Medical students’ self-assessed efficacy and satisfaction with training of endotracheal intubation and central venous catheterization with smart glasses in Taiwan: a non-equivalent control-group pre-and post-test study

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Abstract

Purpose: Endotracheal intubation and central venous catheterization are essential procedures in clinical practice. Simulation-based technology such as smart glasses has been used to facilitate the training of these procedures for medical students. We investigate medical students’ self-assessed efficacy and satisfaction regarding the practice and training of these procedures with smart glasses in Taiwan.

Methods: This observational study enrolled 145 medical students of 5th and 6th year receiving clerkship at Taipei Veterans General Hospital between October 2020 and December 2021. Students were divided into the smart glasses or the control group and received training at the workshop. The primary outcomes included students’ pre- and post-intervention score of self-assessed efficacy and satisfaction with the training tool, instructor’s teaching, and the workshop.

Results: The pre-intervention score of self-assessed efficacy of 5th and 6th year medical students in endotracheal intubation and central venous catheterization procedures had no significant difference. The post-intervention score of self-assessed efficacy in the smart glasses group was better than that of the control group. Moreover, 6th-year medical students in the smart glasses group showed higher satisfaction with the training tool, instructor’s teaching, and the workshop than that of the control group.

Conclusion: Smart glasses act as a suitable simulation tool for endotracheal intubation and central venous catheterization procedures training in medical students. Medical students practicing with smart glasses showed improved self-assessed efficacy and higher satisfaction with training, especially for procedure steps in the space-limited field. Simulation training of procedural skills with smart glasses in 5th-year medical students may be adjusted to improve their satisfaction.

Keywords: Central venous catheterization; Endotracheal intubation; Medical students; Smart glasses; Simulation Training
Introduction

Background/rationale

Endotracheal intubation (ETI) and central venous catheterization (CVC) are both frequently used essential procedures during the clinical practice. These 2 procedures are indicated in many conditions. Recent studies have revealed that early exposure of medical students to medical procedures can improve their competency, confidence, and even the clinical practice of technical skills [1]. Therefore, it is crucial to provide adequate training for future residents to competently perform the essential procedures in their careers.

There are different modalities of simulation, including virtual reality [2], augmented reality [3], or web-based video recording systems, and smart glasses (SG) are one of the simulation modalities in medical education that have drawn attention recently [4]. Smart glasses is one of the emerging technologies used in simulation-based medical education, defined as a computerized communicator, usually with a video camera, a voice recorder, a voice input interface, and a display screen [4]. The usage of smart glasses in the training of ETI and CVC procedures for junior trainees was also noted in recent years [5].

Objectives

The purpose of this study was to examine the self-assessed efficacy of 5th and 6th-year medical students to perform ETI and CVC procedures with smart glasses, and their satisfaction with the training of ETI and CVC procedures with smart glasses.

Methods

Ethics statement
This study received approval from the Ethics Committee (Institutional Review Board [IRB]) of Taipei Veterans General Hospital with IRB number of 2020-06-004BC. Obtainment of informed consent was exempted by the institutional review board.

Study design

This was a non-equivalent control-group pre-and post-test study. This article was described according to the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) statement available from: https://www.cdc.gov/trendstatement/index.html.

Participants

Over 15 months, 145 medical students in 5th and 6th years receiving clerkship at Taipei Veterans General Hospital were enrolled in this study between October 2020 and December 2021. A workshop for ETI and CVC was held for 6th-year medical students who underwent rotation in the critical care units, and 5th-year medical students were also invited to attend the workshop voluntarily. Including criteria is a recruitment of students who voluntarily attended the workshop, and their attendance or performance in the workshop would not influence their clinical score of rotation. There were no exclusion criteria.

Intervention

This study was undergone at a medical center and teaching hospital in Northern Taiwan. Hundreds of medical students receive clerkship, internship, and clinical skills training at this hospital every year. In Taiwan, the 6-year medical education program was carried out in 2013, and medical students would receive clerkship during their 5th and 6th years [6]. In the 5th year of the program in this institution, medical students took a preclinical training course first and then underwent a 3-month rotation of internal medicine, pediatrics and gynecology, and surgical respectively. In the 6th year of the program, they would undergo rotation in critical care units and the emergency department. They may have clinical exposure to ETI and CVC procedures during rotations. Therefore, a standardized simulation-based curriculum of
these procedures has to provide deliberate practice and assessment for medical students. After a field study to investigate 5th and 6th year medical students’ requirements for improving clinical skills, we found that they were interested in essential procedures such as ETI and CVC, which were less available for them to practice in clinical rotations. Therefore, the workshop was opened to better enhance their understanding of lifesaving but risky skills in their future.

