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Original Article

Integrating Basic Electrocardiogram Interpretation into Advanced Cardiovascular Life Support Stations Through Simulation-Based Learning Among Preclinical Medical Students: Comparing Student and Teacher Perceptions

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Abstract

Background: Simulation-based learning (SBL) was introduced at Phramongkutklao College of Medicine to improve electrocardiogram skills within an advanced cardiovascular life support (ACLS) context for pre-clinical students.

Objectives: This study compared the perceptions of third-year students and teachers regarding the SBL course.

Methods: A cross-sectional study included 96 students and 10 instructors. The course featured five stations to assess ECG interpretation, ACLS management, and pharmacological knowledge. The questionnaire included sections on demographics, a 5-point Likert scale to assess satisfaction with preparation, effectiveness, scenarios, equipment, and perception, as well as open-ended questions to explore pros and cons. Internal reliability, construct validity (exploratory factor analysis: EFA), and content validity (item objective congruence: IOC) were assessed. Responses were analyzed using Mann-Whitney U-tests, and open-ended questions underwent content analysis. Stata 17.0 was used for analysis, and $p<0.05$ was considered significant.

Results: Eighty-nine students and 10 instructors responded to the questionnaire. Cronbach's alpha for the satisfaction and perception sections were 0.91 and 0.97, respectively. IOC ranged from 0.67 to 1.00, and EFA confirmed unidimensionality (Eigenvalue1: Eigenvalue2 = 9.31:0.55, $\lambda = 0.55\text{-}0.91$). The participants responded positively to the preparation resources and course effectiveness. Median (IQR) scenario-difficulty scores were 5.00 (4.00-5.00) for the students and 3.50 (3.00-4.00) for the instructors ($p<0.001$), and perception scores were 4.93 (4.43-5.00) for the students and 4.32 (4.00-4.57) for the instructors ($p=0.021$). Content analysis showed that the students valued comprehensiveness and realism but wanted more pre-training. The instructors noted high resource use and information sharing by the morning group tested first, which influenced the afternoon groups and resulted in bias.

Conclusion: The SBL course met learning objectives with high satisfaction and was perceived as effective. The participants agreed that it enhanced knowledge but suggested adding a peer-led mock exam to boost confidence and increasing parallel cases to reduce bias.

Keywords: Simulation; Simulation-Based Learning; ACLS; Electrocardiogram; Medical Student

Background

Electrocardiography (EKG) is a crucial skill in medical practice (1) and is used for screening and diagnosing cardiac diseases, including life-threatening disorders (2). Accurate interpretation of EKGs by medical specialists dramatically improves treatment outcomes, especially in cases of acute myocardial infarction or cardiac arrest (3). Traditionally, EKG interpretation skills are taught through lectures that focus on principles but lack real-world interpretation practice, resulting in students lacking confidence in systematic interpretation (4).

Simulation-based learning (SBL) is a widely used teaching method in medical education (5). As an innovative tool, simulation involves practically emulating scenarios or events for learning, assessment, or research purposes (6). With the expansion of medical knowledge and limited training time, simulation increasingly bridges the traditional apprenticeship model and the need for skills training in modern medicine (6). Learning through realistic simulated scenarios allows medical students to acquire skills using mannequins or other tools before applying this knowledge to real patients (7). This approach provides a safe, controlled environment that enriches experiences and enhances students' confidence and decision-making abilities, ultimately improving their clinical and related skills (7).

Previous studies have reported positive outcomes in enhancing knowledge, skills, and attitudes toward technology-enhanced simulation (8). Research conducted in the United States using SBL to teach 89 fourth-year medical students advanced cardiovascular life support (ACLS) found significant improvements in their knowledge scores after simulation cases and a notable increase in their confidence scores after the simulated experience (6). Implementing SBL within emergency medicine (EM) training programs has created tremendous opportunities for optimizing educational delivery (9). Furthermore, SBL has demonstrated superiority in EKG learning compared to traditional methods (10).

Despite the benefits of SBL and ACLS in improving EKG learning, several schools still teach EKG interpretation using traditional methods and without a simulated environment (3, 11). Furthermore, limited research has focused on the perceptions of undergraduates, particularly preclinical medical students, regarding the effectiveness of SBL strategies (5). Gauging students' satisfaction with this teaching method is crucial to effectively integrate SBL into medical education curricula (5). Student satisfaction is pivotal to their ability to learn and practice clinical skills in a controlled environment before engaging with real patients (12). Integrating the voices of students and stakeholders is important for improving the learning course in future iterations (13).

Although ACLS learning can potentially improve EKG interpretation skills, most medical students take ACLS courses during their late clinical years (14). Hence, Phramongkutklao College of Medicine (PCM) developed an SBL course focusing on EKG interpretation and advanced lifesaving skills for pre-clinical medical students, with approximately 100 participants enrolled. SBL was integrated into EKG interpretation and ACLS management through scenarios featuring ACLS mannequins. The medical students applied their knowledge to various case studies in simulated scenarios. This study evaluated the students' satisfaction and perceptions toward SBL in the EKG interpretation course while comparing these perspectives with those of teachers. In addition, comprehensive details on the course implementation and the obstacles encountered were depicted. The findings can be instrumental in designing future training and implementing simulated activities for pre-clinical medical students.

