Executive Summary: Tong BME Design Award, BME 301

Neonatal Intubation Simulation with Virtual Reality and Haptic Feedback

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Respiratory distress syndrome (RDS) is characterized by difficulty breathing and is the leading cause of death for newborns (“Respiratory Distress Syndrome”, 2018). In the U.S. in 2015, infant mortality rates were nearly 6%, with 13.4% of those deaths attributable to RDS (“Infant Mortality”, 2018). Currently, RDS is treated via a variety of methods including surfactant replacement therapy, oxygen therapy, and breathing support from a nasal continuous positive airway pressure machine. For each of these methods, it is often required that neonatal intubation be performed ("Respiratory Distress Syndrome (RDS)”, 2018). Neonatal intubation must be performed quickly, precisely, and gently. Failure to comply with these guidelines can result in suffocation, tissue damage, or even head trauma ("Neonatal Tracheal Intubation", 2016). According to a variety of studies, neonatal intubation attempts are often unsuccessful, especially among residents. One study listed success rates of resident intubations as low as 24%, while that of fellows and consultants was closer to 80% (Kumar et al., 1996).

Current methods are mainly restricted to video demonstration and intubation practice on neonate mannequins (O’Shea et al.,2018). Based on the low success rates in residents, it is obvious that these methods are not sufficient, and effective training comes primarily from experience. Due to the high-risk nature of the procedure, it is preferred that physicians are able to perform this procedure correctly on their first attempt. Thus, it would be extremely beneficial to develop more effective and accessible training methods that could improve patient outcomes.

Virtual reality (VR) is an emerging tool in clinical medicine with functionalities ranging from medical training to pain management (Pourmand et al., 2017). Current methods are usually limited to VR alone, but 3D Systems produces cutting edge simulations that incorporate haptic feedback devices (“3D Printers…”, n.d.). Haptic feedback has already been successfully implemented in laparoscopy (Pinzon et al., 2016) and prostatectomy (“Radical Prostatectomy”, n.d.) procedures, and is rapidly expanding as a tool to train prospective clinicians.

In light of this research, a virtual simulation of a neonatal intubation procedure is a promising method of training residents. A novel prototype has been assembled featuring an anatomically accurate neonate model (constructed using CT images obtained from real neonates) and a haptic feedback device that lets the user manipulate a virtual laryngoscope using simple hand motions in order to interact with the neonate. The neonate has been equipped with animations which replicate the complex movement of the airway that would be seen during a procedure. Further, bone- and joint-like constraints have been implemented such that the movement of each anatomical feature is realistic. The simulation takes place within a biomimetic environment, complete with equipment commonly found in the Neonatal Intensive Care Unit and audio cues. Notably, the models have been iteratively refined and validated by an expert in the field, Dr. Ryan McAdams, Chief of Neonatology UW Hospitals and Clinics.

This design provides a convenient alternative to the training methods used today; its customizability allows it to convey a much broader and more lifelike array of experience to users. Eventually, various airway models may be implemented, as well as various levels of motion, swelling, or fluid inside the airway. This design also has the potential to be extremely portable, allowing for cutting edge training to be brought to physicians who may not otherwise have access to proper training methods. Ultimately, more advanced training modalities such as this will improve clinical outcomes and treatment availability, lowering costs and saving lives.