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DESIGN OF AN INSERTION FUNNEL FOR A TRAINING SYSTEM FOR CENTRAL VENOUS CATHETER GUIDEWIRE INSERTION

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ABSTRACT

A novel concept is proposed to effectively measure and train central venous catheter guidewire insertion. This system utilizes a 3D printed funnel to direct the insertion of a guidewire from multiple angles and positions. This directed guidewire can then be passed through previously developed sensors to provide the user with valuable training feedback. Experiments are performed to measure the effectiveness of the funnel system under varying insertion positions, angles, and funnel coatings. After experimentation, it was found that a funnel greased with white lithium grease allows the guidewire to successfully make it through the funnel compared to alternatives tested. This design will be applied to the Dynamic Haptic Robotic Trainer Plus (DHRT+) system to train medical residents to safely perform central venous catheterization.

Keywords: Medical Simulation Training, Central Venous Catheterization, Needle Insertion, Guidewire insertion

1. INTRODUCTION

Medical simulators are prominently used in medical training. The ability to train using medical simulators can be cost efficient and help create a realistic scenario for trainees without patient risk [1]. Complications associated with central venous catheter (CVC) insertion (a long, slim tube that is placed in a large vein to deliver medicines, fluids, nutrients, or blood products) can cause morbidity and mortality in hospitalized patients [2]. These complications are often caused by deficits in training, leaning to a need to continuously improve CVC training devices [3].

CVC training has traditionally focused on trainees viewing a CVC insertion, then practicing, and finally, teaching the procedure to someone else. This method of “see one, do one, teach one” is inadequate and lacks repetitive practice [3]. An increased focus on technique and repetition can help reduce errors with CVC insertion and help improve patient safety and the precision of the trainee. The implementation of simulation in CVC training helps trainees to practice in a safe, focused, and repetitious environment - while also gaining experience with a variety of patient scenarios [2].

Traditional CVC training methods have incorporated the use of bodily replications such as manikin trainers or other types of simulators to safely train medical residents and other personnel in CVC, however, many of these trainers lack the incorporation of all procedural components or the flexibility of changing patient anatomy. This is problematic, because every person’s body and anatomical structure is slightly different, and it is important for residents to experience what it would be like to do a CVC on a variety of bodies.

With the accessibility of position sensing already in place in medical simulators, sensors can be easily attached to CVC instruments to track their presence in a well-controlled environment and help further incorporate the full procedure into training [4]. The current state of the art CVC simulation assesses the standard process of CVC insertion, but has no way to change the insertion site and present possible different locations to perform CVC and allow the trainee to practice with varying anatomical structures and locations. The simulator of interest that this paper focuses on is the Dynamic Haptic Robotic Trainer Plus (DHRT+), shown in Figure 1.

The DHRT+ uses a false vein channel, overhead computer vision, and Arduino based sensors to track the movement of medical tools during CVC. The Arduino sits under the body of the simulator and uses sensors in the vein channel to determine when and if tools get inserted into and removed from the vein; however, the configuration of the vein channel and sensors in the DHRT+ limit the insertion site to one option, similar to the problems seen in other CVC simulators. To allow for the user to vary insertion site location a funnel is proposed to be used with the current sensor methods in the DHRT+ to allow insertion from any point at any angle but still be able to utilize the false vein channel for sensing.

Experimentation is performed on funnels with varying coatings to determine effectiveness in aligning the guidewire in the DHRT+ device. These experimental methods, results, and conclusions are presented in this paper.