Objectives

This study compared the perceptions of third-year students and teachers regarding the SBL course.

Methods

The present study employed a cross-sectional design to survey all students and teachers who participated in integrating basic electrocardiogram interpretation into ACLS stations through an SBL course. The study's report on SBL interventions adhered to the STROBE statement and its extension for reporting simulation-based research (Appendix 1) (15, 16).

Study Design and Subject: A sample size of 52 was required for an effect size of 0.82 with 80% power at a significance level of 0.05 for a two-sample Wilcoxon rank-sum (Mann-Whitney) test using G*Power 3.1.9.7 (17, 18). The course involved 96 third-year medical students and 10 PCM instructors. A cross-sectional study was conducted to collect perceptions of the course. At the end of the class, 89 students and all instructors responded to the questionnaire, totaling 99 responses. A course on integrating SBL into basic EKG interpretation and ACLS management was conducted. The course took place in the third trimester of the cardiovascular system block at PCM's simulation center. At the course's conclusion, the students and instructors completed a questionnaire to gauge their satisfaction and perspectives regarding SBL in basic EKG interpretation using an ACLS high-fidelity mannequin. Figure 1 illustrates the stages of the SBL course on basic EKG interpretation using an ACLS high-fidelity mannequin.

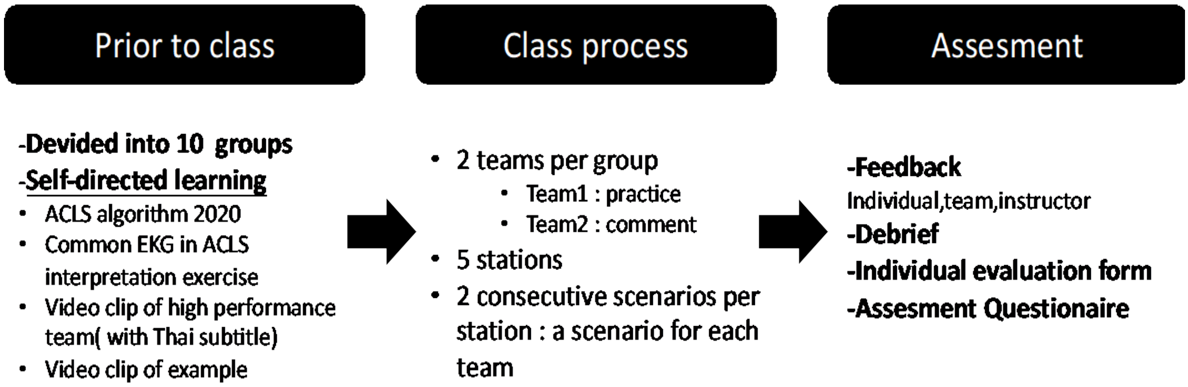

Figure 1. Stages of the SBL course on basic EKG interpretation using an ACLS high-fidelity mannequin

The course is divided into three stages:

1. Prior to the Course

The students received instruction on basic EKG interpretation through lectures. Additionally, they were provided with ACLS guidelines and an EKG review exercise for self-directed learning. A video clip demonstrating the use of the ACLS mannequin and an introductory demonstration of ACLS management were also conducted and distributed to the students for course preparation. Alpha and beta tests were conducted to verify the scenario's feasibility, difficulty, and assessment criteria. The alpha test involved two intern doctors who are now teaching assistants at PCM and hold ACLS certifications. Subsequently, five fourth-year medical students participated in the beta test. Based on feedback from EM staff, the authors refined the scenarios accordingly.

2. During the Course

Ninety-six third-year medical students were divided into 10 groups, each comprising 9-10 students. The groups were further divided into two sessions, with five groups participating in the morning and the other five in the afternoon. All student groups rotated through five stations, each featuring two consecutive scenarios. Each station lasted 30 minutes and had two instructors providing suggestions and learning summaries.

Each group was divided into two subgroups, consisting of five students each, designated as Leader, Airway Manager, Compressor, Nurse, and Recorder. The subgroups were further separated into hands-on groups (subgroup1) and observation groups (subgroup2) to express their opinions. Each subgroup had 10 minutes to perform the simulated scenario. The Leader ran the algorithm, supervised medications, and answered instructor questions verbally. Then, the subgroups switched roles to run the scenario. Instructors could assist or demonstrate clinical procedures, such as intubation. Group leaders were evaluated on their EKG interpretation skills, the pharmacological mechanism of action, and their ability to use the ACLS algorithm under examination conditions. Finally, the instructors conducted debriefing sessions on the scenarios.

3. Post Course

After the course, the students and instructors were asked to complete a questionnaire about their satisfaction and perceptions of the course. Additionally, they were asked to provide comments on the pros and cons. The questionnaire was completed via Google Forms, where the participants scanned the QR code or clicked the link to access and complete it. On the first page of the form was an information sheet, which the participants were asked to review carefully. The collected data were then interpreted for further analysis.

