

Mixed Reality Simulation for Training Reservists and Military Medical Personnel in

Subclavian Central Venous Access

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Introduction

During central venous access (CVA), a needle is inserted into the internal jugular (IJ) or subclavian vein. Unlike IJ CVA, subclavian CVA is commonly performed “blind” without ultrasound (US) guidance because the clavicle casts a large US shadow that interferes with US guidance. Clinicians instead rely on anatomical landmarks such as the sternal notch and heuristics to establish the entry point and a safe trajectory to target. It can be difficult to acquire sufficient practice in subclavian CVA, especially in civilian medicine where the US-guided IJ route is more common. In contrast, subclavian CVA is more widespread in military medicine especially if a neck collar is present and/or the surgeon is performing cricothyrotomy. During deployment, training facilities may not be optimal. We designed a compact, turnkey simulator for use in austere environments that allows reservists/military medical personnel to acquire/maintain subclavian CVA skills/mastery even during deployment.

Methods

We built a simulator that mixes physical and virtual components for training in needle tip placement into the subclavian vein without striking the adjacent artery or lungs. In contrast to existing CVA trainers, our simulator detects lung strikes, displays the margin of safety, i.e., the distance by which artery or lung puncture was avoided and records and plays back the needle’s path for after action review.

We 3D printed the torso, neck and head of an actual human from a contrast-enhanced CT scan including anatomical landmarks (palpable sternal notch and clavicle) and ribs. The remainder of the simulator (veins, arteries, lungs) was virtually modeled and registered to the physical component (a 3D-printed torso) with sub-millimeter accuracy. The tip of an 18 ga. needle on a Raulerson syringe (TeleFlex Medical, Research Triangle Park, NC) was tracked in real time with a magnetic 6 DoF sensor. We implemented a scoring algorithm to automatically score performance. As a preliminary study, the simulator was evaluated with 28 anesthesia residents at an academic health center in the southeastern U.S.; each used the simulator three consecutive times (Runs 1-3).

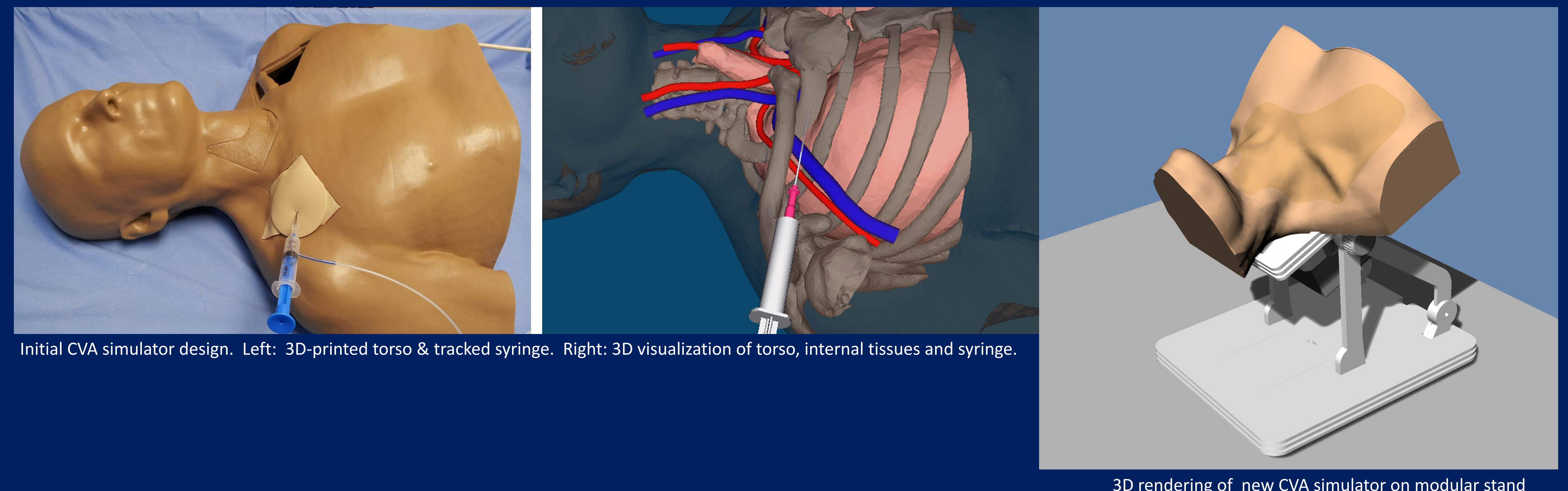
Results

From Run 1 to Run 3, performance score (0-100 scale; lower score is better) for all participants was improved, on average, by 28% with a 71.9 seconds reduction in average time to achieve subclavian CVA. We performed repeated measures ANOVA on the outcomes from the three waves of data collection with follow-up pairwise dependent sample t-tests. There were reductions in average time ($F=14.28$, $p<.0001$), the number of attempts ($F=10.77$, $p=.0001$), number of skin punctures ($F=6.59$, $p=.004$) and score as determined by the scoring algorithm ($F=14.59$, $p<.0001$). Complication rates for pneumothoraces and subclavian arterial punctures were reduced from 11% to 7% and 13% to 7%, respectively. On a five point scale (1=strongly disagree to 5=strongly agree), on average, participants agreed that the simulator was realistic ($M=4.1$) and strongly agreed that the simulator should be used as a training/educational tool ($M=4.8$).

The above data were collected with the initial CVA simulator design. The new modular design will be similar to a modular regional anesthesia simulator which is turnkey and can be set up in 7 minutes by a person unfamiliar with it. We expect similar turnkey characteristics for the new CVA simulator.

Conclusions

Our preliminary data indicate that a CVA mixed simulator may provide military medical personnel a robust, deployable simulator to acquire/maintain skills/mastery.



Initial CVA simulator design. Left: 3D-printed torso & tracked syringe. Right: 3D visualization of torso, internal tissues and syringe.

3D rendering of new CVA simulator on modular stand

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