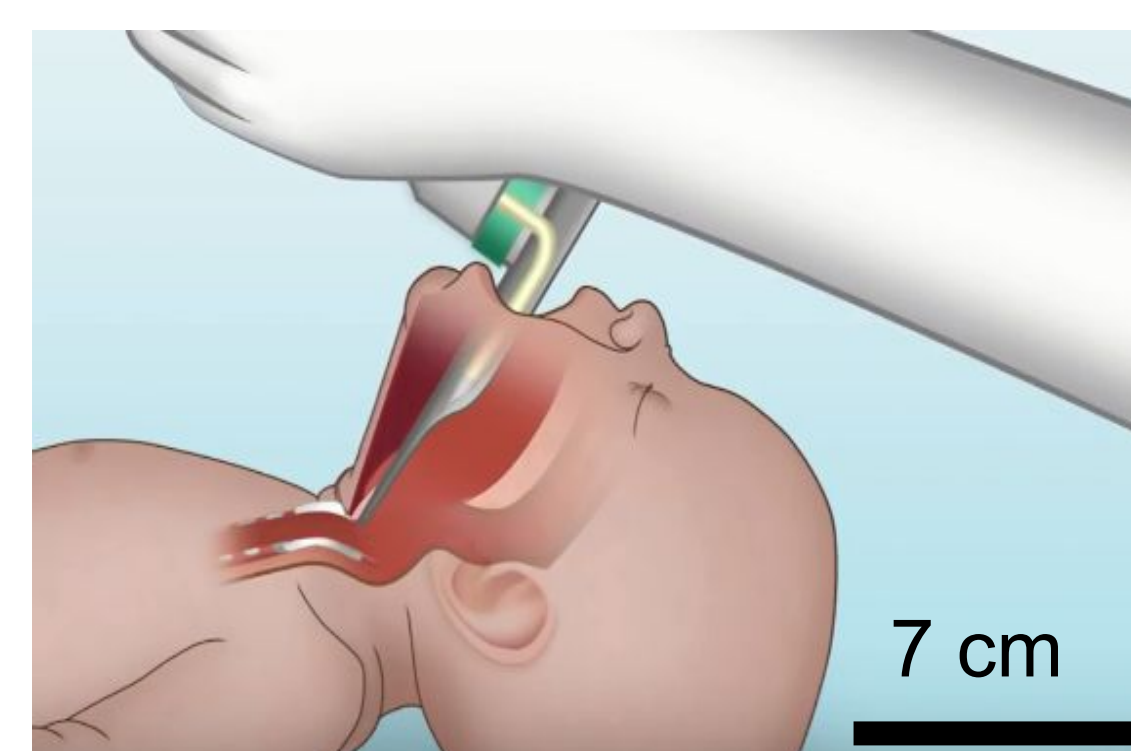
Figure 1: The endotracheal tube is inserted into the mouth to scoop aside the tounge and epiglottis, revealing the vocal cords [6]

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

Design Overview

- The clients desire a virtual simulation which simulates a neonatal intubation procedure for under $6000
- The simulation should incorporate a virtual reality headset (Figure 3) alongside a haptic feedback device (Figure 4) to create a simulation with somatosensory feedback (Figure 5)
  - Virtual reality (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]
- The final design will incorporate a variety of software including:
  - Unity (game development)
  - Solidworks (3D modelling)
  - Blender (3D rendering and animation)
  - 3D Systems OpenHaptics
  - Geomagic Touch (haptic integration)

Figure 3: The Oculus Rift is a prominent VR headset, compatible with most developing platforms [13]

Figure 4: 3D Systems Touch haptic feedback device is an affordable, effective tool for somatosensory feedback [12]

Figure 5: A 3D Systems haptic device simulating a virtual surgery [14]

Current Design

- The current virtual environment models a simple operating room, including:
  - one deformable sphere
  - one rigid sphere
  - one rigid endotracheal tube
  - three rigid laryngoscope blades
- The surgeon can travel about the OR while interacting with rigid and deformable objects
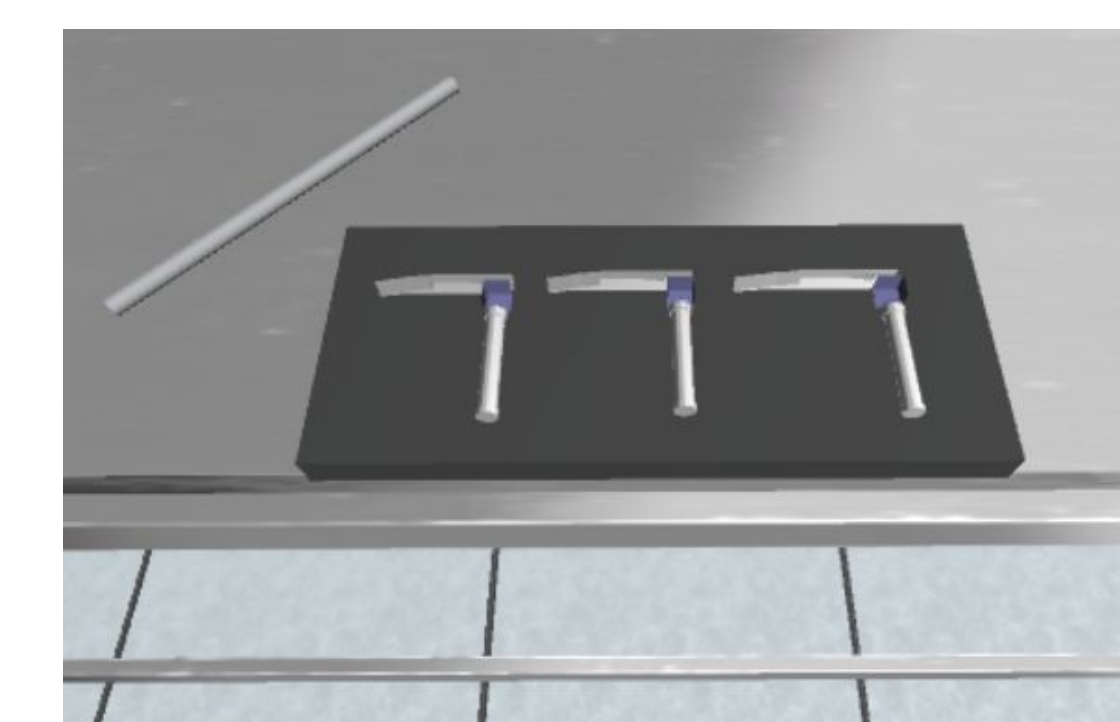
Figure 6: Rigid laryngoscope blades will later be used in conjunction with the Touch haptic feedback device

