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Medical Training Simulator for Central Venous Catheterization

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BACKGROUND

Approximately 1 in 6 of the 800,000 CVC procedures performed in the US[1] will result in complications that could cost patients, hospitals, insurance providers, and the government as much as $2.17 billion[2] this year.

- **Central Venous Catheterization Procedure**
  - Used to deliver drugs to the heart in trauma cases
  - Catheter inserted into the subclavian or jugular vein (**Figure 1**)
  - Risky due to the proximity to major veins and arteries
  - Students often practice on patients since current training simulators are inaccurate and expensive
- **Features of our simulator to overcome current simulator inadequacies**
  - Accurate anatomical landmarks
  - Patent pending ultrasoundable tissue-mimetic cross-linked hydrogel
  - Portable manikin and platform

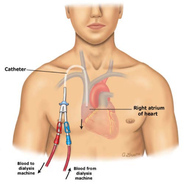

Figure 1 - Implantation of a Central line through the jugular vein

The 2010 Affordable Care Act set many financial incentives for increasing quality of care as well as major disincentives for medical errors. Medicare has also eliminated hospital reimbursement for hospital-acquired conditions. Our goal is to create a safe, affordable, effective Central Venous Catheterization training simulator in order to improve care and reduce medical errors.

VASCULATURE

- Allows for ultrasound guided catheter insertion (**Figure 2**)
- Resistance to leaking
- Elastic arteries that simulate pulsatile flow created via hand pump and veins that expand with pressure created (**Figure 3**)

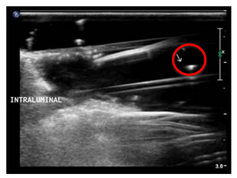

Figure 2 – Ultrasound image of punctured jugular vein; Note needle insertion indicated by red circle

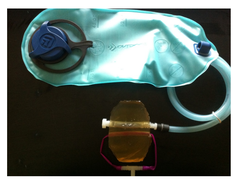

Figure 3 – Model of the vascular system

BONES

- **Inclusion of all bony landmarks**
  - Inclusion of two clavicles, the first and second rib, and the sternum (**Figure 4**)
  - Realistic use of palpable landmarks to locate for insertion
- **Cost effective bone production method**
  - 3D printed bones
  - Durable material allows for reuse
  - Single piece including all necessary bones does not require assembly

Figure 4 – Bone inclusions ready to be placed in the mold

TISSUE ANALOG

- **Mechanical Properties**
  - Mechanical properties at a wide range of temperatures
  - Extended shelf life
  - Opacity hides internal anatomy for realistic training (**Figure 5**)
  - Can be punctured multiple times with minimal damage and does not clog needle (**Figure 6**)
  - Skin analog prevents dehydration and extends shelf life

Figure 5 – Molded puncture tissue analog with preliminary vasculature in place

Figure 6 – Simulator undergoing the CVC procedure

- **Ultrasoundability**
  - Realistic echo texture (**Figure 7**)
  - Shows pulsatile flow in arteries with Doppler ultrasound
  - Visualization of expansion of veins during Valsalva (**Figure 8**)

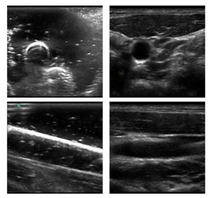

Figure 7 – Ultrasound images of the tissue analog depicting the vasculature

Figure 8 – Simulator undergoing an ultrasound test during puncture in a clinical setting

PLATFORM & MANIKIN

- **Platform**
  - Inclination of 15 degrees to mock the Trendelenburg position (**Figures 9 & 10**)
  - Eliminates need for hospital beds and allows for easy clean-up
- **Manikin**
  - Represents upper torso
  - Mimics natural rotation of human head

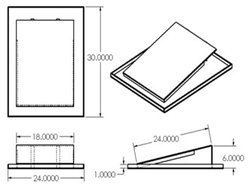

Figure 9 – Diagram representing the structure of the platform

Figure 10 – Simulator on platform design; Note the rotating head

COMMERCIALIZATION

- **Prototype Development**
  - Upgraded to 3D printing from former silicone mold for bones (**Figure 11**)
  - Remodeled tray to house fragile vasculature and provide easy assembly (**Figure 12**)
  - Altered a prefabricated manikin
- **Product Development**
  - Continue to utilize 3D printing in order to standardize manikin torso
  - Develop easy, lightweight packaging
  - Develop disposable tray and gel pad unit to snap into manikin

Figure 11 – Molded sternum and molding technique

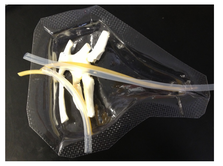

Figure 12 – Mold with bone inclusions and vascular lines in place prior to pouring the gelatin

FUTURE WORK

- Continue conducting IRB Certified surveys and testing by practicing physicians
- Create a streamlined manufacturing process in collaboration with multiple manufacturing and business professionals
- Make a user manual

REFERENCES

1. D. C. Mcgee, M. K. Gould. "Preventing Complications of Central Venous Catheterization," The New England Journal of Medicine, vol. 348, pp. 1123-1133, March 2003.

2. J. Shreve, J. Van Den Bos, Gray, M. Holford, K. Rustagi, E. Ziemkiewicz." The Economic Measurement of Medical Errors," Milliman, June 2010

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