ORIGINAL ARTICLE

# Effects of a Novel Blended Virtual Reality and Clinical Learning Environment on the Learning Transfer of Anesthesiology Residents

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***Received: 21 Apr. 2023; Accepted: 20 Aug. 2023***

**Abstract-** The use of educational technology is considered a necessity due to the increasing changes in medical education. This study aimed to design a novel blended virtual reality and clinical learning environment (CLE) and to investigate its effectiveness in the learning transfer of anesthesiology residents during spinal anesthesia procedures. In this experimental study, 25 residents (academic year 2020/2021) were randomly divided into blended (n=11) and clinical (n=14) groups. Spinal anesthesia training for the blended group was performed in the virtual training laboratory (week 1) and the operating room (from week 2 to week 4), while for the CLE group, it was only performed in the operating room. Training, based on task-centered learning, was provided for both groups, and then, a 360-degree assessment of learning transfer was conducted by professors, patients, co-workers, and self-assessments using a standard questionnaire. Data were analyzed using non-parametric tests. There was a significant difference in the learning transfer of residents between the blended and CLE groups (U=39, $P=0.03<0.05$). There was also a significant difference in the subcategories of learning transfer according to the professors and co-workers; however, there was no significant difference according to the patients and self-assessments. The blended VR/CLE learning environment was more effective than CLE in improving residents' learning transfer. Besides, an increase in scores indicated an improvement in professional competence.

*Acta Med Iran* 2023;61(9):539-546.

**Keywords:** Learning transfer; Virtual reality; Spinal anesthesia; Blended learning environment

## Introduction

Today, the use of blended virtual reality (VR)/clinical learning environments, either simultaneously or asynchronously, can be advantageous as a novel educational intervention due to the increasing changes in medical education caused by the COVID-19 pandemic, significant structural vulnerabilities to the medical education system, and interruptions in the clinical experience of medical students and residents during this crisis (1-4). Therefore, in this critical situation, it is important to take advantage of technologies such as VR because of their merits (e.g., a safe environment, real-life experience for both the patient and the student, repeatability of tasks and control over the sequence of tasks presented, giving feedback, and reflective learning) in training and teaching complex procedures requiring high psychomotor coordination, such as spinal anesthesia for anesthesiology residents. VR promotes active learning by allowing learners to manipulate objects, interact with virtual environments, and solve problems (5-9).

Spinal anesthesia is a technique in which a local anesthetic is administered directly into the subarachnoid space (10,11). Studies have shown that the common method of direct touch for locating the needle placement has a failure rate of 27-32%, which increases to 38.3% in pregnant women (12,14). Improper spinal anesthesia can lead to permanent nerve damage. Multiple puncture attempts may increase the risk of complications, such as post-dural headache, paresthesia, and spinal hematoma

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(15-17).

Besides patient safety risks, studies show that conventional methods such as “see one, do one” and unstructured workplace learning are time-consuming, put patient safety at risk, and inconsistent with current knowledge of how to train health professionals in performing complex procedures (6). There are other challenges in the clinical training of spinal anesthesia, including anxiety in inexperienced students and lack of self-confidence (18), ethical considerations of performing a procedure on a real patient as an educational mediator (19), limitations in performing elective surgery due to the COVID-19 crisis (20), fear of spinal anesthesia for complex cases (21), inattention to individual educational needs, and insufficient attention to competency-based education and integration of knowledge with skills (22,23). Therefore, the design of a new learning environment that can lead to learning transfer is needed because decision-making and performance by integrating knowledge and skills in different real-life scenarios (i.e., at the patient's bedside) can lead to professional competency (23-26).

VR, as an innovative and modern learning environment, is a computer-based technology that uses a combination of hardware, software systems, and sensory synchronization. In VR, a person views a virtual environment and interacts with it through movements of the head and body; after a while, the mind learns to accept the environment as real. This technology can minimize the stress and anxiety of trainees and ultimately reduce the negative effects of traditional education (27-29).

A review of studies on VR or blended VR/clinical learning environments indicated the acceptance of these environments by biology students (3) and confirmed their positive effects on teaching clinical procedures in undergraduate medical imaging (30), surgery (31), neurosurgery (28), anesthesiology (32), medical students (33), sleep disorders (34), and lumbar puncture training for patients with normal and abnormal anatomies (35). On the other hand, the independent use of VR in the clinical training of procedures can cause problems such as false self-confidence and increased anxiety in the operating room (36).

However, our literature review found no study focusing on the learning transfer of anesthesiology residents in a blended clinical training environment (CLE)/VR learning environment. Evaluating the effectiveness of a blended learning environment in a widely used and high-risk procedure such as spinal anesthesia for residents can address the challenges of the learning environment and learning transfer.

