

# Evaluation of Nursing Students' Peripheral Intravenous Catheter (Insertion/Placement) Attempts with Simulator

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## Abstract

**BACKGROUNDS/AIMS:** this study aimed to evaluate the steps of peripheral intravenous catheter (PIVC) insertion through a computer-assisted simulator (virtual intravenous simulator) and determine the errors made in first-year nursing students.

**MATERIALS AND METHODS:** It is predicted that the results obtained in this study will make the necessary arrangements in occupational skills training in the short term and making PIVC application safer for the future graduates in the long term. This descriptive study was evaluated with a descriptive design (survey) of PIVC insertion training in the nursing education program. The data were collected at the Vocational Skills Training Laboratory of Nursing Principles. PIVC placement skills were obtained using the feedback evaluation reports created by the "virtual intravenous simulator" and analyzed with descriptive statistical methods.

**RESULTS:** It has been determined that students made critical and non-critical errors in the PIVC placement. These results are important with regard to the development of the training of PIVC placement.

**CONCLUSION:** Gaining competence at the level of "demonstrates, performs" in PIVC insertion practice, which is one of the basic skills, can contribute to safe care after graduation.

**Keywords:** Intravenous catheter placement, simulation, skills training in nursing, skills training methods, virtual intravenous simulator

## INTRODUCTION

Global transformations driven by socio-economic factors, technological developments in the healthcare system and community expectations have made it necessary to change the nursing education process.<sup>1</sup>

Nursing is an applied profession that requires the merger of theoretical knowledge with application skills in a proper and meaningful way. Nursing education requires detailed and comprehensive knowledge in many areas. Today, the limited clinical application areas, the shortened hospital stays of

patients, medical errors, patient safety and legal regulations within the complex structure of the healthcare system have affected the practical training of students. When educational system-based causes are added to the above stated issues, it is not always possible for students to gain appropriate clinical experience because they spend less time in the clinical setting.<sup>2,3</sup> However, despite these restrictions, it is expected that graduates can perform all the applications of the nursing profession in a complete and correct manner. For this reason, using technical equipment and hardware enabling simulation training in laboratory settings where nursing students can experience nursing practices before working with the patient, and where they can be

**To cite this article:** Akman Ö, Yıldırım D, Sarıkaya A, Öztürk C. Evaluation of Nursing Students' Peripheral Intravenous Catheter Attempts with Simulator. Cyprus J Med Sci 2022;7(1):142-148

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**Received:** 06.05.2020

**Accepted:** 06.04.2021



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taught the necessary skills training, has become a recommended teaching method. Simulation-based learning has become a key component in the teaching of nursing competencies to nursing students who are trained in the ever-changing healthcare system, and who must meet emerging needs in health care.<sup>4,5</sup> Computer-generated virtual simulations are a specific type of computer program that mimics real life clinical scenarios, and students apply healthcare service skills with virtual patients in a reality-based manner.<sup>6</sup> Virtual simulations have become one of the most effective training methods that allows students to practice repeatedly without harming the patient. This gives students the opportunity to make mistakes and to learn the right method, in a safe learning environment; virtual simulations help students gain cognitive and psychomotor skills.<sup>7</sup>

Alinier classified training-oriented medical simulation tools based on the Knows, Knows How, Shows how, and action levels in the assessment of skill/competence/performance, of the learner according to Miller's (1990) pyramid. Based on this classification, "Virtual Reality (VR) simulators were evaluated at the level of Knows How level 2 in terms of the learner. Additionally, they were assessed at Shows How level 3 in a high level of processing power and performance. Jung, et al.<sup>8</sup> (2011) identified VR simulators as the technological tools that provide touch-based feedback. Due to these features, the disadvantage of VR simulators is that they require high levels of processing power and are expensive. Their advantage is that they support self-learning and give feedback on the student's performance.<sup>8,9</sup>

The Nursing Principles class, which includes education in basic practice skills, communication strategies and initial pharmacological principles and practices, is the first class in which students are taught basic skills. One of the invasive procedures taught in this class that creates anxiety and fear of failure in students is placing peripheral intravenous catheters (PIVC).<sup>10</sup> Training in PIVC placement is an extremely important application in nursing education. The PIVC placement skill, which is used for various applications such as intravenous (IV) fluid therapy, IV drug application or taking blood samples, is a difficult skill to acquire and can cause many complications if not done properly. In a recent analysis, it was found that the failure rate of PIVC placement ranged from 35% to 50%, and the main reason for this is the premature removal of the catheter. The early removal of PIVCs is associated with complications such as phlebitis (15.4%), infiltration (23.9%), catheter occlusion (18.8%), the catheter falling out of place (6.9%) and catheter-related infection (0.2%). It was reported that a factor causing this problem is the lack of knowledge and skills of the nurses applying the catheters.<sup>11</sup> One of the proposed solutions for reducing the failure rate and reducing complications is to enhance the nurses' training in PIVC placement. It was reported that the improved development of the nurses' skills in this area and their increased confidence in their performance in relation