During the workshop, the students would receive an introductory lecture, practice, and assessment for 120 minutes in total (Fig. 1). Firstly, they would receive an introductory lecture for 30 minutes, and then the instructor would demonstrate with either smart glasses on the mannequin or only the mannequin for 30 minutes, depending on the month in which the workshop was held. In the smart glasses group, to evaluate their understanding of the essential skills of ETI and CVC, students would practice for 20 minutes after the instructor’s demonstration and complete the first self-assessment by wearing the smart glasses. Through viewing the smart glasses-displayed and gross detail procedural skills of students, the instructor would then give feedback to each student for 10 minutes. Students then practiced again for 30 minutes and completed a second self-assessment checklist and a questionnaire regarding their satisfaction of the learning experience.

Assignment methods of the experimental and control group

For odd months (e.g. 1, 3, 5), medical students attending rotation of intensive care units were assigned to the control group and those attending rotation of intensive care units during even months (e.g. 2, 4, 6) were assigned to the smart glasses group. Medical students in the control group received demonstration and practice on the mannequin only, while those in the smart glasses group received demonstration and practice on the mannequin with smart glasses (Suppl. 1).

As shown in Fig. 1, there are 8-9 students in monthly ETI and CVC workshop. In two paralleled skill rooms, each 4-5 students were led by two similar experienced instructors with consensus for training and assessment. Each student has 20-30 minutes to practice ETI and CVC on the different mannequin with and without SG one by one.
Blinding (masking))

There was no blinding of intervention to participants.

Outcome variables

The outcomes included students’ pre-intervention score of self-assessment, the changed score of self-assessed efficacy (the post-intervention score of self-assessment minors the pre-intervention score, Fig. 1), and students’ satisfaction with the training tool, instructor's teaching, and workshop.

Data sources/ measurement

The examiners collected the students’ self-assessed efficacy and satisfaction using a computer program. All variables were recorded in an Excel spreadsheet (Microsoft Corp., Redmond, WA, USA). We used self-assessment checklists and satisfaction questionnaires to examine medical students’ learning efficacy and their perception of the training. Four statements of procedure steps in ETI and CVC were included in each checklist (Supplement Table 1 and 2) to evaluate the students’ self-assessed efficacy.

Validity and reliability of self-assessment checklists and satisfaction questionnaire

For the content validity of each statements in checklists of ETI and CVC and satisfaction questionnaire, the results examined by four experts revealed content validity index ranged from 0.78 to 0.83 as shown in Supplement Table 4 and 5. For assessing the reliability of each statements in checklists of ETI and CVC and and satisfaction questionnaire, Cronbach alpha coefficient ranged from 0.70 to 0.89. Additionally, the intraclass correlation coefficients (ICCs) was used to assess the agreement across experts of the checklists and satisfaction questionnaire showed 0.78 and 0.75, which shows good reliability.

Bias
No bias was found in the study scheme.

Study size

Sample size calculation was conducted with G*Power ver. 3.1.9.4, based on the independent sample Student’s t-test, a 2-tailed alpha of 0.05, power (1-β) of 0.80, and medium effect size (Cohen’s d) of 0.5 [7]. The result showed that a sample size of around 64 per group was required. Notably, our study included 69 students in the control group, and 76 students in the smart glasses (SG) group.

Unit of Analysis

The unit of analysis is the same as the unit of assignment.

Statistical methods:

For students’ pre-intervention and changed score of self-assessment and score of satisfaction of the questionnaire, a normality test was done, and all of the data was normally distributed. We used the Pearson chi-square test to compare categorical variables of the basal characteristics, and an independent t-test to compare continuous variables. Statistical significance was considered when P values < 0.05. Data were analyzed by SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA). Data were expressed as mean±SD [95% confidence interval, 95% CI].

Results

Participants’ baseline data and baseline equivalence

A total of 145 medical students were enrolled. There were 69 students in the control group, and 76 students in the smart glasses(SG) group. For the gender, there were 89 male students and 56 female
students. For the grade, there were 25 5\textsuperscript{th}-year medical students and 120 6\textsuperscript{th}-year medical students. The percentage of gender and grade was not different between the control and SG groups (Table 1).

