Enhancing Neonatal Care: A Virtual Reality Simulator for Peripherally Inserted Central Catheter (PICC) Insertion Training

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Abstract. *Virtual reality (VR) offers an immersive and interactive solution for health education, enhancing knowledge retention while allowing safe repetition of complex procedures. The PICC (Peripherally Inserted Central Catheter) is vital in neonatal care but requires specialized skill for insertion, with reported adverse events highlighting the need for improved training. PICCBabyRV is a VR simulator designed to train neonatal nurses in PICC insertion for premature infants, aiming to reduce errors, and contribute to the safety and effectiveness of neonatal care. The simulator covers all pre-procedural stages and procedural steps and goes beyond traditional training methods, offering a robust tool to enhance technical skills and confidence for real-world clinical practice.*

1. Introduction

PICCs are crucial in neonatal care, serving as a stable and effective alternative venous access for newborns [Fu T 2024]. However, their insertion is a highly complex procedure that requires specialized knowledge. The decision to use a PICC requires expertise, technical skill, clinical judgment, and sound decision-making on the part of healthcare professionals. Procedure-related adverse events, which can occur during insertion, maintenance, or removal, have been reported and may be linked to the need for enhanced professional training [WU 2016]. According to [Van Rens et al. 2025], who in his review advocates for the implementation of specialized vascular access teams to increase procedural success and reduce device-related complications, future directions for the use of neonatal peripherally inserted central catheters (n-PICCs) include, among other solutions, the development of simulation-based education to advance and maintain clinical competence. Therefore, integrating VR simulation into the training of these professionals represents a promising strategy to reduce errors, improve technical skills, and increase the safety of neonatal patients.

Intravenous therapy stands out among the set of technologies that are essential for the survival of newborns, but at the same time, represent a significant source of pain, stress, and risk of serious environmental complications [RODRIGUES 2008] apud [SALES 2018]. Furthermore, it is possible to highlight the difficulties of an intact and large-caliber vascular network for implantation, the need for special training for catheter insertion and maintenance, specific monitoring of the device, and the need for radiography to select the catheter tip [JESUS 2007] apud [SALES 2018]. Therefore, even though the intravenous route is the primary access for medication administration in newborns admitted to the NICU and is vital for their survival, it is important to plan and exercise caution in the use of intravenous therapy.

According to Braga (cited by [SALES 2018]), in addition to the benefits such as the preservation of the peripheral venous network, causing the stress, pain and discomfort generated by multiple venipunctures, the PICC also generates complications, such as obstruction, catheter fracture, phlebitis, bloodstream infection, poor positioning with risk of infiltration, cardiac tamponade and cardiac arrhythmia; therefore, the nurse has an important role in planning and evaluating catheter care, to minimize these complications. Given this, adequate training of nurses in vascular access becomes mandatory and, according to Murassaki (cited by [SALES 2018]) in his research carried out with the team of 26 nursing technicians from the Neonatal Intensive Care Unit at HUSF (São Francisco University Hospital), nursing care related to patient safety in the intravenous therapy system is still a major challenge in scientific institutions, as most of the indicators evaluated did not reach the IP (Positivity Index) that characterizes safe and quality nursing care.

Virtual reality (VR) has been increasingly integrated into health education, distinguishing itself by providing an immersive, interactive, and innovative learning experience. Evidence suggests that its application significantly enhances the understanding of complex subjects and promotes knowledge retention among learners [Shrivastava SR 2023]. Furthermore, VR, by being able to provide a form analogous to the real environment, allows the simulation of problems that will arise during medical practice [Catarina Amorim Baccarini Pires and Cupertino 2021], as well as facilitating the safe repetition of clinical and surgical procedures, and the simulation of interactions with patients [Dhar 2023], such as the insertion of a Peripherally Inserted Central Catheter (PICC).

2. Implementation of the Experience

PICCBabyVR is a virtual reality simulator designed to train neonatal nurses in the insertion of a Peripherally Inserted Central Catheter (PICC) in premature infants, ensuring safe and prolonged vascular access while considering the fragility and small size of these infants' blood vessels. In the simulator, the nurse receives comprehensive guidance, from case analysis, including reviewing the patient's medical chart to determine if a PICC is indicated, to communicate with the patient's guardians and preparing for the procedure itself (Figure 1).

The simulation was built using version 2022.3 of the Unity game engine, which was used to build the mechanics and interactivity, animate the 3D models, and create visual effects. Within Unity, the following packages were used: XR Interaction Toolkit, a core package for VR development resources; OpenXR, a package that enables connectivity with VR devices; and XR Management, a package responsible for managing the remaining components and enabling customizations within the VR application. 3D modeling and texturing were performed using Blender, an open-source software for 3D modeling, graphics rendering, visual effects, and animation; and Sketchup, 3D modeling software, to build the neonatal ICU environment, using the floor plan of a real neonatal ICU as a basis (Figure 2).