Data Collection: The study utilized a 33-item electronic questionnaire divided into three sections: (1) short-answer questions for demographic data (3 items), (2) a 5-point Likert scale to assess satisfaction with skill improvement, course preparation, scenario suitability, and device suitability (4 items each), and (3) perceptions of SBL in EKG interpretation (14 items). The questionnaire also included two open-ended questions to explore the pros and cons of the course, with completion taking approximately 15 to 20 minutes. Skill improvement covered EKG interpretation, ACLS algorithm management, medication selection based on pharmacodynamics and pharmacokinetics, and holistic care. Course preparation included learning resources such as sample videos of medical teams, common EKG examples, ACLS algorithms, and allocated preparation time. Scenario suitability was evaluated based on the number, variety, difficulty, and duration of each scenario. Equipment adequacy was assessed by the quantity and realism of medical instruments, the complexity of using the high-fidelity mannequin, and the comprehensiveness of the instruction manual. The perception of SBL was gauged using an adapted questionnaire.

Questionnaire Reliability and Validity Analysis: The questionnaire was adapted and translated based on previously published work on satisfaction and perception relevant to this paper, as well as the investigators' experience and the context of PCM (19). Before distribution, three expert instructors reviewed the content of the assessment form using the item objective congruence (IOC) approach to ensure its content validity regarding simplicity, relevance, and language. Each question received an IOC index between 0.67 and 1.00, above the threshold of 0.50, and amendments were made according to the suggestions (Appendix 2) (20). The construct validity of the perception questionnaire was also confirmed through extensive adaptation using exploratory factor analysis. Moreover, Cronbach's alpha was analyzed to determine the questionnaire's reliability.

Statistical Analysis: All data were downloaded from Google Forms, and data analyses were conducted using Stata Statistical Software: Release 17 (Stata Corp, 2021. College Station, TX: Stata Corp LLC). A frequency distribution of demographic characteristics was used to describe the study subjects. Categorical data were presented as percentages, while continuous variables were expressed as means and standard deviations (SD). Due to the violation of the normality assumption, the two-sample Wilcoxon rank-sum (Mann-Whitney) test was used to compare the ratings between the students and teachers on the Likert scale. All statistical tests were two-sided, and a p-value less than 0.05 was deemed statistically significant. The comments regarding the course's pros and cons were analyzed using content analysis, and similar contexts were organized into themes.

Ethics Approval and Consent to Participate: The study was approved by the Medical Department Ethics Review Committee for Research in Human Subjects, Institutional Review Board, RTA (Approval no. S023q/66_Exp), in accordance with international guidelines, including the Declaration of Helsinki, the Belmont Report, CIOMS Guidelines, and the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use - Good Clinical Practice. Documentation of informed consent was obtained, and the Institutional Review Board, RTA Medical Department, granted permission.

Results

Characteristics of Participants: Ninety-six third-year medical students and 10 instructors participated in the study. Of these students, eighty-nine (92.7%) responded to the questionnaire. Approximately 64.0% of the participants were male. More than 40 students (45.0%) spent over 5 hours on course preparation, while only two participants (2.3%) devoted less than an hour to the course preparation. Ten instructors responded, six of whom graduated with a Doctor of Medicine degree and had previous experience with ACLS, while the others were from different health professions, including basic science and pharmacology.

Satisfaction of the Integration of Basic EKG Interpretation into ACLS Stations Through the SBL Course: Table 1 presents the satisfaction levels of the students and instructors with SBL, assessed using a Likert scale. The overall Cronbach's alpha for the satisfaction section is 0.91. Within each satisfaction domain, Cronbach's alphas for skill improvement, course preparation, scenario suitability, and equipment suitability were 0.83, 0.76, 0.86, and 0.89, respectively. The students reported a median (IQR) satisfaction with the learning outcome score of 4.25 (4.00–5.00), while the instructors reported 3.88 (3.75–4.25) ($Z = 1.796$, $p=0.072$, effect size $d = 0.59$). Over 50% of the students strongly agreed that the course enhanced their EKG interpretation skills and ACLS algorithm management. However, more than half of the instructors disagreed that the course effectively improved the students' ability to select pharmacological agents based on pharmacodynamics and pharmacokinetics. Regarding learning resources and allocated preparation time, the median (IQR) scores were 4.50 (4.00–5.00) for the students and 4.50 (4.50–4.75) for the instructors, with both groups generally agreeing that the resources were effective. Regarding scenarios, the students and instructors scored them 4.75 (4.25–5.00) and 4.00 (3.75–4.50), respectively ($Z=3.012$, $p=0.003$, effect size $d=2.06$), with 60% to 70% of the students strongly agreeing on their effectiveness. In contrast, the instructors rated the scenario difficulty less favorably ($Z=3.670$, $p<0.001$, effect size $d=1.38$). Additionally, the students rated their satisfaction with the equipment higher than the instructors, with median (IQR) scores of 5.00 (4.00–5.00) and 3.75 (3.50–4.25), respectively ($Z=3.111$, $p=0.002$, effect size $d=1.06$).

