Original Study

An Electronic-based Simulator for Intramuscular Injection in Newborns

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ABSTRACT

Background: Injection is an essential skill for nurses. In **nurse education**, **simulators** assist learning of nursing students. There are various types of simulators for practicing intramuscular injections in neonates. However, cost, time, and ability to provide formative feedback to learners remain issues in many simulators for nursing education. Intramuscular **injection** in **a newborn** is significantly different from other ages and simulator for this purpose is lacking.

Methods: This pilot study aims to present the design and development of an electronic **simulator** as an instructional tool for a nursing student to practicing **newborns**' intramuscular **injection** and to examine its effectiveness.

Results: An electronic-based **simulator** for a **newborn**'s intramuscular **injection** was designed and developed. The **simulator** contains three parts: 1) a manikin with an **injection** area that is made of soft silicone; 2) a box of an electrical circuit, and 3) **an injection** kit. By using a semi-structured interview technique, we show that the developed **simulator** is helpful for learning **injection** skill due to feedback of formative assessment.

Conclusion: The proposed electronic-based **simulato**r is a prototype of an instructional tool for a nursing student to practicing **newborns**' intramuscular **injection**. However, based on the user comments and suggestions, the weight of the **proposed simulator**, its safety, and its pattern in giving feedback are needed to be improved in future studies.

Keywords: Injection, Newborn, Nursing Education, Simulator

INTRODUCTION

Drug administration is the process to provide humans with some drug, which is any substance that affects the human's structure or function[(1)]. Injectiondelivers agiven drug into the human body by using a syringe and a needle [(2)]. Four types of injections depend on the target site of the human skin layer include intradermal injection, subcutaneous injection, intramuscular injection, and intravenous injection [(3)]. To deliver a vaccine, a biological agent, helps prevent the disease [(2)]. It can be given by gastrointestinal routes such as the Polio vaccine, or injection routes such as the Hepatitis B vaccine, etc. For the newborn or the baby whose age is afterbirth to twenty-eight days, most vaccines are administered via the "intramuscular injection route" [(4)].

The intramuscular injection delivers drug into the muscle layer using a syringe and a needle [(5)]. Many drugs intramuscularly injected into the newborn group are Vitamin K

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and Hepatitis B vaccine [6]. Both are important recommended drugs for all newborns due to prevent the body's bleeding and Hepatitis disease, respectively [7-9]. The technique of intramuscular injection can be administered at four different sites: the deltoid muscle located at the shoulder site, the ventrolateral muscle located at the hip site, the gluteal muscle at the buttock, and the vast lateral muscle located at the thigh [10-12]. For the children under one year, an appropriate intramuscular injection's landmark is the vastus lateralis muscle which is located at the anterior of the thigh. This muscle is preferred for injection because of its easy-to-assess position, large size, less painful, well developed, and located far from major blood vessels and nerves [10, 13].

The safety injection is performed based on the Rights principle of injection: the right drug, right dose, right time, right patient, right route, right form, right preparation, right reason, right documentation, and right response [14-16]. Providing the safety injection to newborns is an essential psychomotor skill of a nurse. On the other hand, the inappropriate injections, for example incorrect site of injection or incorrect depth of injection can lead to nerve injury [17], or partial rupture of the muscle [18]. For these reasons, completing the safety injection skill thus is a requirement for all nursing students to graduate. Generally, nursing students would be assigned to completed their classroom learning, and thendemonstrate their injection skills by using a sponge simulator.

The proposed simulator for learning of a newborn's intramuscular injection consists of (i) a doll resembling a newborn, (ii) a sponge resembling the injection landmark, and (iii) equipment for injection. We conducted surveys on our nursing students and the registered nurses, and found that the sponge is unable to indicate a correct depth and a correct site of the injection. Accordingly, they cannot measure their injection ability, especially the ability of the injection site and injection depth which is an essential key of injection for reaching a target site [19].

