Original Article

Comparison of discussion-based and simulation-based learning methods using the Gas Man® on knowledge of the uptake and distribution of inhalation anesthetics of anesthesia resident: A randomized controlled trial

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Abstract

Background and Aims: Inhalation anesthetics is basic knowledge that must be mastered by an anesthesiologist. Lack of competencies can result in higher morbidity and mortality in anesthesiology practice. Various learning methods were developed to improve understanding and retention. With the advancement of technology, the utilization of screen-based simulation (SBS) using applications is common, such as the Gas Man® application, to help students understand physiology, pathophysiology, and kinetic inhalation anesthetic agents. The primary objective of this study was to compare the knowledge improvement of anesthesia residents between the simulation-based and discussion-based learning methods on the uptake and distribution of anesthetic inhalation. The secondary objective was to compare the satisfaction levels of participants in both learning methods.
Material and Methods: This study is a randomized controlled trial involving anesthesiology and intensive care residents from the Faculty of Medicine, Universitas Indonesia (FKUI) 2022–2023. The participants were randomized into two groups (simulation and discussion groups). A senior attending anesthesiologist led the discussion. The participants answered a pretest, followed by a 1-hour lecture about inhalation gas. Lastly, participants answered a posttest and filled in the satisfaction survey. Statistical analyses used the Mann–Whitney test to compare the two groups. The Wilcoxon test was used to compare the knowledge improvement between the two groups.
Results: Thirty-eight residents underwent simulation-based (n = 19) and discussion-based (n = 19) learning methods. The simulation group demonstrated a median (interquartile range) posttest score of 80 (76.67–83.33) compared with the discussion group with a score of 50 (40–66.67) (P value <0.05). More than half of the participants in both groups answered "satisfied."
Conclusion: The simulation-based learning method using the Gas Man® application performed better than the discussion-based learning method on increasing knowledge of the uptake and distribution of inhalation anesthetics in anesthesia residents.

Keywords: Discussion, Gas Man®, learning methods, screen-based simulation, simulation

Key Message: Simulation-based learning method may improve understanding and retention. This study supported the conclusion that the simulation-based learning method with Gas Man is better than the discussion-based learning method for improving knowledge of the uptake and distribution of inhalation anesthetics.

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Introduction

An anesthesiologist must be able to provide inhalation anesthetic agents and monitor drug effects.[1] To reach the competencies, anesthesiology residents should learn the pharmacology of inhalation anesthetic agents. However, the topic is broad and complex. Several methods have been developed, including lectures, group discussions, and simulation-based scenarios.[2] Lecture as a learning method has the lowest retention among other methods.[3] The group discussion method requires considerable resources, which is not ideal for anesthesia residents who spend more time on patient management. Computer technology advancements currently allow screen-based simulation (SBS) in the form of applications as a cost-effective alternative compared with other learning methods and allow independent learning for students. Learning with the current SBS method is proven to increase students' knowledge.[4,5] The Gas Man® (Med Man Simulations, Inc., Boston, Massachusetts, USA) application combines computer simulations and graphics with written explanations where users can utilize it for general to in-depth learning about the dynamic nature of the absorption and distribution of anesthesia wherever they are.[6]

This study aimed to compare discussion-based learning with SBSs using the Gas Man® application on knowledge uptake and distribution of anesthetic inhalation of anesthesia residents. We hypothesize that the simulation-based learning method using the Gas Man® application is better than the discussion-based learning method on improving knowledge on inhaled anesthetic uptake and distribution.

Material and Methods

This study is a randomized controlled trial with a population of resident of anesthesiology and intensive care at the Faculty of Medicine, Universitas Indonesia (FKUI). After obtaining permission from the Research Ethics Committee of the FKUI (KET/1007/UN2.F1/ETIK/PPM.00.02/2022; September 19, 2022), thirty-nine participants were randomly divided into two groups: discussion group and simulation group. The inclusion criteria for this study were as follows: first- and second-year residents (training and apprenticeship learning stages) of anesthesiology and intensive care at UI. All first- and second-year anesthesia residents who had training at Dr. Cipto Mangunkusumo Hospital were invited to participate in the study through the resident's social media. All participants who agreed to participate in this study signed the informed consent. The exclusion criteria for this study were participants who experience health problems that cause them to be unable to attend education and refuse to participate. Participants were deemed as dropouts if they did not participate in the learning activities from beginning to end. Participants who cheated during the pretest and posttest are considered dropouts. Cheating was determined by observing the participants during the pretest and posttest where those who discussed the answer (directly or using social media) were considered cheating. The study was conducted at the Department of Anesthesiology and Intensive Care, FKUI—Cipto Mangunkusumo Hospital, Jakarta, Indonesia. All funding and provision of rooms and materials for discussion were supported by the Department of Anesthesiology and Intensive Care, FKUI—Cipto Mangunkusumo Hospital.