Perception Toward the SBL Course: Exploratory factor analysis was performed with maximum likelihood extraction and orthogonal (varimax) rotation. Unidimensionality was confirmed in the perception questionnaire (Eigenvalue component 1: Eigenvalue component 2 = 9.31:0.55). The Kaiser–Meyer–Olkin measure of sampling adequacy was applied, yielding an overall index of 0.90, indicating sufficient data for factor analysis. Additionally, Bartlett's test for sphericity confirmed that the intercorrelation matrix was factorable ($\chi^2 = 1522.51$, $p<0.001$). The factor loadings are strong, ranging from 0.55 to 0.91, with all values above 0.30. Moreover, the Cronbach's alpha for the perception of SBL is 0.97.

Table 2 illustrates perceptions of the SBL course, stratified by the students and teachers. The median (IQR) scores were 4.93 (4.43–5.00) for the students and 4.32 (4.00–4.57) for the teachers, respectively ($Z = 2.314$, $p = 0.021$, effect size $d = 0.82$). Over 96% of the students expressed positive views (strongly agree/agree) about the SBL course. Significant discrepancies emerged between the teachers and students regarding the learners' ability to apply prior basic skills during simulations, the effectiveness of the course in enhancing practical skills, the realism of the mannequin, and the integration of SBL into the curriculum. Conversely, both groups positively noted that the SBL course improved student communication skills, critical thinking, decision-making abilities, clinical skills and competence, EKG interpretation skills, and ACLS management skills. Figure 2 further depicts the students' perceptions of the SBL course.

Content Analysis of Pros and Cons: A content analysis of the participants' comments was conducted. The students indicated that SBL provided a superior understanding compared to traditional learning methods (N = 27) and offered practical, realistic simulations that closely mirrored actual clinical practice (N = 23). Some students expressed enjoyment and excitement about the course (N = 11), while others noted the practical applicability of the experience gained (N = 7).

However, concerns were raised about additional lectures and training before the course (N = 14). Both students (N = 8) and instructors (N = 3) also observed discrepancies between morning and afternoon sessions and variations in the difficulty levels across stations (N = 7). The instructors highlighted the need for better preparation and prior knowledge to enhance student engagement and noted the substantial resource use, including teaching staff, preparation time, and facilities.

Discussion

The study demonstrated a course that integrated EKG interpretation into an ACLS station for pre-clinical students without experience in patient care. The findings indicated positive satisfaction and perception of SBL among the participants. The students reported considerable contentment with the learning outcomes, including enhanced EKG interpretation skills, proficiency in managing ACLS algorithms, effective medication selection, and comprehensive, holistic care. While the instructors also expressed satisfaction with the learning outcomes, their scores were slightly lower than those of the students. The students expressed a desire for additional lectures and training before the course, and the instructors highlighted the need for improved preparation and prior knowledge among the students. Furthermore, various comments emphasized aspects that could prove beneficial in implementing SBL, including the identification of disparities in the difficulty levels across stations.

Regarding the perception of learning resources, both students and instructors found the provided materials-such as sample videos of medical teams, common EKG examples, and ACLS algorithms-suitable and beneficial for course preparation. The students noted that the SDL resources were particularly helpful, especially for those with lower GPAs, as a study in Oman indicated a preference for SDL among such students (21). This may be because students with higher GPAs already possess prior knowledge before the course. The scenarios used during the SBL course were well-received, with the students rating them highly in terms of quantity, variety, difficulty, and duration. The participants also positively evaluated the equipment's suitability, noting the adequacy and realism of the medical instruments, the usability of the high-fidelity mannequin, and the thoroughness of the instruction manual.

In terms of perceptions regarding SBL, the students consistently rated higher scores than instructors across all categories. Similar to findings in related studies, the medical students perceived that SBL not only facilitated the integration of their knowledge into clinical practice and elevated their medical skills but also heightened their interest in learning and provided a practical, lifelike experience akin to real clinical settings (22). The lower instructor satisfaction may primarily stem from the belief that pre-clinical students require more knowledge before integrating EKG into workplace-based assessments. Additionally, the substantial use of resources and time was noted. A potential solution could involve providing formative examinations or peer-led mock practice rounds to enhance student knowledge and confidence before summative assessments (23).

Although this study's findings support prior research on the efficacy of SBL in medical education, it is important to note that SBL requires significant resources and numerous instructors. This can lead to lower instructor satisfaction when conducting the course, presenting a major barrier to adopting active learning methods (24). Thus, applying generalizability theory might be beneficial in determining the optimal number of instructors and scenarios required to achieve reliable assessments (25).

The study examined the participants' perceptions of SBL as a teaching method, indicating its potential to enhance learning experiences and clinical preparedness, while also highlighting a notable disparity in SBL perceptions between the students and teachers, with the teachers generally scoring it lower. Some teachers believed that augmenting SBL with more lecture-based learning (LBL) could improve its effectiveness, a sentiment echoed by students who desired additional lectures and training before SBL courses. While lectures on EKG and ACLS are beneficial, incorporating SBL can motivate students and provide realistic clinical insights for pre-clinical learners. LBL remains essential in undergraduate medical education (26). For instance, an Indian study found that although a lecture-based group outperformed a simulation-based group on MCQ tests in a status epilepticus scenario, the simulation group showed greater confidence in patient management, underscoring SBL's role as an effective complement to LBL (27).