**Numbers analyzed**

All participants were included in each analysis. There was no loss pre- and post-intervention test.

**Outcomes and estimation**

Medical students’ changed score of self-assessed efficacy in the SG group was better than that of the control group.

The pre-intervention self-assessed efficacy of 4 steps in ETI and CVC procedures was not different between 5\textsuperscript{th} and 6\textsuperscript{th} year medical students (Fig. 2a and 2b, supplement Table 6). In either 5\textsuperscript{th} year and 6\textsuperscript{th} year medical students, there was a trend that the pre-intervention self-assessed efficacy in the control group was higher than the SG group in most steps of ETI and CVC procedures (Fig. 2c and 2d, supplement Table 7).

Most medical students reached full score of self-assessed efficacy in each step of both ETI and CVC procedures at the second assessment (Supplement Table 7, Post-intervention score). In either 5\textsuperscript{th} year and 6\textsuperscript{th} year medical students, there was a trend that the changed score of self-assessed efficacy in SG group was higher than that of control group in most steps of ETI and CVC procedures (Fig. 3a and 3b, supplement table 8) especially for 6\textsuperscript{th}-year medical students in ET3, ET4, CVC2, CVC3, CVC4 (Fig. 3b, ET3 = ‘Proper use of laryngoscope, without grinding the teeth’, ET4 = ‘Remove stylet and inflate the cuff’, CVC2 = ‘Insert the guide wire properly with sterile technique and appropriate depth’, CVC3 = ‘Place the skin dilator properly with appropriate depth’, CVC4 = ‘Insert the catheter properly’). Significance was noted at the statement of CVC4 and ET1, and an opposite trend was seen in the result of ET1 (Fig. 3b). In either female or male medical students, there was no significant difference in their self-assessed learning efficacy in either control or smart glasses group between different gender (Supplement table 9).
6\textsuperscript{th} year medical students in the SG group showed higher satisfaction with the training tool as well as the instructor's teaching and workshop than control group.

In 6\textsuperscript{th} year medical students, SG group's score of satisfaction of training tool-related statements (Q1, Q2, Q3, and Q4 in Fig. 4b), instructor's teaching and workshop-related statements (Q5, Q6, and Q7 in Fig. 4d) were higher than the control group (Supplement table 10). Significance was noted at statements of Q1 and Q3 in Fig. 4b as well as (Fig. 4b, Q1 = 'The training tool could provide accurate information of the practice in space-limited field.', Q3 = 'The instructor could teach students with the training tool properly', Q6 = 'The instructor's demonstration and practice is useful for clinical rotations', Q7 = 'Overall, I am satisfactory to this workshop'). In 5\textsuperscript{th} year medical students, there was a trend that control group's score of satisfaction of training tool-related statements (Q1, Q2, Q3, and Q4 in Fig. 4a) and satisfaction of instructor's teaching and workshop-related statements (Q5, Q6, and Q7 in Fig. 4c) was higher than SG group. In either female or male medical students, there was no significant difference of their score of satisfaction in either control or smart glasses group between different gender (Supplement table 11).

### Adverse events

There was no adverse event reportable.

### Discussion

**Key results:** In this study, most students considered themselves competent to complete steps of these procedures after the second round of practice, and the improvement of self-assessed efficacy was higher in students with the usage of smart glasses. As for the satisfaction of students with smart glasses in the training, 6\textsuperscript{th}-year medical students showed higher satisfaction contrary to the responses from 5\textsuperscript{th} year medical students.
Interpretation

Although medical students were more confident in performing ETI and CVC procedures after being familiar with smart glasses and receiving repetitive practice, there may be some inherent difference in learning ETI and CVC procedures between 5th and 6th year medical students.

For ETI and CVC procedures, we found that medical students often could not see the detailed practice of certain steps in these procedures, especially when the clinical environment was crowded. They could not see the operator's point of view to explore the practice of certain steps related to anatomical positions. Even when the student was the operator, instructors might not be able to see the student's point of view to know the problem of practice and provide real-time instructions.

As described by Chao, the most common reasons for failure in ETI and CVC procedures of medical students were poor visualization of vocal cords, suboptimal placement of laryngoscope in ETI, and the inability of finding the vein, failure of passing the guidewire in CVC [8,9]. These steps involved practices in space-limited fields, such as the opening of the mouth in ETI, and the sterile field of the puncture site in CVC. With smart glasses, students could practice on the mannequin under the real-time supervision of instructors and see other operator's practice in first person point of view through online video [10].