We developed five scenarios as guidance for the discussions and the SBS. The cases in the scenarios were chosen by the research team (L.M.S.K.R. and A.A.W.R.) from the actual patient lists and were modified to meet the learning objectives. The learning objectives were the same for each scenario, which were as follows:

1. Understand the factors influencing the inhalational anesthetic agent during induction.
2. Understand the effect of changes in cardiac output on the induction and maintenance of inhaled anesthetic gases.

Each scenario was completed with questions as guidance for discussions and simulations. The body of the scenarios contained the patient characteristics and anesthesia technique, with a clear description of the anesthetic agent used. The scenarios were evaluated with different research team members before the research (A.H. and A.P.). The questions for the multiple-choice question (MCQ) were developed following the learning objectives and were chosen by research team members (J.H. and L.M.S.K.R.) from the already established board examination question book. The questions were written in English, assuming that all anesthesiology residents in the institution understand the language. For the simulation group using Gas Man, a guidebook was provided to ease learning as it contains information on how to operate the application.[6]

The sample size was calculated using this formula for unpaired numerical analysis.

For comparison of the posttest, the minimal difference that was deemed significant is 10 points (X1–X2), the standard deviation was 8,32, with type I error of 5% ($Z\alpha = 1,96$) and type II error of 20% ($Z\beta = 0.84$);[7] thus, based on the formula, the minimum number of residents included in this study was eleven students. In addition to the possibility of dropout (an additional 10% of participants), the number of samples for each group was 13 participants. Hence, 26 people for two groups was the minimum number of study participants recruited.

The participants underwent a pretest before continuing the series of research. Pretest questions consist of 30 questions in the form of MCQs. After completing the pretest, all participants participated in an interactive lecture by an attending anesthesiologist about the pharmacology of anesthetic inhalation gas. Participants' knowledge was assessed using scores (range 0–100) of pretest and posttest (score calculation formula = participant's score/total score × 100).

Participants were then assigned into two groups (allocation ratio = 1:1) using a simple randomization method with *www.randomizer.org* by the principal investigator. Randomization is based on the attendance number of each participant. An instructor accompanied the simulation group and another instructor accompanied the discussion group to take notes of the discussion. A senior attending anesthesiologist led the discussion in the discussion group from the institution. Each group received the same scenarios and guidance questions. All five scenarios should be finished in 60 minutes for each group. The research team handled the technical problems for the simulation group. At the end of the learning process, each participant was asked to complete the posttest, and the data collection was completed. As for a fair opportunity, the groups were changed to allow the participants to experience both learning methods (the SBS and the discussion-based simulation). However, knowledge assessment using pretest and posttest was only conducted once after group assignment using randomization. After experiencing both methods, all participants were asked to fill in the questionnaire using the Educational Practice Questionnaire (student version)[8] to assess the satisfaction level for both learning methods. The primary outcome of this study is to compare the knowledge improvement of anesthesia residents in simulation-based and discussion-based learning methods about the uptake and distribution of anesthetic inhalation. This is performed by comparing the posttest score gain from the pretest score of both groups and comparing the posttest scores between the two groups. Our secondary outcome is to compare the satisfaction levels of participants in both learning methods using the Educational Practice Questionnaire (student version).[8]

The data obtained were analyzed using Statistical Package for the Social Sciences (SPSS) version 25.0 software. The hypothesis test used to compare the two groups is the Mann–Whitney U-test. The Wilcoxon test is used to assess each group's knowledge improvement. A P value of <0.05 is deemed significant.

Results

Forty-two anesthesiology and intensive care residents who met the inclusion criteria were recruited for the study. Three subjects were excluded from this study as they refused to join. Hence, only thirty-nine participants were included in the study, which was then assigned to the two groups: 19 for the discussion group and 20 for the simulation group. One participant dropped out of the study; thus, 19 participants in each group were included for statistical analysis [Figure 1]. The characteristics of the participants in both groups did not differ significantly [Table 1]. Thus, the two groups are similar and can be compared.

To test the hypothesis, we utilized the Mann–Whitney U-test. The result of the analysis to compare the simulation and discussion groups is summarized in Table 2.