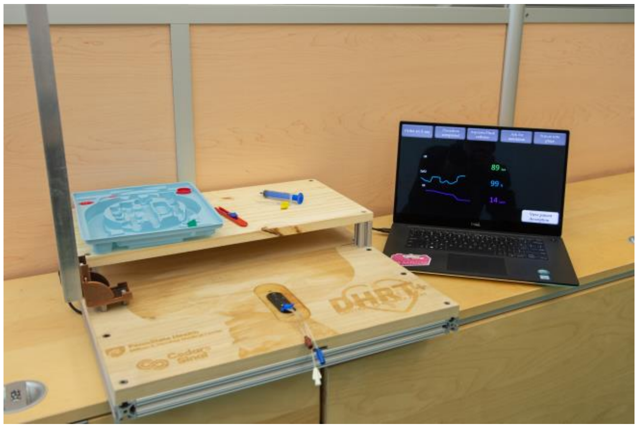


FIGURE 1: THE DHRT+ SYSTEM USED FOR TRAINING

2. MATERIALS AND METHODS

Experimentation is performed to determine an optimal funnel material surface to allow guidewire alignment through the funnel. It is important to note that for this experiment, the medical tool that was tested was the guidewire because it is the hardest to sense and has the smallest surface area and diameter of any of the tools used in CVC.

A 3D printed funnel was developed with two openings to ensure the guidewire traveled the least possible distance from any angle and to create the least possibility for the wire to bind to the side of the funnel and make it into the exit hole of the funnel, as shown in Figure 2. This funnel had a large open diameter of 65 mm to allow the user amble range of positions to insert the needle and guidewire.

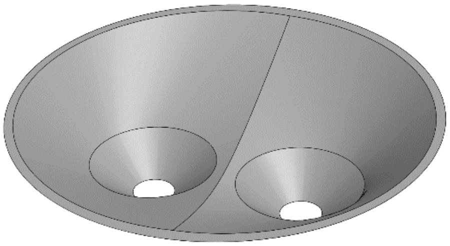
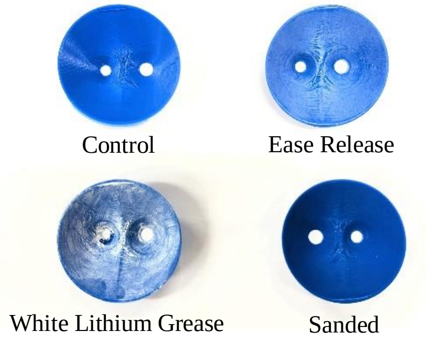


FIGURE 2: FUNNEL CAD MODEL

To ensure the wire is able exit the funnel smoothly, the guidewire was tested with four different funnel material surfaces as shown in Figure 3. The four types of funnels tested include one control funnel that is 3D printed with no alterations. The other three funnels were sanded with 100 grit sandpaper. One was greased with Ease Release 205 (Mann Release Technologies, PA), while another was greased with white lithium grease, and the final funnel is left sanded, but ungreased.



Control

Ease Release

White Lithium Grease

Sanded

FIGURE 3: FUNNELS TESTED WITH DIFFERENT MATERIALS TO CHANGE FRICTION ON SURFACE

Varying angles and positions were tested using a brachytherapy needle grid, see Figure 4. This allowed for consistent guidewire insertion during experimentation. The guidewire was inserted at angles of 30, 45, and 90 degrees, as shown in Figure 5. The 90-degree angle was used for control and the 30- and 45-degree angles were used because the proper angle of insertion for CVC is between 30 and 45 degrees for optimal performance [3]. The positions were varied by inserting the guidewire into each hole of the brachytherapy grid. In summary, each material was tested at 169 positions and at three different angles of 30, 45, and 90 degrees.