to this skill have resulted in fewer complications.<sup>12</sup> In the quasi-experimental study by Dinç and Erdil<sup>13</sup> with 60 patients receiving total parenteral nutrition and having PIVC, they reported that the training given to nurses was successful in reducing complications related to PIVC insertion procedures. Similarly, in the study investigating the effect of education on the rate of and the understanding of risk factors for intravascular catheter-related infections and including 44 doctors, 17 interns, and 52 nurses, it was found that training was very effective in reducing catheter-related infections.<sup>14</sup>

Training in PIVC application skills can be done in laboratory environments using traditional plastic arm models with traditional methods. But nowadays, the use of modern technological computer-based intravenous simulators is becoming increasingly widespread. In a study with 46 nurses, it was found that the number of failed attempts to place PIVC in patients was significantly lower in the participants who received simulation-based training, as opposed to participants who received traditional training ( $p=0.043$ ). Additionally, reported complications were lower among the simulation-based educated nurses (21% vs. 33%), but this result was not regarded as statistically significant.<sup>15</sup> In a randomized controlled study with nurses working in the internal medicine and surgical departments, it was shown that the training program using a computer-based simulator significantly increased the knowledge, skills and confidence of nurses in the application of PIVC.<sup>16</sup>

It has been determined that PIVC practitioners in particular have a lack of knowledge and skills related to patient evaluation, area selection for the catheter insertion, catheter selection and insertion, catheter fixation, length of duration and definition of complications and treatment, and that more effective training is needed in these matters.<sup>17</sup> Any study examining the teaching of PIVC insertion skills of nursing students with VR simulators present in few nursing programs due to the high cost could not be reached in Turkey. Considering the relevant literature, it was required to determine critical and non-critical errors were made by students at which steps of PIVC insertion skills by using VR simulators. Defining incorrect steps in PIVC insertion with VR simulators will learn outcomes in improving the education process by using PIVC insertion instructions with basic arm simulators that are cost-effective and commonly used in the short term. It can be predicted that PIVC insertion skills will be improved in graduates or novice nurses who acquire this sensitive application skill in the long term.

This study aimed to evaluate the use of computer-assisted simulator (virtual intravenous simulator or VR) in teaching PIVC insertion in the first-year nursing students and to determine the incorrect steps.

## Questions of The Study

Do first-year nursing students correctly perform intravenous catheter placement procedures? Which mistakes are first-year nursing students most likely to make during intravenous catheter placement?

## MATERIAL AND METHODS

In this study, the PIVC insertion training in nursing education program was evaluated with a descriptive research design (survey). The research was carried out within the scope of the Nursing Principles course in the spring semester at a foundation university in Istanbul. The nursing occupational skills laboratory contains simple patient care models, the tools and equipment required in the training of each skill, and advanced simulation-based tools. Every 10–14 students in the laboratory work together with a teaching staff.

### Study Sample

All of the first-year nursing students (n=47) formed the sample of this study. The sample size was calculated as 42 students based on alpha 0.05 error margin and 95% confidence interval to reach 80% power. As a result, no sample selection was made and all students were included in the sample.

### Data Collection

The data were obtained from the feedback reports of the “virtual intravenous simulator” which was used to teach the students the PIVC placement skill.

### Virtual Intravenous Simulator

The Adult Virtual IV Simulator Self-Directed Training System was developed by company. The Adult Virtual IV Simulator Self-Directed Training System works as follows:

- (1) Username and password must be entered for login.
- (2) There are 150 event scenarios based on training purposes (in the hospital, pre-hospital, military care).
- (3) The event scenarios include medicines ordered by the physician and nursing interventions in drug applications.
- (4) Each scenario lesson includes videos and graphics covering pre-processing, preparation, and post-processing stages. These steps are applied by the student.
- (5) At the end of the procedure, the system provides a feedback report on the correct application areas, such as correct selection of equipment, successful placement, hematomas, pain score, needle angle, time suitability, and an evaluation score based on 100 points. The performance duration and the results of all students are identified by the computer.