We also analyzed participants' knowledge improvement on the uptake and distribution of anesthetic inhalation. The

Table 1: Study participants' characteristics

Characteristics	Simulation group *n* (%)	Discussion group *n* (%)	*P*
Gender			
Male	10 (26,3)	13 (34,2)	0,915*
Female	9 (23,7)	6 (15,8)	
Current grade point average			
3	18 (47,4)	19 (50)	0,198*
<3	1 (2,6)	0 (0)	
Learning stage			
Training	10 (26,3)	10 (26,3)	0,148*
apprenticeship	9 (23,7)	9 (23,7)	
Marital status			
Have family with children	10 (26,3)	5 (13,2)	0,347†
Have a family without children	2 (5,3)	4 (10,5)	
Single	7 (18,4)	10 (26,3)	

**Mann–Whitney test. †Kruskal–Wallis test*

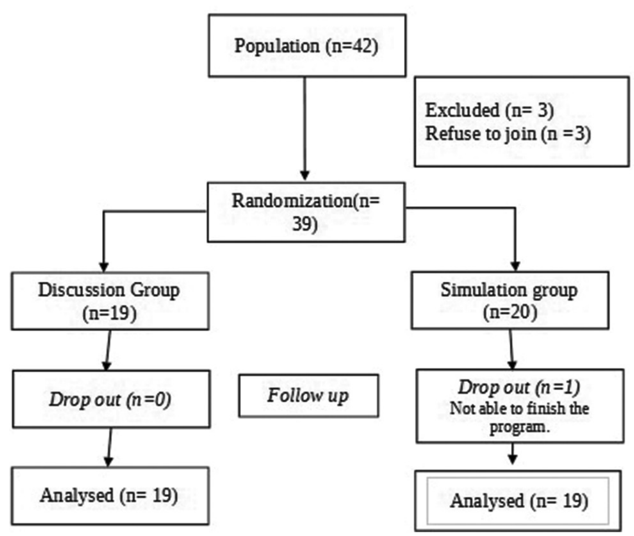

Figure 1: Schematics on the recruitment of study participants

following results on knowledge improvement in the simulation and discussion groups are presented in Table 3.

Aside from the analysis that compares the posttest score between the two groups, we performed an analysis to compare participants' level of satisfaction with anesthesia residents after using the Gas Man® application. Before analyzing the influence or relationship between groups, descriptive statistics were performed on the values obtained through the survey. The calculation was based on each category of satisfaction-level survey questions, encompassing the category of active learning, collaboration, diversity of learning methods, and high expectations [Table 4]. More than 50% of participants from both groups were satisfied with the aforementioned aspects. Regarding active learning, 57.9% of participants in the stimulation group and 63.2% of participants in the discussion group were satisfied using the respective learning method. Similarly, the survey on collaboration satisfaction level revealed that 63.2% of participants in both groups were satisfied. Regarding the diversity of learning methods, 63.2% of participants in the simulation group answered that they were satisfied with the learning method, which was lower in percentage than satisfied participants in the discussion group (68.4%). On the feedback of high expectations, 52.6% of participants of both groups were shown to be satisfied. The percentage of the whole questions demonstrated that 63.2% of participants from the simulation group answered satisfied, whereas 68.4% of participants in the discussion group were satisfied [Table 4].

Discussion

This study showed that simulation-based learning methods using the Gas Man® (Med Man Simulations, Inc., Boston, Massachusetts, USA) application are better than discussion-based learning methods in improving anesthesia residents' knowledge of the uptake and distribution of anesthetic inhalation. The Gas Man® (Med Man Simulations, Inc., Boston, Massachusetts, USA) program is designed with a guidebook. The guidebook has steps on how to use the applications as a means of practice. The tutorial will introduce a basic system first and then combine it.[6] Students will fully understand the system's complexity at the end of the learning process, sufficient to explain clinical events. In this application, various inhalation anesthetic provision techniques can be displayed, and their impact is explored.[6,9]

The Gas Man® (Med Man Simulations, Inc., Boston, Massachusetts, USA) application is a form of SBS that aims to help students understand the pharmacodynamics and pharmacokinetics of inhalation anesthetic agents. The application of Gas Man® (Med Man Simulations, Inc., Boston, Massachusetts, USA) illustrates the amount of gas and steam pressure and inhalation anesthetics in each body compartment in graphics. The simulation in the application also considers the effect of the amount of fresh gas flow, gas vapor pressure, the choice of the respiratory circuit, venous backflow, and blood anesthetic gas uptake by blood. Gas Man® (Med Man Simulations, Inc., Boston, Massachusetts, USA) simulation can be used to study the effects of solubility, cardiac output, and anesthetic duration.[3,4,10] Gas Man® (Med Man Simulations, Inc., Boston, Massachusetts, USA) [Figure 2] can be used as an alternative for discussion-based learning methods in inhalation anesthetic learning, where students can learn without being bound by time and space. Therefore, it can also be used as a distance learning program. This application is easy to use, cheap, and can be used by many students simultaneously.