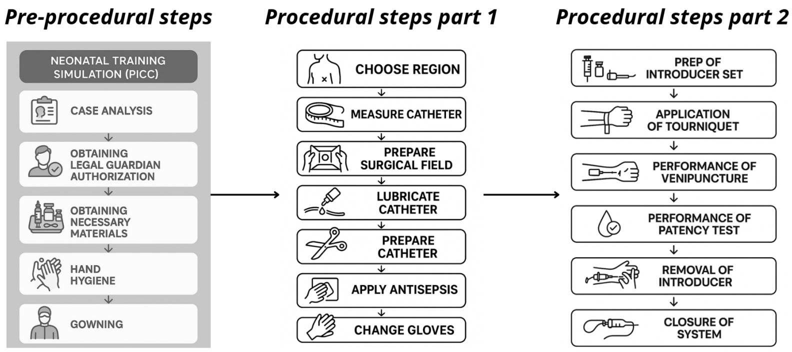

Figure 1. Simulation Flow

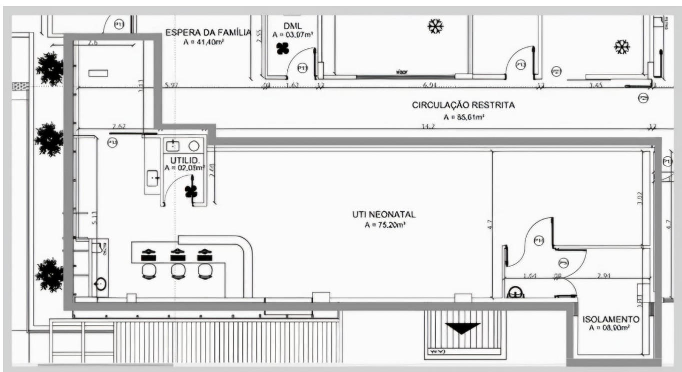

Figure 2. Neonatal ICU floor plan (Modeling based on the area marked in gray)

2.1. Pre-Procedure

When starting the simulation, the user must approach one of the five incubators in the room to analyze a case. By interacting with a button on the front of the incubator, activated by the user's interaction radius, the patient's case is displayed for analysis **(3a)**. After reviewing the information, the user must decide: Yes, it is a PICC case; or No, it is not a PICC case. If yes, the nurse must go to the NICU reception desk, retrieve the procedure authorization form, and present it to the patient's guardian. The nurse's goal is to clearly explain the situation to obtain authorization for the procedure. As the nurse approaches the guardian, a dialogue begins in which the user must select the most appropriate of three response options to convey the message clearly, objectively, and respectfully, ensuring that the patient's guardian understands the need for the procedure and authorizes its performance **(3b)**.

Once the procedure is authorized, the user is directed to an area with cabinets and drawers containing various supplies and a Mayo stand. The task consists of selecting the correct materials for PICC insertion and placing them in the Mayo holder, assessing the nurse's technical knowledge regarding the materials required for the PICC insertion procedure **(3c)**. Once the nurse has all the necessary materials organized, they should prepare for the procedure by thoroughly sanitizing their hands, covering all surfaces (between the fingers, palms, backs of the hands, and nails) for at least one minute **(3d)**, and donning the appropriate surgical gown, surgical cap, gloves, and surgical mask **(3e)** (Figure 3).

2.2. Procedure

The PICC insertion procedure can be performed in the newborn's lower or upper limbs **(4a)**, so the nurse first chooses the preferred location. After this decision, the nurse approaches the baby and, using a tape measure, measures the ideal catheter size, which varies from patient to patient and according to the insertion site **(4b)**. Before beginning to prepare the procedure materials, the nurse creates a maximum sterile barrier, covering the patient with sterile drapes and exposing only the area to be treated **(4c)**.

With the sterile barrier created, it is time to prepare the catheter for antisepsis of the insertion site. First, lubrication is performed, in which the nurse connects a 10 ml syringe to the saline bag to aspirate the saline solution and then to the catheter connector to lubricate it. Finally, the nurse uses the measurement obtained in the measuring step to cut the catheter to the correct length for the patient, using Mayo scissors. Using Foerster forceps, the user grasps a piece of gauze at its tip, dips it in a 0.5% chlorhexidine alcohol solution, and applies the antiseptic to the area for approximately 30 seconds, using a back-and-forth motion **(4d)**.

Due to contact with the patient's skin and possible bodily fluids, a glove change is necessary to maintain a sterile environment. After this brief step, the introducer set for venipuncture begins to be prepared. The user again uses a 10 ml syringe filled with saline, this time to lubricate the introducer.