Concerns regarding bias between the morning and afternoon groups were also noted. The afternoon group may receive unauthorized information from the morning group, leading to unfairness. To address this, additional parallel scenarios should be provided for further development to ensure parity between the morning and afternoon groups. Additionally, enhancing the assessment form and determining the appropriate number of teachers needed to achieve reliable assessments would be beneficial.

The instructors did not fully agree that the students could effectively utilize their basic knowledge in the simulated environment, suggesting that more preparation, including high-stakes examinations, is necessary to enhance the course's effectiveness. Future developments should include formative or peer-led examinations. Developing student-friendly rubrics could also help students assess their own or peers' performance. Rubrics, which delineate explicit performance criteria and expectations, ensure uniform grading, provide targeted feedback, and promote peer assessment (28, 29), could reduce the number of teachers required for formative SBL rounds. Additionally, applying generalizability theory may help determine the optimal number of raters needed for reliable assessments, thereby minimizing resource requirements (25).

It is worth noting that this pilot study has several limitations. Firstly, it was conducted at a single institution with a relatively small sample size, potentially restricting the generalizability of the findings to other medical schools or larger populations. Secondly, since the study was an initial attempt, there were several opportunities for improvement. Further research would provide more substantial evidence regarding the development of the SBL course during the pre-clinical years. Thirdly, implementing SBL requires significant resources, including costs and personnel (30). Therefore, conducting multiple sessions was not feasible in the present study, and comparisons across different sessions were impossible. Fourthly, the number of experts available for content validity in the present study was three, which is the minimum acceptable number for content validity (31). However, this number is considered acceptable since fewer raters are needed to assess the same items in a school district compared to a statewide study. Additionally, when the content domain being rated is narrowly defined, rater agreement tends to be higher, thus requiring fewer raters (32). Lastly, although assessing the retention of knowledge and skills is recommended, it may be challenging due to potential confounding factors encountered throughout the clinical years. Nonetheless, concerns raised, such as disparities between the morning and afternoon groups, variations in the difficulty levels of stations, and the scoring criteria employed by instructors, highlight the need for refinement and optimization in future implementations of the SBL course.

Conclusion

The study investigated the implementation of SBL for EKG interpretation among third-year medical students at PCM, revealing a favorable reception and perception of SBL. The findings underscored the efficacy of SBL in enhancing students' knowledge and proficiency in EKG interpretation and ACLS management. The study supported the incorporation of SBL as a valuable pedagogical approach in medical education curricula, offering a secure and controlled setting for acquiring clinical skills and bolstering students' confidence and decision-making abilities from the pre-clinical years onward. However, significant resource needs and inadequate student preparation were noted. To address these issues, we recommend developing peer-led practice rounds to enhance confidence and skills, increasing the number of parallel cases with similar difficulty to reduce bias, and assessing knowledge retention in future clinical years.

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Conflict of interests: There is no conflict of interest.

Ethical approval: The study was approved by the Medical Department Ethics Review Committee for Research in Human Subjects, Institutional Review Board, RTA (Approval no. S023q/66_Exp), in accordance with international guidelines, including the Declaration of Helsinki, the Belmont Report, CIOMS Guidelines, and the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use - Good Clinical Practice. Documentation of informed consent was obtained, and the Institutional Review Board, RTA Medical Department, granted permission.

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Table 1. Student and Teacher Satisfaction with the Integration of Basic EKG Interpretation into ACLS Stations Through the SBL Course

