

Simulation Framework for Training Chest Tube Insertion Using Virtual Reality and Force Feedback

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Abstract

Most virtual reality simulators are aimed at complex procedures, such as laparoscopic surgery. While important, only a subset of specialized doctors would use these simulators. There is a need for simulators that train clinicians to perform more common emergency procedures such as chest tube insertion. This work describes the design of a virtual reality simulator that utilizes force feedback devices to train the cognitive and motor tasks that underlie the chest tube insertion procedure. The simulator's framework was designed to allow for providing real-time feedback to trainees and assessing user performance. The training environment includes a pre-simulation test, a vital signs monitor, a virtual operating room for hands-on interaction, and a post performance feedback report. Major hardware components include the two force feedback devices (SensAble OMNI), audio speakers, and two graphics displays. The virtual environment was programmed using primarily Python and the H3D haptic library.

Chest Tube Procedure Major Tasks and Milestones

A chest tube insertion is an emergency procedure to place a flexible, hollow drainage tube into the chest in order to remove an abnormal collection of air or fluid from the pleural space. The three conditions that require the need for a chest tube are pneumothorax (air leak from the lung into the chest), hemothorax (bleeding into the chest) and empyema (lung abscess or pus in the chest). The basic task of the procedure are as follows:

Task 1: Prepare Patient for Surgery: Acquire consent, create a sterile environment, position the patient, apply local anesthesia.

Task 2: Create Skin Incision: Determine where to cut the skin and the length of the incision.

Task 3: Penetration into Pleura Space: Create a tract to the rib-cage and puncture through the pleura.

Task 4: Verification of Pleura Space Entry: Determine if incision broke through the plural and that there are no adhesion complications within the chest.

Task 5: Chest Tube Insertion: Insert the tube through the incision and into plural cavity.

Task 6: Securing the Chest Tube: Confirm that tube is properly secured in order to complete the overall goal of removing excess fluid from around lungs.



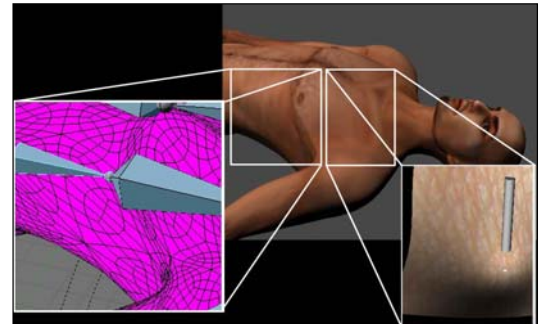
Currently, most students are taught the chest tube insertion procedure using chest mannequins and pig ribs.

Simulation Components



The training environment includes a pre-simulation test, a vital signs monitor, a virtual operating room for hands-on interaction, and a post performance feedback report. Major hardware components include the two force feedback devices, audio speakers, a computer and two graphics displays.

The virtual patient is a modified version of a freely available 3D geometric model that was refined to a high level of detail. The model consists of a mesh of approximately 10,000 polygons which is loaded into the H3D haptic library. The polygon mesh is assigned stiffness and frictional properties which determine the nature of the forces returned to the user's hands as he or she touches the skin of the virtual patient. The user controls several virtual surgical tools that visibly deform the skin as it is touched. Incisions are drawn on the skin by modifying the 3D model's texture at the location touched by a virtual surgical tool

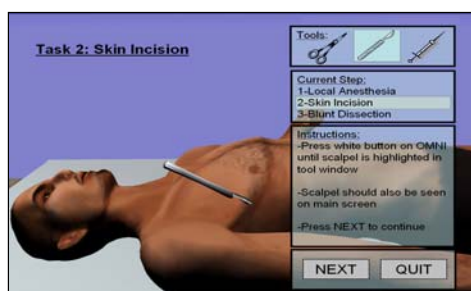


Simulation Features

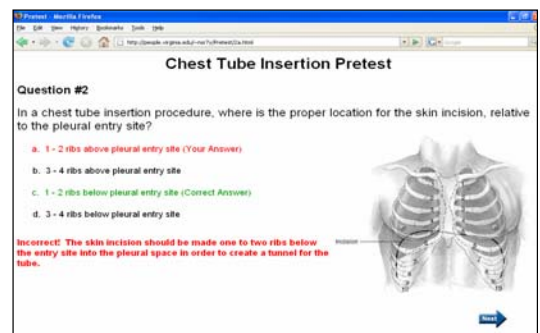
- Virtual Tools:** The virtual tools were created using a X3D format within Blender, a 3-D modeling program. These virtual tools include a scalpel, a Kelly clamp, a cotton swab, a Kelly clamp with a chest tube and a syringe.
- Switching Virtual Tools:** By pressing a button on the Sensable OMNI device, the user is able to switch between the virtual tools throughout the simulation.
- Viewpoint Adjustment:** The simulator automatically adjusts viewpoints so that the user is able to focus solely on the task at hand.
- Incision and Location:** The user is able to make an incision on the simulated patient's chest. The simulation contains palpating ribs to allow a user to feel the virtual ribs and locate the proper location for the incision.
- Navigation and Status Aids:** User interfacing features were designed to help the user navigate between the tasks and understand his current state within a task in our simulation environment. Four features include: a tool menu, a step status indicator, a within-step instruction dialog, a step status change box. Also, a fifth feature, a user interaction button appears at the bottom left when the step requires only that the user acknowledge that a step must be made (e.g., obtain patient consent).



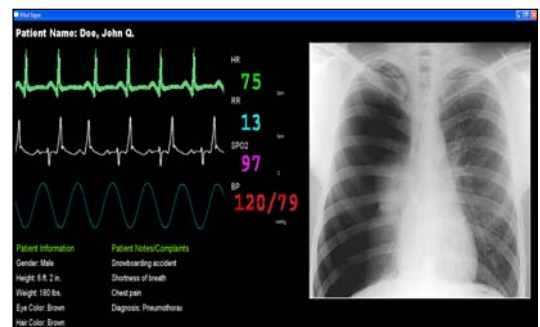
Virtual Tools: The above screenshot details a scalpel, a Kelly clamp, a syringe and a chest tube.



A screenshot detailing the navigation and status aids displayed to the user during the second task.



The pre-simulation test is designed to familiarize the user with details key to the insertion procedure and those details not currently implemented. For example, users are taught historically noted difficulties, mistakes and injuries associated with the chest tube procedure. The pre-simulation test also includes lower level details, such as incision location and size, tube insertion location and indications of pleural entry.



The patient vitals and x-ray information allow the student to visualize and assess the dynamic state of the patient's condition. Included are the vital signs, heart rate, respiratory rate, oxygen saturation and blood pressure of the patient. The values on the display change as the user progresses through the simulation. To the right in the display is presented an x-ray of the simulated patient's chest to diagnosis the condition of pneumothorax.