Table 2: Statistical description between groups for pretest and posttest scores

Variable	Group		*P*
	Simulation	Discussion	
Pretest	50 (10)	46,67 (16,7)	0,734
Posttest	80 (6,7)	50 (26,7)	0,000
Gain score	30 (6,6)	3,33 (3,3)	0,000

*Median (IQR); Mann–Whitney test

Table 3: Knowledge improvement in simulation group

	Median (IQR)	*P*
Simulation group		
Pretest	50 (10)	0,000
Posttest	80 (6.7)	
Discussion group		
Pretest	46,67 (16.7)	0,492
Posttest	50 (26,7)	

* Wilcoxon test

Based on assessing the improvement of participant ability in answering the test questions, we found that the simulation group has higher scores in the pretest, posttest, and gain value than the discussion group. A previous study by Philip J.H.[11] concluded that SBSs could improve the patient's service by improving student knowledge (resident).

Lawson *et al*.[12] also identified a significant gap in knowledge of pharmacokinetic inhalation anesthesia that can be reduced by Gas Man® (Med Man Simulations, Inc., Boston, Massachusetts, USA). Garfield[13] demonstrated that this SBS is an effective educational tool to improve the knowledge of anesthesia residents regarding the pharmacokinetics of anesthetic inhalation. The improvement of performance of resident knowledge is related to the amount of time spent using the SBS. The more time spent using the application, the more understanding the resident about anesthetic inhalation drugs will improve.

Table 4: Percentage of level of satisfaction in each group

	Group	
	Simulation *n* (%)	Discussion *n* (%)
Active learning		
Very satisfied	7 (36,8)	7 (36,8)
Satisfied	11 (57,9)	12 (63,2)
Neutral	1 (5,3)	0
Not satisfied	0	0
very not satisfied	0	0
Collaboration		
Very satisfied	7 (36,8)	7 (36,8)
Satisfied	12 (63,2)	12 (63,2)
Neutral	0	0
Not satisfied	0	0
Very not satisfied	0	0
Diversity of learning methods		
Very satisfied	6 (31,6)	6 (31,6)
Satisfied	12 (63,2)	13 (68,4)
Neutral	0	0
Not satisfied	1 (5,3)	0
very not satisfied	0	0
High expectation		
Very satisfied	8 (42,1)	9 (47,4)
Satisfied	10 (52,6)	10 (52,6)
Neutral	0	0
Not satisfied	0	0
Very not satisfied	1 (5,3)	0
Percentage of the whole question		
Very satisfied	6 (31,6)	6 (31,6)
Satisfied	12 (63,2)	13 (68,4)
Neutral	1 (5,3)	0
Not satisfied	0	0
Very not satisfied	0	0

Various types of software have been developed to facilitate learning in pharmacology, such as simple questions and answers; electronic books; video material; and tutorial programs in the form of simulations. Various tools are used in different ways to achieve specific and efficient learning goals. The software can be used as a tool in the discussion, preparing students before managing patients, including providing options with limited resources, especially time and human resources, which are limitations encountered during the discussion-based learning method. Discussion as a learning method also has limitation in terms of participation, in which each participant has unequal participation (some may dominate the discussion). Because of its application-based nature, the simulation-based learning method using Gas Man® (Med Man Simulations, Inc., Boston, Massachusetts, USA) becomes easy and flexible, not bound by the availability of human resources and the availability of classrooms.[13,14] However, a limitation of the SBS learning method is that, as it utilizes screen, it may lack functional fidelity for health professionals who do not use screen frequently.[15]

To obtain a more measurable result, this computer-based learning material must be integrated with the curriculum. In environmental conditions with high pressure and high dynamic, the presence of this software can facilitate learning to maintain high scientific quality in the pharmacology of inhalation anesthetic agents.

Considering the posttest result was better in the simulation group, we expected higher satisfaction in the same group. Interestingly, most participants' feedback on the survey said that the discussion-based learning method was more satisfying than the simulation-based learning method, although they were satisfied with both methods. The survey contains five different subjects as follows: active learning, collaboration, diversity of learning methods, high expectations, and percentage of the whole question. A survey concerning satisfaction level on collaboration yielded satisfaction in both simulation and discussion groups. A survey regarding the diversity of learning methods revealed that most feedback was satisfactory in both groups. A survey on high expectations showed that most participants were satisfied in the simulation and discussion groups.

