Intraousseous Access Simulator in Newborns VR System

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Abstract

Simulators in medical procedures are important tools for learning, teaching and training allowing practices in a wide range of scenarios of life-like situations. In the field of vascular access, the use of virtual reality has been emerging as a complement to address the current problems due to the low availability of simulation manikins for training and its high cost. Intraosseous access in newborns is an invasive, fast and effective medical procedure of high complexity employed in critically ill newborns as an option to access veins after peripheral access has failed. Due to vein vasoconstriction present in neonatal shock and cardiorespiratory arrest among other life-threatening conditions it is difficult to perform any other forms of venous access. Intraosseous access requires the proper handling of the related equipment and knowledge, this is only possible with continuous training that cannot be done in real patients. Mastering this technique is required to preserve patient's life, achieve a good recovery and reduce the risk of infection or even death. This paper presents the development of a newborn's intraosseous access simulator for training covering the required steps involved in the procedure. To increase the immersion of the simulation, a force feedback haptic device is integrated to simulate the needle insertion beneath leg tissues to the bone with a biomechanical tissue model, which is the more important skill to be developed in this procedure, and a consumer head mounted display to provide a stereo view of the operation room to give depth to the user when approaching to the patient leg. Our preliminary results were evaluated by a medical expert in terms of usability of the prototype.

Index Terms: J.3 [Computer Applications]: Life and Medical Sciences—Health; H.5.2 [Information Interfaces and Presentation]: User Interfaces—Haptic I/O;

1 Introduction

Intraosseous (IO) access is an invasive medical procedure used when a newborn requires nutrition or medication through bloodstream after peripheral access is not suitable or has failed, or when is in shock [5]. According to World Health Organization [6], between 12% and 25% patients die at intensive care units due to bloodstream infections by the improper use of central and peripheral venous catheters. Practicing these medical procedures in newborns is required to develop skills and proficiency but has limitations due to related ethical issues to gain access to patients. A solution to overcome this problem is the use of medical simulators for replicate life-like scenarios [1]. Several initiatives has been proposed to overcome this problem using physical manikin based, virtual and/or augmented reality (VR/AR) simulators. Nasco (Fort Atkinson, WI) have developed a physical manikin for IO access simulation to demonstrate and simulate the intraosseous infusion procedure in newborns, this simulator permits the palpation of anatomical landmarks and perform only tibial access using real equipment but with the disadvantage of the wear of its components and use of consumables.

Current advances in VR/AR permit exploring different solutions to provide complex task trainers to represent clinic environments with high fidelity [7]. Lampotang et al [2] presents a mixed reality training system for adult central catheter placement but does not have the option to IO access. Ortegon-Sarmiento et al [3] developed a jugular central venous access simulator in neonates with haptics and hand interactions but does not include the option to peripheral or IO access simulation.

In this paper a IO access simulator prototype using virtual reality is presented. The development is presented in section 2 and initial results and conclusions in section 3.

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2 Prototype for Intraosseous Access Simulation

In order to develop a prototype for IO access the real procedure was characterized [5] and three modules were proposed to handle theory and practice. The first one describes all the theoretical part of the procedure covering the main topics of the IO access as indications, contraindications, sites of insertion, the required equipment and surgical instruments used. The second module presents the proper sequence of steps to perform the IO access technique and necessary equipment and a simulation system for practicing the procedure using the VR equipment. The practice module is the last one and it is intended only for the user that already learned the required knowledge to perform the procedure. Figure 1 presents the prototype structure.

2.1 IO Access Procedure

Starting from the characterization of real procedure the following steps were included in the prototype in order to properly simulate it.

1. Insertion site: The user must choose the insertion site, distal femur or proximal tibia, according to medical guidelines.

2. Position the leg with the knee slightly bent and semi-externally rotated.

3. Apply an antiseptic and a local anesthetic at the puncture site, except in situations of cardiorespiratory arrest.

4. Choose a mechanical intraosseous device: infusion needle, bone injection gun, or EZ-IO pediatric gun (Teleflex, Inc.).

5. For the case of EZ-IO device, the user must handle the device with the dominant hand perpendicularly over the surface to be punctured by means of the haptic device.

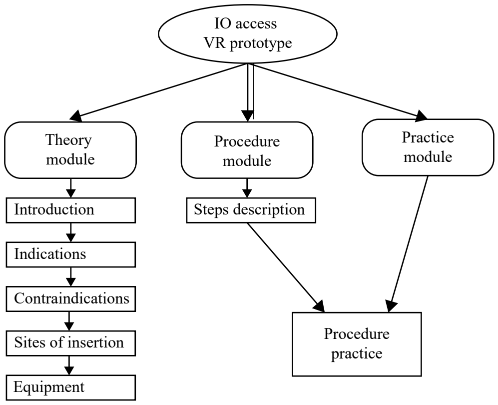

Figure 1: Prototype structure

6. Move the haptic device towards the bone. The user can feel the bone resistant and should immediately release the trigger when a loss of resistance is felt as the needle reach the medullary space.

7. Hold the hub in place and pull the driver straight off; continue holding the hub and twisting the stylet counterclockwise.

8. Place an EZ stabilizer over the hub and place a catheter. Aspirate for blood / bone marrow extraction.

2.2 Virtual Environment

The prototype was developed in Unity 3D using geometry of a newborn including related internal anatomy such as femur, tibia and fibula, as well as skin, from Digimation (Lake Mary, FL). Even though they aren't anatomically correct, the geometry provide all the information of its location and size. The region of interest for the IO access includes anatomical landmarks in order to locate the insertion site. This information is rendered to the user by means of a haptic device, for the developed prototype it was used the 3D Systems Touch 3D Stylus (3D Systems, Inc.) because its range of forces can represent the reactions of needle insertion. The leg model for the newborn includes the mechanical behavior of skin and bone using a linear model for the cortical and cancellous bone [4] having into account that children's bones can absorb 45% more energy than adult ones but are weaker and can be 68% stiff as adult bone. The collisions were handled using a mesh of small interconnected spheres across the surfaces of all organs to address fast calculations.

For an increased immersion an Oculus Rift (Oculus VR, LLC) was integrated to the prototype for helping the user to locate in a more accurate way the anatomical structures and, combined with the haptic device, perform the puncture in the right place.

2.3 Prototype Evaluation

In order to analyze user perception with the developed prototype, an expert neonatologist pediatrician was invited to evaluate and test the prototype. The expert states that the use of Oculus helps the location of anatomical landmarks and the sensation of puncturing the tissues are similar to the real procedure being an interesting complement for learning the procedure. As a suggestion a customized handle for the haptic device could be attached with the shape of the EZ-IO device.

3 Conclusions and Future Work

We have presented a prototype of IO access simulator for newborn patients using virtual reality. Our preliminary results shows a high

Figure 2: A user interacting with the simulator

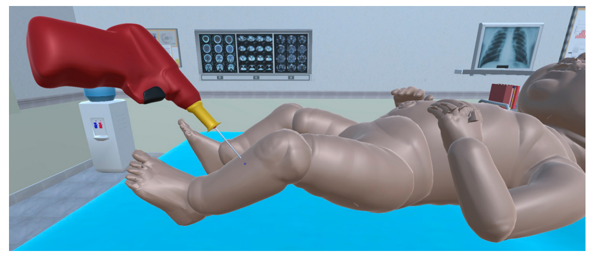

Figure 3: Virtual environment with EZ-IO pediatric gun

potential of use in training scenarios. The biomechanical models of the tissues help to improve the realism perception of the user.

Future work will include feasibility and preliminary effectiveness of using the prototype through a group of pediatric surgeons students and specialists.

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