The teaching staff responsible for vocational skills presented the PIVC skills training first in theory, and then in the laboratory, in accordance with the skill checklist given to the students beforehand. The students repeated the procedure on the simple arm simulator until they reached the necessary skill level. Afterwards they practiced the same technique with a 3D visualization, and then for the second time with the computer assisted Virtual Intravenous Simulator under the supervision of a responsible teaching staff member. The practices and evaluations of this training process are excluded from the research data. The Research Data were collected 15 days after the training, where each nursing student themselves re-implemented the PIVC placement process with the 3D computerized Virtual Intravenous Simulator under the “poisoning scenario”; the feedback reports (Table 1) which were analyzed and scored on the basis of 100 points by the computer were recorded, and the data were collected.

### Statistical Analysis

The data were analyzed by descriptive statistical methods. Descriptive statistics, number, percentage were used for statistical analysis by Statistical Package for Social Science 25.0 (IBM Corp.; Armonk, NY, USA) package program.

### Ethical Considerations

Written permission was obtained from the Head of the Nursing Department since the nursing program was a descriptive study or survey in teaching PIVC insertion in the study. Students who participated in the study were informed about the study and verbal consent was obtained.

## RESULTS

When the students are examined by gender, 80.85% are women and their average age is  $19.11 \pm 1.4$ . The economic situation of 63.82% of students is equal to income and expense. Additionally, 4/5 of the student work (Table 2).

Data regarding the PIVC placement skill in the study are presented below according to the feedback report of the Virtual Intravenous Simulator (Table 3).

The highest scores regarding the steps assessed in the intravenous catheter placement procedure of the nursing students were achieved in the following categories: completion of the procedure at the right and appropriate time 100% (n=47), entering the vein after the patient has been warned 97.9% (n=46) and verifying the identity of the patient 93.6% (n=44).

The steps that the students made the most errors in were removing the catheter needle correctly after the vein has been entered 70.2% (n=33), using the tape to record the initials, date and time when applying the catheter 61.7% (n=29), choosing the right catheter size 51.1% (n=24) and ensuring catheter safety 51.1% (n=24).

In the study, the analysis of the variables was not made due to the limited proportion of students in their sociodemographic characteristics. In this research, it was especially focused on determining which PIVC placement skills steps were made. It is suggested to investigate the effect of variables in different and more samples.

## DISCUSSION

One of the most difficult skills taught in nursing education is PIVC placement. For this reason, students work very hard to develop this skill. Students are more anxious about failing at PIVC placement particularly in clinics, as they are worried about causing pain to the patients. If a student fails to perform PIVC placement correctly, he or she will experience difficulties, such as lack of self-confidence, and an unsuccessful clinical skill performance. For this reason, it is critical for students to gain these skills in vocational skills laboratories, improve their skills and gain confidence in this matter, to reduce their worries when applying the procedure to patients in the clinic environment. However, most nurses are expected to acquire this invasive procedural skill with little formal training

and limited practice.<sup>18</sup> According to the results of the Infusion Nurses Society IV Safety Practice (2013) (n=345) it was reported that 57% or less of nursing students received PIVC placement training and only 71% of those nurses received additional training in the workplace after graduating from nursing school.<sup>19</sup> Lyons and Kasker<sup>20</sup> reported that because many nurses are only receiving limited training during orientation, they are experiencing stress during PIVC placement, which causes inadequate patient care. One of the causes of PIVC related complications is due to lack of knowledge, skills and confidence among nurses. In the literature it is stated that the inability to insert into the peripheral vein affects infiltration formation<sup>21</sup> and if the skill of the person placing the catheter is insufficient, infiltration risk is increased.<sup>22</sup> In this study, it was seen that students made both critical and non-critical mistakes. The only step the students carried out without any errors was "the completion of the procedure at the right and appropriate time". Not choosing the right catheter size,<sup>23</sup> not ensuring catheter safety (no proper stabilization)<sup>24</sup> are among the effective causes of phlebitis formation. Errors in entering the vein and advancing the catheter in it, and not positioning it in the appropriate area<sup>25</sup> are factors that cause both phlebitis and infiltration. Similarly, not observing the aseptic technique is among the factors that result in the formation of catheter-related infections. When studies conducted are examined, it is seen that there is a lack of knowledge and skills regarding the placement of the PIVC, the choice and placing of the catheter, the fixation of the catheter, the choice of the appropriate vein, the evaluation of the patient and the definition of complications and treatment.<sup>26,27</sup> In this study, it is seen that the students made the same mistakes and results are compatible with said studies. In individual short face-to-face interview after the procedure, when the students were asked what the reasons for the mistakes may be, their feedback was: "that they do not need to pay attention to the age and sex of the patient in the virtual environment and that