Many learning simulators for injection have been developed, for examples (1) an intramuscular injection model which is made of low-cost Chamois sponge to prevent fungal growth[20], (2) a deltoid muscle intramuscular injection model made of underwear[21], (3) an intramuscular injection simulation made of silicone[22], (4) a smartphone invertor application to demonstrate intramuscular injection made of silicone and microcontroller[23], (5) an intramuscular injection model made of hard silicone[24], (6) an intramuscular injection and blood collection model made of natural rubber[25], (7) a low-fidelity model for needle decompression procedure made of Jell-O[26], (8) a low-cost transcervical laryngeal injection made of toilet paper tube[27], and (9) a simulation model for transcervical laryngeal injection made of silicone and electromyographic[28]. There are many advantages of these previous instructional materials. They can provide real-time feedback to improve students' injection skill using sound feedback[28], which are inexpensive, and reusable[20-22, 24-26], and realistic[22, 25].

However, we have found that still, no simulator could measure the correct position and the correct depth of the intramuscular injection in newborns, and provide informative feedback to the learners. Therefore, we propose here an electronic-based simulator of newborn's intramuscular injection for nursing students that could show accuracy of nursing students' injection in terms of the correct site and correct depth of injection, and could provide feedbacks to the students.

MATERIALS AND METHODS

To develop the simulator are consists of three main parts are as follows;

Development of the manikin with an injection area

A hard silicone doll represented a newborn. The hard silicone doll is an easily available material in the market and inexpensive. The criteria we used to select the doll for being the manikin are size and shape of its legs.

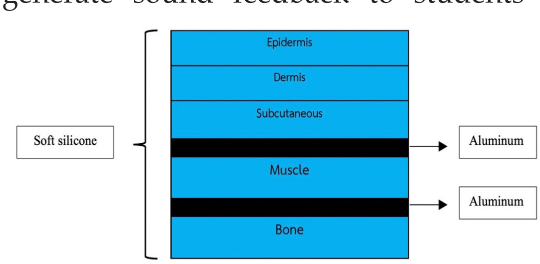
The normal skin structure of a newborn baby consists of four layers, from top to bottom: the epidermis, the dermis, the subcutaneous, and the muscle, respectively. In this research, all layers of skin to bone are mimicked by soft silicone. The conductive aluminum foil sheet is a material that detects the injection's site and injection depth. The first layer of the aluminum foil is inserted between the subcutaneous skin layer and the muscle layer. The second layer of the aluminum foil is inserted between the muscle layer and the bone layer. The component of the skin layer is shown in figure 1.

We developed the vocalization of the electronic-based simulator. Firstly, the three layers of skin were created. Secondly, the area of injection at the position in front of the doll's leg was created by the hard silicone cutting off, and then replaced by a soft silicone for mimicking the three skin layers. The two types of solenoid valves were placed adjacent to the mimicked subcutaneous layer and acts as a key to control the correct position and depth of injection.

Next, the muscle layer was created. The soft silicon was used to mimic the tissue layer for the correct size and at the position of depth for injection. Next, a conductor made of aluminum sheet was inserted between the subcutaneous layer and the muscle layer, and that between the muscle layer and the bone. A small holewas made for connecting the wires between the electrical circuit and the two aluminum sheets. Finally, an electronic circuit board was created and connected to the wires that are linked to the injection's area.

Development of an electrical circuit

The knowledge of electronics is applied to generate sound feedback to students and is inexpensive and available during the COVID-19 outbreak. The electronic circuit consists of three major systems: (1) an injection system simulated by an electrical system; (2) an evaluation injection system simulated by checking the electrical energy, and (3) a response system in which the audio source responds to provide verbal instructions to the student



Fig/ 1: The component of skin layers simulated by s oft silicone and aluminum sheet.

The first system, it uses the flow of electricity to represent the flow of medicine injected by the needle. When injected, the electric current travels from the syringe to the skin layers according to the depth of the needle injected. For example, when the student injects to the target depth at a position ⅝ to 1 inch for a newborn, the electrical system will be connected and becomes a closed circuit at the position [29].

The second system, it assesses the electrical current that has passed through the different layers of the skin.The current is passed to the relay (NO I)and to the solenoid valve, which is responsible for converting the electrical energy from the power generating source into kinetic energy [30].Consequently, an audio device is activated to provide real-time feedback to the learner regarding the location and depth of the injection. The liquid in the syringe will be drained into the storage tank that is in the box until its level reaches the defined level. Lastly, *a response system* includes liquid in the storage tank that stimulates the audio module to provide a sound of *very good*.