Questions	Profession	5 [n (%)]	4 [n (%)]	3 [n (%)]	2 [n (%)]	1 [n (%)]	Median (IQR)	Z	p-value
The integration of basic EKG interpretation into ACLS stations through the SBL course to improve these learning outcomes									
EKG interpretation skills	Student	44 (49.4)	34 (38.2)	11 (12.4)	0	0	4 (4-5)	0.689	0.491
	Teacher	4 (40.0)	4 (40.0)	2 (20.0)	0	0	4 (4-5)		
ACLS management skills	Student	50 (56.2)	33 (37.1)	6 (6.7)	0	0	5 (4-5)	2.046	0.041*
	Teacher	2 (20.0)	7 (70.0)	1 (10.0)	0	0	4 (4-4)		
Drug selection based on pharmacokinetics and pharmacodynamics	Student	37 (41.6)	36 (40.5)	16 (18.0)	0	0	4 (4-5)	2.117	0.034*
	Teacher	2 (20.0)	3 (30.0)	4 (40.0)	1 (10.0)	0	3.5 (3-4)		
Holistic care of a patient	Student	38 (42.7)	40 (44.9)	11 (12.4)	0	0	4 (4-5)	0.878	0.380
	Teacher	3 (30.0)	5 (50.0)	2 (20.0)	0	0	4 (4-5)		
Overall learning outcome Likert score (Median (IQR))	Student	4.25 (4-5)						1.796	0.072
	Teacher	3.88 (3.75-4.25)							
Satisfaction of the self-directed learning resources and the allocated time									
Sample videos/medical team for pre-learning purposes	Student	34 (38.2)	34 (38.2)	19 (21.3)	1 (1.1)	1 (1.1)	4 (4-5)	-0.884	0.377
	Teacher	4 (40.0)	6 (60.0)	0	0	0	4 (4-5)		
Common EKG examples	Student	54 (60.7)	26 (29.2)	7 (7.9)	2 (2.2)	0	5 (4-5)	0.020	0.984
	Teacher	6 (60.0)	3 (30.0)	1 (10.0)	0	0	5 (4-5)		
ACLS algorithms for pre-learning purposes	Student	55 (61.8)	26 (29.2)	6 (6.7)	2 (2.2)	0	5 (4-5)	-1.218	0.223
	Teacher	8 (80.0)	2 (20.0)	0	0	0	5 (5-5)		
The amount of time for preparation before class is appropriate	Student	45 (50.6)	35 (39.3)	7 (7.9)	1 (1.1)	1 (1.1)	5 (4-5)	0.528	0.597
	Teacher	4 (40.0)	5 (50.0)	1 (10.0)	0	0	4 (4-5)		
Overall learning resource Likert score (Median (IQR))	Student	4.5 (4-5)						-0.390	0.696
	Teacher	4.5 (4.5-4.75)							
Satisfaction with the scenarios and equipment									
Number of scenarios	Student	57 (64.0)	32 (36.0)	0	0	0	5 (4-5)	1.690	0.091
	Teacher	4 (40.0)	5 (50.0)	1 (10.0)	0	0	4 (4-5)		
The diversity of the scenarios	Student	63 (70.8)	25 (28.1)	1 (1.1)	0	0	5 (4-5)	2.703	0.007*
	Teacher	3 (30.0)	6 (60.0)	1 (10.0)	0	0	4 (4-5)		
The difficulty of the scenarios	Student	54 (60.7)	28 (31.5)	7 (7.9)	0	0	5 (4-5)	3.670	<0.001*
	Teacher	1 (10.0)	4 (40.0)	5 (50.0)	0	0	3.5 (3-4)		
The duration of each scenario	Student	54 (60.7)	27 (30.3)	7 (7.9)	1 (1.1)	0	5 (4-5)	1.880	0.060
	Teacher	3 (30.0)	5 (50.0)	2 (20.0)	0	0	4 (4-5)		
Overall scenarios Likert score (Median (IQR))	Student	4.75 (4.25-5)						3.012	0.003*
	Teacher	4 (3.75-4.5)							
Satisfaction with the equipment									
Number of pieces of equipment	Student	57 (64.0)	24 (27.0)	7 (7.9)	1 (1.1)	0	5 (4-5)	2.598	0.009*
	Teacher	2 (20.0)	6 (60.0)	2 (20.0)	0	0	4 (4-4)		
The equipment is realistic	Student	59 (66.3)	25 (28.1)	5 (5.6)	0	0	5 (4-5)	2.371	0.018*
	Teacher	3 (30.0)	5 (50.0)	2 (20.0)	0	0	4 (4-5)		

The level of difficulty in handling the high-fidelity mannequin is appropriate	Student	59 (66.3)	22 (24.7)	7 (7.9)	1 (1.1)	0	5 (4-5)	3.118	0.002*
	Teacher	2 (20.0)	4 (40.0)	4 (40.0)	0	0	4 (3-4)		
Teaching and learning manual	Student	53 (59.6)	28 (31.5)	8 (9.0)	0	0	5 (4-5)	2.356	0.019*
	Teacher	2 (20.0)	6 (60.0)	2 (20.0)	0	0	4 (4-4)		
Overall equipment Likert score (Median (IQR))	Student	5 (4-5)						3.111	0.002*
	Teacher	3.75 (3.5-4.25)							

5: Strongly agree, 4: Agree, 3: Mediocre, 2: Disagree, 1: Strongly disagree, ACLS: Advanced Cardiovascular Life Support, EKG: electrocardiogram, SBL: simulation-based learning, *$p<0.05$

Table 2. Student and teacher perception on the Integration of basic EKG interpretation into ACLS stations through the SBL course