This study demonstrated that the simulation-based learning method using a computer application is better than the discussion-based learning method in improving knowledge of intake and distribution of anesthetic inhalation. The majority of study participants were satisfied, and none were not satisfied. The result of this study can be applied to a broader population, such as all residents of anesthesiology at FKUI and other institutions. This study provided additional information about learning anesthetics using simulation-based learning methods. Additionally, this study provided contributions to anesthetic education, namely the development of simulation methods in improving resident capabilities; thus, the result of this study can be utilized as a reference for upcoming studies.

Throughout the study, there were several limitations encountered. The study was conducted only at one research location. Therefore, bias due to socio-demographic factors cannot be eliminated from this study. In addition, the assessment is conducted only once, thus removing/practical abilities in the field. This can be seen from the level of education, which does not affect the ability to answer the questions. In theory, a resident with a higher stage of education should have higher knowledge of anesthetic inhalation. In our sample, there was inequality in the proportion of the stage of education, which is due to the limited number of populations that meet the inclusion criteria. Thus, it is prone to bias. In addition, we ought to consider that the resident undergoing their residency program may experience fatigue

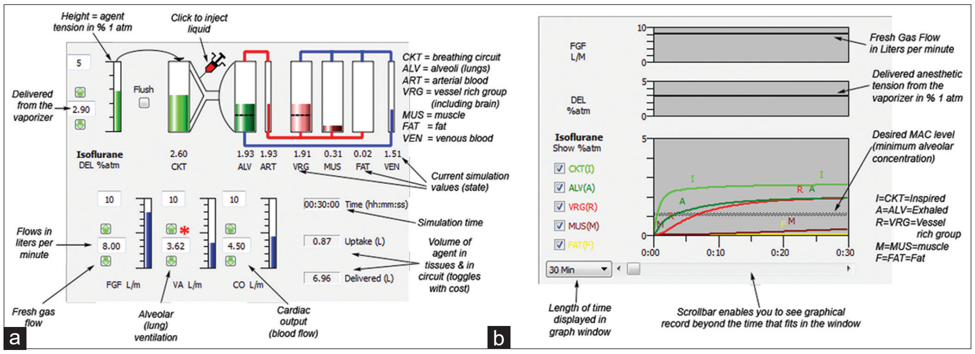

Figure 2: (a) Screen view of Gas Man® Application. The GasMan simulation output is presented as an annotated image, detailing the descriptions of its various components.[6,9] Source: Philip JH. Using screen-based simulation of inhaled anaesthetic delivery to improve patient care. Br J Anaesth. 2015;115:89–94; https://www.gasmanweb.com/ (b) Screen view of Gas Man® Application. The GasMan simulation graph is annotated with component descriptions.[6,9] Source: Philip JH. Using screen-based simulation of inhaled anaesthetic delivery to improve patient care. Br J Anaesth. 2015;115:89–94; https://www.gasmanweb.com/

due to numerous workloads; thus, they may not concentrate and participate optimally during the learning activities. This may also affect the participant's ability to answer the questions optimally. Another limitation is that the discussion and simulation forums consist of variable educational stages of FKUI residents, which may lower the participants' self-confidence with lower stages of education, thus affecting the participant's activeness to participate in the learning activities. Additionally, there is a high chance for participants to discuss the answers to pre- and posttest questions. This is due to the limited number of committees; hence, the supervision of participants was weak. Based on the results and limitations of our study, we recommend further analysis, such as cost analysis in both types of learning methods. It would be valuable if this simulation-based learning method were applied to a broader scope of students. In this study, although all participants in both groups received the same treatment, variability was still encountered.

To address the limitations of this study, it should be conducted using similar applications in a broader study population to reduce bias. In addition, a cost analysis of both methods might be valuable. It is also necessary to do a broader analysis of other factors that may influence a student's knowledge and data collection regarding the student's learning styles.

Conclusion

Based on the results obtained in this study, SBS learning methods using the Gas Man® (Med Man Simulations, Inc., Boston, Massachusetts, USA) application are better than discussion-based learning methods in improving the knowledge for uptake and distribution of anesthetic inhalation of anesthesia residents with a high level of satisfaction. The methods might be an alternative to a busy schedule of staff and residents.

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Conflicts of interest

There are no conflicts of interest.

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