**Table 1. Intravenous catheter application competence list**

Events related to catheterization
1. Correct catheterization
2. Venipuncture
Steps in which critical errors occur
1. Completion of the procedure at the right and appropriate time
2. Taking the correct standard precautions
3. Correct use of the tape where the date, time and initials of the person applying the catheter are recorded
4. Correct detection of the catheter
5. Correct removal of the catheter needle
6. Washing and observing the vein correctly with liquid
7. Attempting placement in the right area
8. Not contaminating the area
9. Accurate and complete preparation of materials (equipment)
10. Notifying the patient and entering the vein
11. Verifying the identity of the patient
Steps in which non-critical errors occur
1. Determining the application zone (distal to periphery) correctly
2. Informing the patient at the right time
3. Inserting the catheter from the correct angle
4. Proper application of infusion
5. Providing catheter safety
6. Choosing the right catheter size
7. Right palpation of the vein
8. Preventing hemorrhage by applying pressure to the entrance zone
The IV catheter application steps are listed in the form of the feedback report of the simulator, not in the order of execution and not in the order of the intervention steps.

**Table 2. The Sociodemographic characteristics of the students**

Characteristics	Mean-SD	Min-max	
Age	19.11±1.4	19–21	
	n	%	
Gender	Female	38	80.85
	Male	9	19.15
Economic condition	Income and expense are equal	30	63.82
	Income higher than expense	9	19.15
	Income lower than expense	8	17.03
Employment status	Working	9	19.15
	Not working	38	80.85
SD: standard deviation, n: number.			

they just want to finish the process”, “that they feel like they are conducting a virtual process while ensuring catheter safety and thus put safety in the background”, “that they think it is sufficient for them to succeed in entering the vein and that they forget about the other steps after that” and “that it seems unimportant because it is not a real patient”. Additionally, the students stated that learning with the simulator “is fun, motivating and exciting, and realized the importance of being more careful than basic arm simulators.”

When it is considered that it is difficult to teach/learn basic nursing skills and especially PIVC placement, it can be said that the trainers should continue to develop methods that will allow the students to perform these skills precisely and accurately. For students in the 21<sup>st</sup> Century in nursing education it is necessary to provide (a) self-learning packages through multimedia e-learning curriculum components; (b) integration of simulation-based technologies that provide the training of invasive procedural skills and sufficient feedback until all errors

**Table 3. Distribution of students' PIVC placement skills by their success rate**

	Successful		Unsuccessful		Total	
	n	%	n	%	n	%
<b>Events related to catheterization</b>						
1. Correct catheterization (no folding of the catheter, placement of the catheter in one try)	40	85.1	7	14.9	47	100
2. Vein puncture (entrance) (advancing along the vein, finding the right vein, correct determination of catheter entry angle, vein fixation, correct needle holding)	43	91.5	4	8.5	47	100
<b>Steps in which critical errors occur</b>						
1. Completion of the procedure at the right and appropriate time	47	100	0	0	47	100
2. Taking the correct standard precautions (wearing gloves, preparation of the area with the correct antiseptic, cleansing at the right time)	39	83	8	17	47	100
3. Use of the tape where the date, time and initials of the person applying the catheter are recorded	18	38.3	29	61.7	47	100
4. Detection of the catheter	43	91.5	4	8.5	47	100
5. Correct removal of the catheter needle	14	29.8	33	70.2	47	100
6. Cleansing and observing the vein correctly with liquid	31	66	16	34	47	100
7. Attempting the placement in the right area	37	78.7	10	21.3	47	100
8. Not contaminating the area	41	87.2	6	12.8	47	100
9. Proper and complete removal of materials (equipment)	37	78.7	10	21.3	47	100
10. Notifying the patient and entering the vein	46	97.9	1	2.1	47	100
11. Verifying the identity of the patient	44	93.6	3	6.4	47	100
<b>Steps in which non-critical errors occur</b>						
1. Determining the application zone (distal to periphery) correctly	29	61.7	18	38.3	47	100
2. Informing the patient at the right time	39	83.0	8	17.0	47	100
3. Inserting the catheter from the correct angle	36	76.6	11	23.4	47	100
4. Proper application of infusion	43	91.5	4	8.8	47	100
5. Providing catheter safety	23	48.9	24	51.1	47	100
6. Choosing the right catheter size	23	48.9	24	51.1	47	100
7. Right palpation of the vein	27	57.4	20	42.6	47	100
8. Preventing hemorrhage by applying pressure to the entrance zone	37	78.7	10	21.3	47	100

n: number.