In the present study, after designing a blended VR/clinical learning environment, we aimed to determine whether the use of this environment can be effective in the learning transfer of anesthesiology residents and whether the evaluators (i.e., professors, patients, co-workers, and self-assessments) considered the use of this environment to be effective in the learning transfer of anesthesiology residents.

## Materials and Methods

### Setting and participants

This experimental study was performed on 30 first-year anesthesiology residents of the Tehran University of Medical Sciences, Tehran, Iran. Of all the Iranian universities, Tehran University of Medical Sciences admits the highest number of students and delivers high-quality education; accordingly, it was selected as the setting for this study. All residents of Tehran University of Medical Sciences who had been accepted and registered for the anesthesiology residency course during the academic year 2020/2021 were invited to voluntarily participate in this study. The participants were informed about the experiments and the researchers’ reasons and interests in this study. Residents were allowed to withdraw from the study at any time. Using the simple random sampling method, the residents were assigned into two groups: a control group in a clinical learning environment (CLE) and a test group in a blended VR/CLE environment. The number of hours/time spent training over the four weeks was the same between the blended and clinical training groups. According to the approved curriculum, each resident is required to perform at least 20 observations, 5 participations, and 60 independent spinal anesthesia procedures in real patients undergoing various surgeries during their residency. Based on the progress level of the residents, the giving of supportive and procedural information (feedback) was reduced by the professor. Three months after the end of the training, which was initiated in December 2020, learning transfer questionnaires were presented to the evaluators of both groups (i.e., professors, co-workers, patients, and self-evaluations) by four evaluators on four different patients for each resident. professor included one faculty member, experienced clinicians, and experts in the anesthesiology field per group. The flowchart of the details of the two groups is illustrated in Figure 1.

The evaluators (coworkers and patients) were blinded to the method of training (CLE vs. blended VR/CLE) of anesthesiology residents when completing the questionnaires.

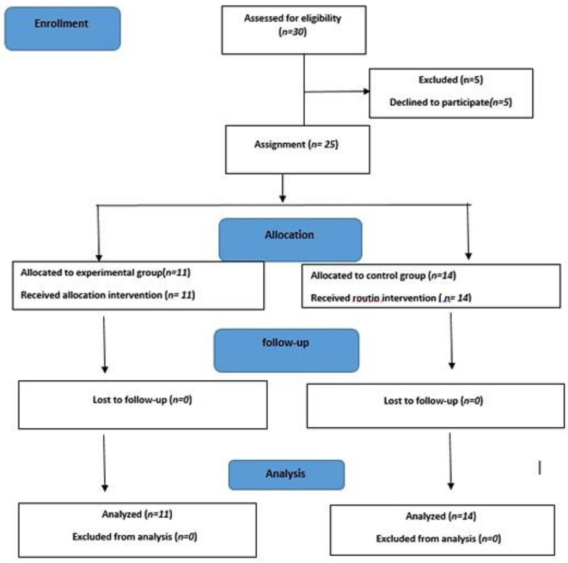


**Figure 1.** Consort flowchart

## Materials

### Blended VR/CLE learning environment

Spinal anesthesia training was designed in four stages with the participation of instructional design specialists, anesthesiologists, software engineers, and graphic designers according to the task-oriented model proposed by Merriënboer (37). The four stages were as follows: 1) video presentation of the spinal anesthesia procedure through VR, complementary explanations by the professor, and group questions and answers; 2) performance of the procedure on a virtual patient by the resident in the VR laboratory and corrective feedback from both the professor and the software; 3) performance of the procedure by the professor on a real patient in the operating room, with the resident observing the procedure, followed by group questions and answers; and 4) participation of the anesthesiologist resident in the procedure on a real patient under the professor's supervision in the operating room and receiving corrective feedback. Moreover, the professor designed various scenarios as tasks and asked the residents to perform all stages of the procedure, that is, selection of the method, type of anesthetic and its dose, patient position, and management of unexpected challenges; these tasks were designed from simple to complex. The total implementation time of the program was four weeks. In the first week, training was provided in the VR laboratory on a virtual patient and then in the operating room on real patients for three weeks. In the laboratory environment, residents were allowed to practice the procedure repeatedly and independently.

The VR module was executed using state-of-the-art virtual reality technology, utilizing Quest1 VR headsets and controllers to create a fully immersive experience. The spinal anesthesia procedure was designed and developed by a team of anesthesiologist professors, instructional designer VR specialists, and software engineers, ensuring accuracy, realism, and education residents could interact with virtual patients through a headset that can be used to interact with virtual patients. These modules provide real virtual environments in the hospital operating rooms. They also received feedback from the staff anesthesiologist and the virtual reality machine if the procedural steps were performed incorrectly, for example, by displaying the phrase "out of zone" for incorrect needle injection. During the pilot phase and validation, we found that one of the residents experienced VR dizziness due to execution in a headset. Therefore, in consultation with professors, we decided for the resident to sit in a chair during the training sessions to reduce the possibility of dizziness.