Questions	Profession	5	4	3	2	Median (IQR)	Z	p-value
Experience with the simulation benefits clinical practice	Student	68 (76.4)	21 (23.6)	0 (0)	0 (0)	5 (5-5)	1.947	0.052
	Teacher	5 (50.0)	4 (40.0)	1 (10.0)	0 (0)	4.5 (4-5)		
The learner was able to utilize prior basic skills during the simulation	Student	67 (75.3)	22 (24.7)	0 (0)	0 (0)	5 (5-5)	2.655	0.008*
	Teacher	4 (40.0)	4 (40.0)	2 (20.0)	0 (0)	4 (4-5)		
The simulation course improves the learner teamwork skills	Student	65 (73.0)	21 (23.6)	3 (3.4)	0 (0)	5 (4-5)	2.001	0.045*
	Teacher	4 (40.0)	6 (60.0)	0 (0)	0 (0)	4 (4-5)		
The simulation course improves the learner communication skills	Student	63 (70.8)	24 (27.0)	2 (2.2)	0 (0)	5 (4-5)	2.051	0.040*
	Teacher	4 (40.0)	5 (50.0)	1 (10.0)	0 (0)	4 (4-5)		
The simulation course improves the learner critical thinking and decision-making skills	Student	67 (75.3)	19 (21.3)	3 (3.4)	0 (0)	5 (5-5)	1.573	0.116
	Teacher	5 (50.0)	5 (50.0)	0 (0)	0 (0)	4.5 (4-5)		
The simulation course improves the learner clinical skills and competence	Student	69 (77.5)	18 (20.2)	2 (2.2)	0 (0)	5 (5-5)	1.308	0.191
	Teacher	6 (60.0)	3 (30.0)	1 (10.0)	0 (0)	5 (4-5)		
The simulation course improves the learner practical skills	Student	67 (75.3)	19 (21.3)	3 (3.4)	0 (0)	5 (5-5)	3.393	<0.001*
	Teacher	2 (20.0)	8 (80.0)	0 (0)	0 (0)	4 (4-4)		
The simulation course improves the learner EKG interpretation skills	Student	60 (67.4)	26 (29.2)	3 (3.4)	0 (0)	5 (4-5)	1.382	0.167
	Teacher	5 (50.0)	3 (30.0)	2 (20.0)	0 (0)	4.5 (4-5)		
The simulation course improves the learner ACLS management skills	Student	66 (74.2)	23 (25.8)	0 (0)	0 (0)	5 (4-5)	0.282	0.778
	Teacher	7 (70.0)	3 (30.0)	0 (0)	0 (0)	5 (4-5)		
The high-fidelity mannequin is realistic	Student	55 (61.8)	32 (36.0)	2 (2.2)	0 (0)	5 (4-5)	2.838	0.005*
	Teacher	2 (20.0)	6 (60.0)	2 (20.0)	0 (0)	4 (4-4)		
The learner enjoys simulation-based learning	Student	56 (62.9)	32 (36.0)	1 (1.1)	0 (0)	5 (4-5)	1.947	0.052
	Teacher	3 (30.0)	7 (70.0)	0 (0)	0 (0)	4 (4-5)		
The use of simulation increased the learner motivation to learn	Student	61 (68.5)	26 (29.2)	2 (2.2)	0 (0)	5 (4-5)	2.295	0.022*
	Teacher	3 (30.0)	7 (70.0)	0 (0)	0 (0)	4 (4-5)		
Using simulation increased the learner interest in learning the subject.	Student	62 (69.7)	27 (30.3)	0 (0)	0 (0)	5 (4-5)	1.254	0.210
	Teacher	5 (50.0)	5 (50.0)	0 (0)	0 (0)	4.5 (4-5)		

Simulation-based learning should be incorporated into the curriculum	Student	63 (70.8)	26 (29.2)	0 (0)	0 (0)	5 (4-5)	2.326	0.020*
	Teacher	4 (40.0)	4 (40.0)	1 (10.0)	1 (10.0)	4 (4-5)		
Overall perception Likert score (Median (IQR))	Student	4.93 (4.43-5.00)					2.314	0.021*
	Teacher	4.32 (4.00-4.57)						

5: Strongly agree, 4: Agree, 3: Mediocre, 2: Disagree, 1: Strongly disagree (No response from the participants), ACLS: advanced cardiac life support, EKG: electrocardiogram, SBL: simulation-based learning, *$p<0.05$