Once the introducer, the material responsible for creating venous access, is ready, the user applies a tourniquet—a temporary venous constrictor to facilitate visualization of the vein—and performs the venipuncture. The simulation presents a precision-based system for this step, in which the user must reach the green area to ensure successful venipuncture—that is, reach the lumen of a vein, thus allowing safe and functional access to the bloodstream **(4e)**. Access has been created, so the catheter must now be fully inserted. To do this, the user removes the introducer's protective sheath and takes the anatomical forceps from the Mayo table, using them to advance the catheter in a controlled manner through the introducer channel **(4f)**. The nurse then performs a patency test, which consists of irrigating the venous channel with saline to ensure successful venipuncture and correct catheter placement **(4g)**. The introducer is then removed, leaving only the catheter positioned under the skin **(4h)**.

At the end of the procedure, the system is closed. The catheter is first secured to the skin with sterile adhesive, and then the access is connected to a non-reflux valve. After this connection, a new permeability test is performed, and once functionality is confirmed, a transparent sterile dressing is applied to the insertion site, concluding the procedure, maintaining sterility, and leaving the catheter ready for clinical use **(4i)**. The incubator is then closed again and the user can access the remaining incubators again to analyze the remaining cases and practice other scenarios (Figure 4).

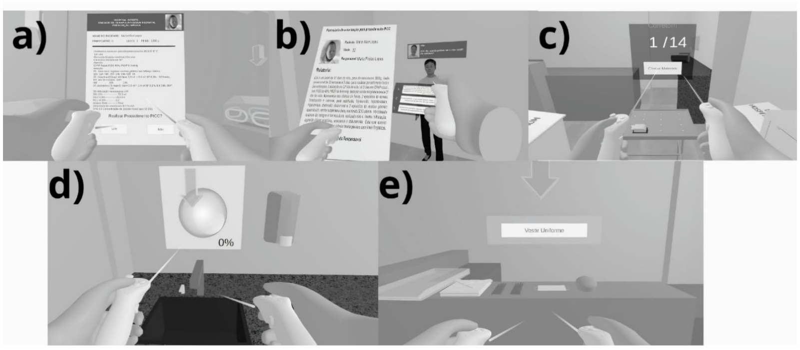

Figure 3. Pre procedure steps

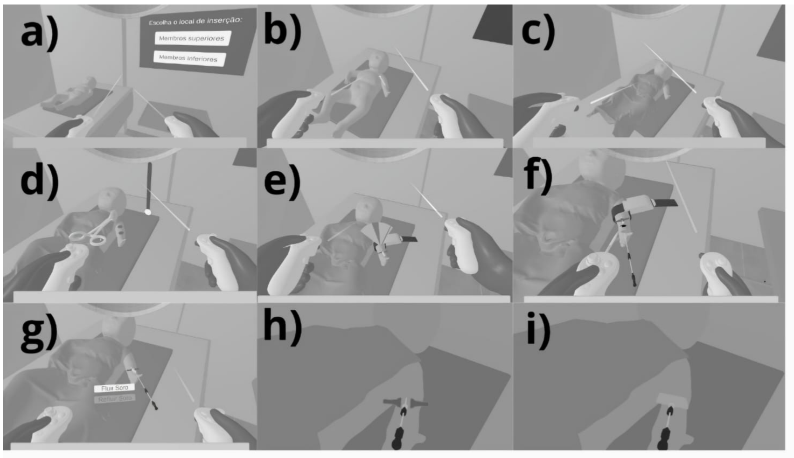

Figure 4. Procedure steps

3. Discussion and Conclusion

During the software development process, a team of healthcare professionals with expertise in the subject matter closely accompanied the system's construction, providing technical guidance related to the peripherally inserted central catheter (PICC) insertion procedure and participating in laboratory testing. This collaboration enabled practical refinements, such as adjustments to hand hygiene and gowning steps in accordance with specific protocols, as well as discussions regarding the alignment of the tool with the needs of health education.

The software is currently at the Minimum Viable Product stage, pending usability evaluation by specialists, specifically neonatologists and neonatal nurses. To this end, submission to the research ethics committee is planned, since the study involves human participants. The main limitation identified is the issue of feedback on the force applied, since a delicate surgical procedure, such as the insertion of a PICC catheter, requires a certain degree of force control and precision in movements. In the absence of a device that generates this force feedback, the focus was on creating mechanisms that would generate an approximate effect.

The educational impact of the product may be assessed in comparison with traditional methods, such as mannequin-based training, involving undergraduate medical and nursing students in future studies. This process will allow measurement of the contribution of virtual reality–based simulation to the development of clinical reasoning, decision-making, procedural sequencing, and communication skills, in contrast with well-established training practices.

In the long term, the system is expected to be integrated into health education curricula, allowing multiple simulations of neonatal PICC insertion prior to practice with real patients, and supporting performance assessment through indicators such as execution time, error rate, protocol adherence, and self-confidence. From a technical expansion perspective, the implementation of a Unity-integrated API, developed in NestJs, is planned to enable dynamic management of clinical cases and monitoring of simulation outcomes. This solution will provide greater flexibility in scenario creation and in tracking users' progression.

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