### Clinical environment

The four training stages were completed over four weeks on real patients in the operating room; the residents' roles changed depending on their ability to observe, participate, and perform independently. In this group, the residents were not allowed to perform the procedure independently until the professor's approval due to patient safety risks.

**Outcomes measured**

To evaluate the variable of learning transfer, a valid and reliable 360-degree assessment tool, designed by the University of Calgary, Canada and localized in Iran by Neshatavar *et al*., (38), was used. This tool includes resident evaluations by the professor, co-workers, patients, and self-evaluations. Each participant was evaluated by a professor, co-workers, and a patient. The questions were designed for four different groups of evaluators, including professors with 29 items, patients with 12 items, self-evaluation with 29 items, and co-workers with 20 items. All items of the questionnaire were Likert-scale questions and scoring was based on a five-point Likert scale, ranging from one ("never") to five ("always"). Besides, the option "cannot be assessed" was considered when a person could not answer a question. The questions covered the following three domains: communication, interpersonal skills, clinical care, and professionalism.

The reliability of the questionnaire was determined based on Cronbach's alpha coefficient (0.97 for professor assessment; 0.8 for patient assessment; 0.96 for self-evaluation; and 0.95 for co-workers). Considering the construct validity of the questionnaire, the correlation coefficients between the items of the different domains and the items of each domain were above 0.4.

**Analysis of the outcomes**

The collected data were analyzed using SPSS version 23. Means and standard deviations were reported for descriptive data, and non-parametric Mann-Whitney and Kruskal-Wallis tests were used to evaluate statistical data (due to non-normal distribution of data based on the Kolmogorov-Smirnov test) at a significance level of 0.05. This study was approved by the IRAN National Committee for Ethics in Biomedical Research with a bioethics code (IR.UM. REC.1399.102).

## Results

Of the 30 residents who consented to participate in the study, five (16%) were excluded from the study due to infection with COVID-19 or leaving school. Finally, 25 participants (76%), five males (46%) and six females (54%) remained in the blended VR/CLE group, and seven males (50%) and seven females (50%) remained in the CLE group. The descriptive characteristics of the two groups are presented in Table 1.

The results of the Mann-Whitney test in Table 2 indicate a significant difference between the two variables of learning environment and total learning transfer. U=39, $P$=0.03<0.05, and the mean score of the blended environment was higher than that of the CLE group.

**Table 1. The descriptive characteristics of between the learning transfer score and learning environments**

| Variable | Group | Mean score | S.D |
|---|---|---|---|
| **Total learning transfer** | Blended(VR+CLE) group | 391.54 | 17.9 |
| | CLE group | 359.28 | 35.7 |
| **Professor** | Blended(VR+CLE) group | 136.27 | 6.21 |
| | CLE group | 125.64 | 12.1 |
| **Co-worker** | Blended(VR+CLE) group | 92.63 | 5.35 |
| | CLE group | 77.92 | 13.7 |
| **Patient** | Blended(VR+CLE) group | 50.18 | 4.57 |
| | CLE group | 47.57 | 4.61 |
| **Self-evaluation** | Blended(VR+CLE) group | 112.45 | 7.2 |
| | CLE group | 108.14 | 11.53 |

According to the results of the Kruskal-Wallis test in Table 2, there was no significant difference in the variable of learning transfer between the learning environment and patient or self-evaluations ($P$>0.05). Although the mean score of the blended VR/CLE group was higher than that of the CLE group in the patient assessment, the chi-square statistic (1.96) and the significance level (0.16) indicated no significant relationship between the learning environment and patient assessment. Moreover, in the domain of self-evaluation, although the mean score of the blended VR/CLE group was higher than that of the CLE group, the chi-square statistic (3.27) and significance level (0.07) indicated no significant relationship between the learning environment and self-evaluation assessment.

**Table 2. The results of Mann-Whitney & Kruskal-Wallis tests between the learning transfer score and learning environment variables**

| Variable | U/Chi-Square | z/df | *P* |
|---|---|---|---|
| **Total learning transfer** | 3.34 | 23 | 0.003 |
| **Professor** | 4.45 | 1 | 0.03 |
| **Co-worker** | 7.06 | 1 | 0.008 |
| **Patient** | 1.96 | 1 | 0.16 |
| **Self-evaluations** | 3.27 | 1 | 0.07 |

However, in the domains of professor and co-worker assessments, the results showed a significant difference in the learning transfer and learning environment variables ($P<0.05$). Additionally, in the professor assessment domain of the questionnaire, the chi-square statistic (4.45) and the significance level (0.03) indicated a significant positive relationship between the learning environment and professor domain, and the mean score of the blended environment was higher than that of the CLE. Moreover, in the domain of co-worker assessment, the chi-square statistic (7.066) and the significance level (0.008) indicated a significant positive relationship between the two variables of the learning environment and co-worker domain, and the mean score of the blended group was higher than that of the CLE group.