For 5th and 6th year medical students, the effectiveness of SG in assisting their learning of ETI and CVC procedures with smart glasses is different. First, their clinical exposure differs. 6th year medical students had received 1 year clinical rotations and had the experience of overnight shift with the senior residents, which gave them more access to critical clinical conditions which ETI and CVC procedures were involved. Furthermore, their level of competency is different.

6th year medical students may already have the awareness of the key difficult steps of these procedures after clinical exposure and having failure experience. By contrast, 5th year medical students are naïve to the clinical environment without real failure experience of ETT or CVC. Therefore, in our study, the 5th year medical students with smart glasses showed lower satisfaction than the control group.

In this study, there was a trend that the pre-intervention self-assessed efficacy of students in the control group was higher than the SG group in most steps of ETI and CVC procedures [Fig. 2c and 2d,
However, at the second assessment (Post-intervention score, [supplement Table 7]), there was a trend that the changed score of self-assessed efficacy in SG group was higher than control group in most steps of ETI and CVC procedures [Fig. 3a and 3b, Supplement Table 8]. Instructors’ feedback mentioned the problem of adjusting the display by moving the head to ensure the recorded video was compatible with the student’s point of view. It is possible that in the students first practice with SG, they are not familiar with SG that resulted in lower performance. However, after SG group students familiar with SG in second practice, the benefits of SG can be clearly observed. This problem could be resolved by beforehand instructions of the smart glasses.

Recent study revealed gender disparities in medical student’s procedural skills such as ETI and CVC during clerkship [11]. However, this effect was not seen in either control or smart glasses group in our study. This may be explained by the fact that smart glasses were used in the simulation environment, rather than actual clinical practice. Future study may explore the effects of medical students’ gender in clinical practice of procedural skills using smart glasses.

Limitations/generalizability

The assessment of student’s performance only includes self-assessed efficacy, without objective evaluation by instructors. The previous experience on the procedure or usage of smart glasses should also be considered. In addition, this is a single-center pilot study, and many enrolled participants are 6th year medical students. More 5th year medical students should be enrolled to optimize the training workshop for 5th and 6th year medical students.

Suggestions

We believe this study can facilitate future training of procedural skills by smart glasses in medical students.
Conclusion

Smart glasses is a suitable simulation tool for training ETI and CVC procedures, with improving self-assessed efficacy and higher satisfaction of training, especially for procedure steps in space-limited field. For junior students, training of procedures could be adjusted for their limited clinical exposure. Before practicing skills with smart glasses, instructions on using new technology should precede to improve students’ satisfaction.

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Conflict of interest

No potential conflict of interest relevant to this article was reported.

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**Data availability**

Dataset 1. Raw score data of self-assessment checklist and satisfaction questionnaire for each students had been included.

**Acknowledgments**

None.

**Supplementary materials**

Supplement 1. Video of smart glasses practice

**References**


| Table 1. Basal characteristics of medical students |
|------------------------------------------|--------|--------|--------|
| Group | Control group | SG group | Total |
|       | (N=69)         | (N=76)   | (N=145)|
| Gender – no. (%) |        |        |        |        | 0.57  |
| Male  | 44(64)         | 45(59)   | 89     |        |
| Female | 25(36)         | 31(41)   | 56     |        |
| Grade – no. (%) |        |        |        |        | 0.96  |
| 5th year | 12(17)         | 13(17)   | 25     |        |
| 6th year | 57(83)         | 63(83)   | 120    |        |
a) SG: smart glass, *P values were calculated with use of pearson’s chi-square test.
Legends for figures

Fig. 1. Workshop protocol for SG and control groups

Images of the practice in the workshop included (A) Instructor’s demonstration in SG group, (B) MS’ practice in SG group, (C) Introductory lecture by the instructor, and (D) Instructor’s demonstration in the control group. Source: Professor Ying-Ying Yang. The corresponding author, Dr Ying-Ying Yang, is the owner of the photos in Fig. 1. MS = medical students. SG = smart glasses.
Fig. 2. The distribution of medical students’ pre-intervention score of self-assessed efficacy in different groups

Fig. 3. The distribution of medical students’ changed score of self-assessed efficacy in different groups
Fig. 4. The distribution of medical students’ satisfaction with the training-related statements in different groups