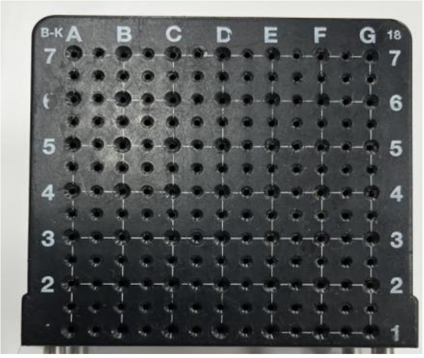


FIGURE 4: BRACHYTHERAPY NEEDLE GRID USED TO STANDARDIZE GUIDEWIRE POSITIONING

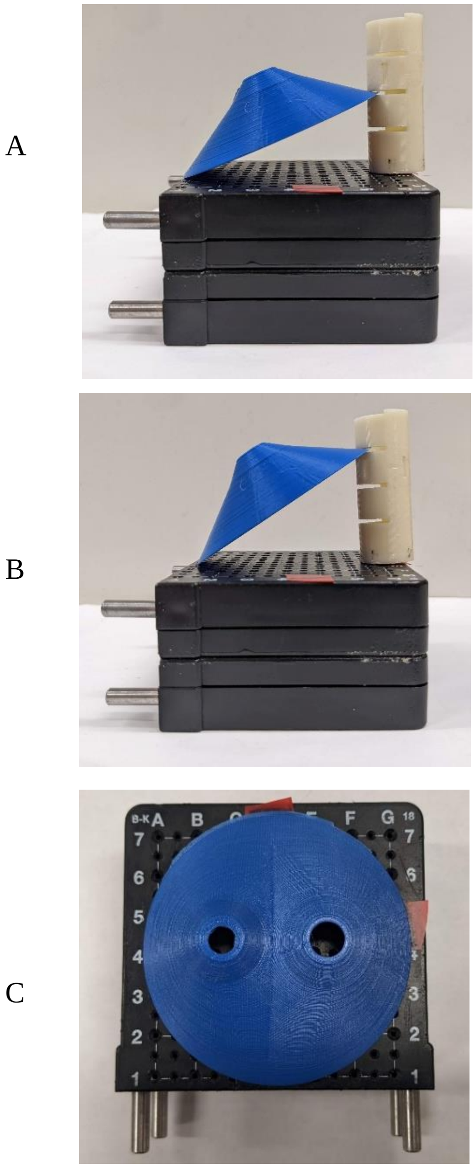


FIGURE 5: FUNNEL MOUNTED AT (A) 30 DEGREES, (B) 45 DEGREES, AND (C) 90 DEGREES

For each insertion location on the grid, the guidewire was inserted and it was recorded if it exited or got stuck on the funnel. This information is used to evaluate the effectiveness of the funnel system to align the guidewire into a narrow tube where RGB sensors are used to provide performance assessment and feedback.

3. RESULTS AND DISCUSSION

The results indicate that steep angles make insertion difficult and that white lithium grease can improve guidewire insertion into the funnel, as shown in Figure 6. The results depict white lithium grease having the highest number of successful insertions (31) compared to the control, sanded, and Ease Release 205 (20, 23, and 19, respectively). This is anticipated as the white lithium grease is able to reduce the coefficient of friction between the guidewire and the funnel. The Ease Release 205, which is a much less viscous material compared to the white lithium grease, did not show benefits.

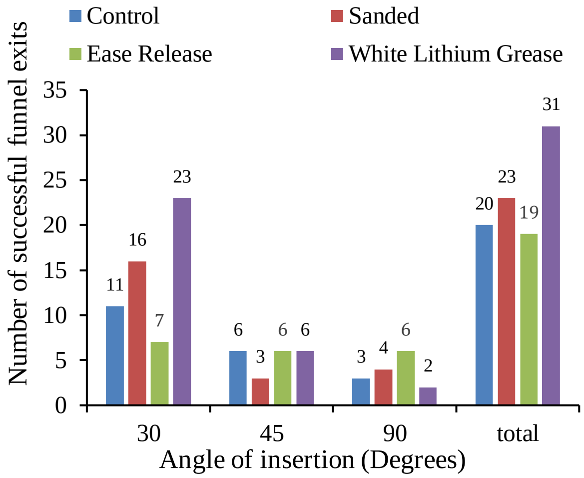


FIGURE 6: HISTOGRAM OF ANGLE OF INSERTION VS QUANTITY OF SUCCESSFUL GUIDEWIRE EXITS

The angle of insertion and placement of insertion was tested within these four materials, and the success rate for the white lithium grease is shown Figure 7. The red on each grid represents a position where the guidewire got stuck or did not make it through the funnel, while the green means the guidewire successfully made it through the funnel and would be detected by the current DHRT+ sensors. The black sections of the grid signify that the guidewire was out of range and did not contact the funnel when inserted at this point. As shown the steeper angles of insertion greatly limited the success that could be achieved with the funnel.