## Discussion

In this study, a blended VR/CLE learning environment was designed based on the principles of task-oriented learning in laboratory and operating room environments. Next, in a 360-degree assessment, the effectiveness of this blended environment in the learning transfer of anesthesiology residents during the spinal anesthesia procedure was compared with the CLE environment. Moreover, the effectiveness of this learning environment was independently evaluated from the perspective of four groups of evaluators. The results showed that the blended learning environment had a positive effect on the learning transfer of anesthesiology residents. In addition, in separate examinations by the evaluator groups, it was found that the blended learning environment had a positive impact on the residents' learning transfer according to the professor and co-worker groups; nevertheless, according to the patient and self-assessments, the blended environment had no significant effects on learning transfer.

In a similar study, Marei *et al*., investigated the effects of integrating virtual patients into collaborative learning on the retention and learning transfer of dental students and concluded that it increased their learning transfer (39). Moreover, a study by Cooper *et al*., on the learning transfer of a group trained by VR reported an increase in their practical experience as well as performance in real-world scenarios (40).

Meanwhile, a study by Våpenstad *et al*., showed that the use of VR in teaching laparoscopic skills to medical students could not lead to skill transfer as successfully as in the clinical environment (36). In this study, students in the test group only learned the procedure in the virtual environment, while the control group only received training in the clinical environment. The results showed that students in the experimental group were less able to perform similar scenarios in the operating room environment compared to the control group. According to the results of our study and similar research, it can be concluded that the independent use of a VR learning environment not only does not influence the learning transfer of students but may also have opposite effects. It should be noted that real-world clinical learning environment have unique features that VR environments lack. When it comes to combining VR with a Clinical Learning Environment (CLE), there are specific aspects where VR can enhance learning transfer skills beyond traditional clinical environment training. Here are a few examples:

Realistic Simulations: VR allows residents to engage in realistic simulations of complex clinical scenarios that may be challenging to recreate in traditional clinical settings. This immersive experience enables residents to practice critical decision-making, problem solving, and clinical reasoning skills in a controlled environment. By repeatedly engaging in these simulations, residents can develop and transfer these skills to real-world patient-care situations (8,9).

Immediate Feedback and Reflection: VR technology can provide immediate feedback to residents during interactions with virtual patients or scenarios. Residents can reflect on their actions, identify areas for improvement, and make real-time adjustments. The process of receiving immediate feedback and engaging in reflective practice can accelerate the learning transfer process (4,36).

Stress Inoculation: VR simulations can expose residents to high-stress situations, such as emergencies or challenging patient interactions, in a controlled and safe environment. By repeatedly experiencing and managing stressful scenarios in VR, residents can develop resilience, emotional regulation, and effective coping strategies. These skills can then be transferred to real-world clinical settings, where high-stress situations are encountered (27,36).

It seems that a blended learning environment has the potential to improve medical education and lead to more efficient learning transfer, besides educational improvement. Moreover, it highlights the role of instructors as facilitators; represents the importance of flexibility depending on the students' abilities, needs, and interests; and attracts their attention. Finally, it enhances the level of learning due to rapid feedback, reduces the costs in the long run, and decreases the time required for teaching and learning process (4,8,41).

## Limitations

The co-occurrence of the study with the fourth and fifth waves of COVID-19, restrictions on elective surgeries due to COVID-19 (i.e., resulting in a lower sample size due to the exclusion of consenting participants, lack of clinical training opportunities, etc.), and the low number of samples were the limitations of this study. Although we used an independent evaluator in each group, it is necessary to acknowledge a potential methodological flaw in our study regarding the blinding of the professor to the randomization process. It has come to our attention that the professor may have been aware of the assigned interventions (VR+CLE) during the evaluation process. This awareness may have influenced expectations and introduced a source of bias in the evaluation. We acknowledge that this compromises the objectivity of the evaluation and may impact the validity of our results.

The results of the present study showed that our blended VR/CLE environment, which was designed based on task-oriented principles as a novel educational intervention, was more effective than the CLE environment in the learning transfer of anesthesiology residents during spinal anesthesia procedures. The increase observed in the 360-degree assessment scores of residents' learning transfer who used this blended environment indicated an increase in their professional competence. The present findings can help instructional designers of medical universities and medical education policymakers improve their professional competence.

## Acknowledgements

The authors should appreciate from Ferdowsi University of Mashhad for the funding of the design and production of the content of the virtual reality spinal anesthesia procedure, as part of the learning environments program. Also thanks from Prof. Reza Shariat Moharari and Dr. Alireza Saliminia for their collaborating and the anesthesia residents in Tehran University of Medical Sciences for participating in the study.

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