Nonetheless, there would no electricity in the electrical circuit if the student injects the needle at the incorrect injection site or depth. The third normally closed type of relay (NC) will be open and then inhibit the current from the first normally opened relay (NO I). The pressure of the plunger's force then stimulates the pressure switch and the second normally opened type of relay (NO II), respectively. Consequently, the liquid in the syringe will not be drained into the storage tank, and the audio module will generate the sound of *checking it again*. The mechanism of providing audio feedback is shown in figure 2.

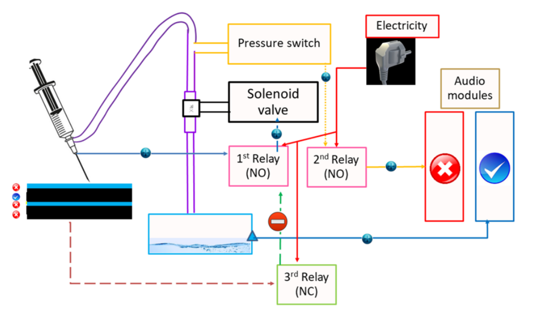


Fig. 2: The mechanism providing feedback to learners

RESULT

The finished simulator comprises of a newborn manikin (1) with the injection area (2) connected to a box of the electronic circuit (3). The power resource 220 voltages (4) is used in this simulator and connects to the box of the electronic circuit. The final simulator is shown in figure 3.

The audio feedback is specific in terms of the correct injection site and depth. The learners will be received audio feedback of "very good" when their injection's ability of site and depth is correct. On the other hand, the audio feedback will be appeared to "check it again" when their injection's ability is incorrect in either site or depth. The audio feedback is shown in table 1.

Prototype testing

Due to the pandemic of Covid-19, it was tested with only one registered nurse who had

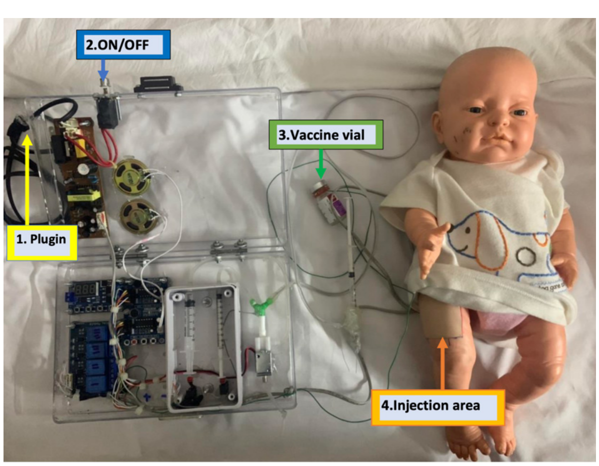


Fig. 3: The electrical-based simulator of a newborn's intramuscular injection

Table 1: The audio feedbacks of electrical-based simulator

Injection site	Injection depth	Audio feedback
Correct	Correct	Very good
Correct	Incorrect	Check it again
Incorrect	Correct	Check it again
Incorrect	Incorrect	Check it again

eight years of pediatrics' injection experience. She evaluates that it is useful in evaluating the ability of injecting the correct position and depth, and providing audio feedback to help the learners improve their learning. Additionally, it is reusable and inexpensive when compared to commercial devices.

However, it still has the limitation that the weight of the electrical box is too heavy to carry. The syringe's weight is also too heavy which would affect the psychomotor skill. The battery should be used instead of the main electricity for safety. Moreover, it would be more useful if the feedback could be specific in terms of correcting depth to help learners understand more about their skill of injection depth.

CONCLUSION

The proposed electronic-based simulator can be used as a learning material for newborn's intramuscular injection in nursing education. It is specifically designed for injecting in a newborn which differs from other ages, and provides formative assessment to learners for improving their skills. Finally, future studies are needed to further optimize and address current limitations.

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Ethical Clearance- This research has been declared ethical by the Mahidol University Central Institutional Review Board with the number MU-CIRB 2021/450.1910

Conflict of Interest- None declared

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