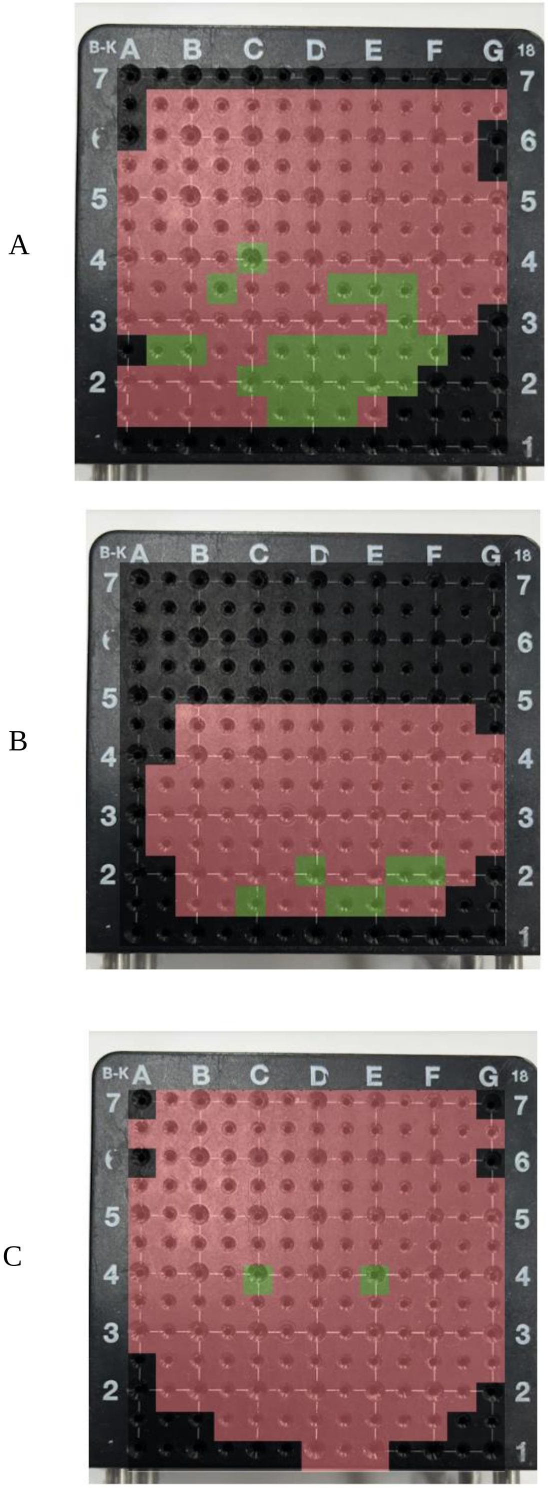


FIGURE 7: GUIDEWIRE INSERTION TRIAL FOR WHITE LITHIUM GREASE AT (A) 30 DEGREES, (B) 45 DEGREES, AND (C) 90 DEGREES

4. CONCLUSION

The results show that white lithium grease improved guidewire insertion compared to the other three methods. Out of the 169 insertion tests (for each angle), the funnel coated with white lithium grease successfully exited the guidewire 31 times, which was 8 more than the next best funnel (sanded).

The funnel poorly managed to align the guidewire when there was a steep angle of insertion. Future work will evaluate alternative funnel shapes, such as designs with steeper slopes, to reduce the frictional force and improve guidewire alignment at steep angles.

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