are eliminated and the student becomes competent enough to conduct the procedure; (c) collaborative experiential learning environments where students can share their knowledge and experiences and (d) a robust curriculum of meaningful and comprehensive learning tests to confirm that the curriculum is effective in transferring new knowledge and skills.<sup>28</sup> In this study, theoretical information, a simple simulator and a computer-assisted simulator were used to teach the PIVC placement skill. After 15 days, the skill steps of the students based on the PIVC placement skill simulator feedback reports were evaluated. However, the students only carried out one step without error, while they made mistakes in all others. This can be explained in particular by the fact that the PIVC placement skill is the hardest skill to gain, and that students forgot some steps after 15 days. Also, the simulator carefully assesses each step. Simultaneously, as students have stated, working with a virtual sensor and not a real patient may have also caused some steps to be skipped. These results also indicate that students should repeat the practice to sharpen their skills. In a randomized controlled trial conducted by Engum et al.<sup>29</sup>, with 163 nursing and medical students to compare effectiveness of computer-assisted IV simulators with traditional method in intravenous catheter insertion under laboratory conditions, both methods were reported to be similar in terms of gaining experience. Additionally, because of the study, the authors recommended that both methods should be used together. In a randomized controlled trial conducted by Wilfong et al.<sup>15</sup>, with 42 nurses to compare the effectiveness of a computer-assisted IV simulator with traditional method in intravenous catheter insertion training, it was stated that those using the traditional method inserted the catheter using fewer catheters. However, it was reported that the traditional method group established the vascular access at a better level. In a randomized controlled experimental study by Sotto et al.<sup>30</sup>, to compare the efficacy of the computer-assisted simulator (Laerdal Virtual I.V. simulator) with the traditional method in medical students, it was stated that the intravenous catheter insertion success scores of those using the computer-assisted simulator were higher than the other group.

In a laboratory study by Schoening et al.<sup>28</sup>, they stated that multiple repetition makes students feel comfortable and improves learning. For this reason, it is thought that it is necessary for the students to continue to learn on their own to ensure the permanence of the skill, which is taught within a limited time. Similarly, it is necessary to support students because they do not use critical thinking and problem-solving skills in the laboratory. It can be said that this result is important in helping pre-graduate students improve their skills; self-assessments are also important to prepare for actual post-graduation clinical practice. However, these findings are limited to IV simulator performance data.

### Limitations of the Study

This study was conducted in a single center and in a small sample group. Therefore, the study findings should not be generalized all nursing students.

### CONCLUSION

Given that students were making critical and non-critical mistakes in training of PIVC insertion, it was determined that the students needed more practice under the supervision of their trainers. The students realized that they needed to do this skill very cautious. In the same way, it can be said that the application of PIVC insertion should continue to be taught to the students in each lesson until graduation. To ensure self-learning, learning packages must be prepared and the students should be encouraged to work in the occupational skills laboratory to improve this skill. Additionally, students should be given the opportunity to perform this practice in clinical settings and learning setting should be provided to them.

In the clinics, the students should be observed by the trainers, and the trainers should intervene when the students are using the wrong practices. This can prevent students from learning the wrong methods. Measures should be taken to improve the students' clinical skills and competence, as well as to improve critical thinking skills and self-confidence. Because errors by nursing professionals can have dreadful results, the necessary efforts and time required for effective vocational skills training should must be made, and the training process should be assessed continuously. VR simulators can be used for both teaching and evaluating skills in nursing curricula. Additionally, orientation training should be continuously supported for newly hired graduates.

### ACKNOWLEDGEMENTS

We would like to thank all the students who took part in the study.

### MAIN POINTS

- This study was determined that the students needed a more intravenous catheter insertion practice under the supervision of their trainers.
- This study was determined that the nursing students PIVC insertion should continue to in each lesson until graduation
- It was determined in which steps the nursing students made mistakes when PIVC insertion

### ETHICS

**Ethics Committee Approval:** This study was approved by Istanbul Sabahattin Zaim University Ethics Committee, 2016/84772076/8.

**Informed Consent:** Written permission was obtained from the Head of the Nursing Department since the nursing program was a descriptive study or survey in teaching PIVC insertion in the study. Students who participated in the study were informed about the study and verbal consent was obtained

**Peer-review:** Externally peer-reviewed.

### Authorship Contributions

Concept: O.A., D.Y., Design: O.A., D.Y., Supervision: O.A., D.Y., Data Collection and/or Processing: O.A., D.Y., Analysis and/or Interpretation: A.S., C.O., Literature Search: A.S., C.O., Writing: A.S., C.O., Critical Review: A.S., C.O.

### DISCLOSURES

**Conflict of Interest:** The authors declare no conflict of interest.

**Financial Disclosure:** The authors declare that this study received no financial support.

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