Figure 7: The above image illustrates a simple, proof-of-concept operating room developed in Unity, intended to simulate a clinical environment and exemplify the character-object interactions that will be encountered while developing the surgical simulation

Future Work

- Refine the virtual reality environment
- Implement two haptic feedback devices
- Introduce multiple difficulty levels for the simulation
- Develop equations and models to simulate the tissue's physical properties

Refine neonatal model; create lifelike appearances and textures → **BME 400/402 Fall 2018**

Refine haptics; fully integrate feedback into neonatal model → **BME 400/402 Spring 2019**

If incomplete, pass to another BME team or developing firm

Discussion and Conclusion

- A successful implementation of the proposed design would 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
  - Samsung phone
  - Computer and external server
  - SolidWorks
  - Blender
  - Unity

References

1) Reuter, S., Moser, C. and Baack, M. (2014). Respiratory Distress in the Newborn. Pediatrics in Review, 35(10), pp.417-429.
2) Beck, S., Wojdyla, D., Say, L., Pilar Bertran, A., Meraldi, M., Harris Requejo, J., Rubens, C., Menon, R. and Van Look, P. (2010). The worldwide incidence of preterm birth: a systematic review of maternal mortality and morbidity. Bulletin of the World Health Organization, 88(1), pp.31-38.
3) Kumar, A. and Vishnu Bhat, B. (1996). Epidemiology of respiratory distress of newborns. The Indian Journal of Pediatrics, 63(1), pp.93-98.
4) Haubner, L., Barry, J., Johnston, L., Soghier, L., Tatum, P., Kessler, D., Downes, K. and Auerbach, M. (2013). Neonatal intubation performance: Room for improvement in tertiary neonatal intensive care units. Resuscitation, 84(10), pp.1359-1364.
5) O'Donnell, C. (2006). Endotracheal Intubation Attempts During Neonatal Resuscitation: Success Rates, Duration, and Adverse Effects. PEDIATRICS, 117(1), pp.e16-e21.
6) OPENPediatrics (2016). "Neonatal Tracheal Intubation" by Lindsay Johnston for OPENPediatrics. [video] Available at: https://www.youtube.com/watch?v=tGTaA_Ud9Xw [Accessed 31 Jan. 2018].
7) O'Shea, J., Thio, M., Kamlin, C., McGory, L., Wong, C., John, J., Roberts, C., Kuschel, C. and Davis, P. (2018). Videolaryngoscopy to Teach Neonatal Intubation: A Randomized Trial. [online] Available at: http://pediatrics.aappublications.org/content/136/5/912 [Accessed 10 Feb. 2018].
Kresge, N. (2018). Improving neonatal intubation training to boost clinical competency | Children's National. [online]
8) InnovationDistrict. Available at: https://innovationdistrict.childrensnational.org/improving-neonatal-intubation-training-boost-clinical-competency/ [Accessed 10 Feb. 2018].
9) Pinterest. (2018). School & Educational Supplies. [online] Available at: https://www.pinterest.com/pin/835417799599311875/ [Accessed 2 Mar. 2018].
10) "Oxford Medical Simulation - virtual reality training for optimal patient care". Oxford Medical Simulation. 2018. [Online]. Available: https://oxfordmedicalsimulation.com. [Accessed: 24- Feb- 2018].
11) H. Garden and E. Tech. "How Haptic Technology Works". HowStuffWorks. 2018. [Online]. Available: https://electronics.howstuffworks.com/everyday-tech/haptic-technology4.htm. [Accessed: 24- Feb- 2018].
12) "Touch | 3D Systems", 3D Systems, 2018. [Online]. Available: https://www.3dsystems.com/haptics-devices/touch. [Accessed: 25- Feb- 2018].
13) Amazon.ca. (2018). Amazon. [online] Available at: https://www.amazon.ca/Oculus-Touch-Virtual-Reality-System/dp/B073X8N1YW [Accessed 21 Feb. 2018].
14) 3D Systems. (2018). LAP Mentor VR | 3D Systems. [online] Available at: https://www.3dsystems.com/healthcare/lap-mentor-vr [Accessed 23 Apr. 2018].

Acknowledgements