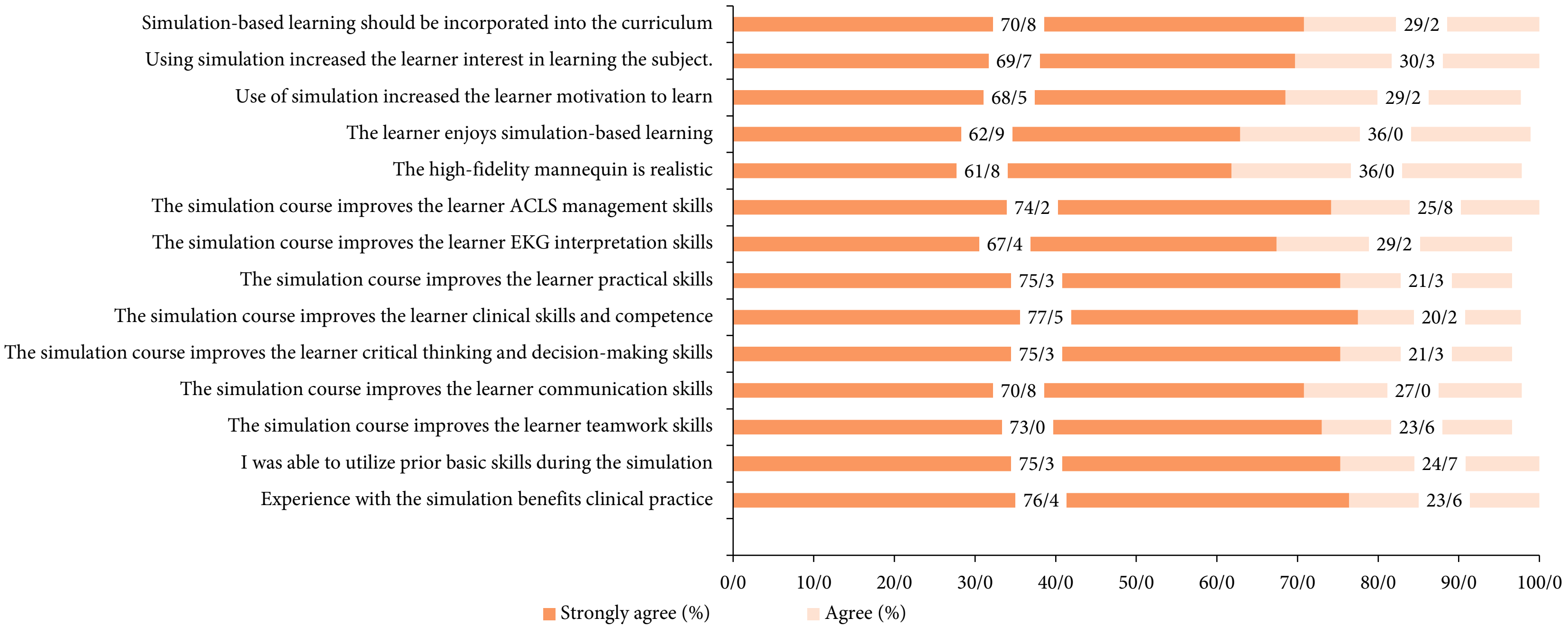

Figure 2. Student perception toward simulation-based learning course

Appendix 1. STROBE Statement-Checklist of items that should be included in reports of cross-sectional studies

	Item No	Recommendation	Extension for SBR	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	In abstract or key terms, the MESH or searchable keyword term must have the word "simulation" or "simulated."	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found		1
Introduction				
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Clarify whether simulation is subject of research or investigational method for research.	3-5
Objectives	3	State specific objectives, including any prespecified hypotheses		4-5
Methods				
Study design	4	Present key elements of study design early in the paper		5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection		5-6, 8-9
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants		5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Describe the theoretical and/or conceptual rationale for the design of the intervention/exposure. Describe the intervention/exposure with sufficient detail to permit replication. Clearly describe all simulation-specific exposures, potential confounders, and effect modifiers.	5-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*In describing the details of methods of assessment, include (when applicable) the setting, instrument, simulator type, timing in relation to the intervention, along with any methods used to enhance the quality of measurements. Provide evidence to support the validity and reliability of assessment tools in this context (if available).*	5-9
Bias	9	Describe any efforts to address potential sources of bias		
Study size	10	Explain how the study size was arrived at		5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why		6,8,9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Clearly indicate the unit of analysis (e.g., individual, team, system), identify repeated measures on subjects, and describe how these issues were addressed.	6,7,9

		(*b*) Describe any methods used to examine subgroups and interactions		N/A
		(*c*) Explain how missing data were addressed		N/A
		(*d*) If applicable, describe analytical methods taking account of sampling strategy		N/A
		(*e*) Describe any sensitivity analyses		N/A
	Item No	**Recommendation**	**Extension for SBR**	**Page No**
Results				
Participants	13*	(a) Report numbers of individuals at each stage of study-e.g., numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed		10
		(b) Give reasons for non-participation at each stage		N/A
		(c) Consider use of a flow diagram		N/A
Descriptive data	14*	(a) Give characteristics of study participants (e.g., demographic, clinical, social) and information on exposures and potential confounders	In describing characteristics of study participants, include their previous experience with simulation and other relevant features as related to the intervention(s)	10
		(b) Indicate number of participants with missing data for each variable of interest		N/A
Outcome data	15*	Report numbers of outcome events or summary measures		N/A
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included	For assessments involving >1 rater, interrater reliability should be reported.	N/A
		(*b*) Report category boundaries when continuous variables were categorized		11-15
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period		N/A
Other analyses	17	Report other analyses done- e.g., analyses of subgroups and interactions, and sensitivity analyses		N/A
Discussion				
Key results	18	Summarise key results with reference to study objectives		17
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Specifically discuss the limitations of SBR.	20
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence		17-20

Generalisability	21	Discuss the generalisability (external validity) of the study results	Describe generalizability of simulation-based outcomes to patient-based outcomes (if applicable).	19-20
Other information				
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	List simulator brand and if conflict of interest for intellectual property exists.	N/A

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

The extension of the Simulation-based report is adapted from the following:

Cheng, A., Kessler, D., Mackinnon, R. et al. Reporting guidelines for health care simulation research: extensions to the CONSORT and STROBE statements. Adv Simul 1, 25 (2016). https://doi.org/10.1186/s41077-016-0025-y

Appendix 2. Content validity by Item-objective congruence method

Questions	**Expert 1**	**Expert 2**	**Expert 3**	**Total score**	**Average score**	**Result**	**Suggestions before amendment**
The integration of basic EKG interpretation into ACLS stations through the SBL course could improve these learning outcomes	1	1	0	2	0.67	Revision	It could be more concise and be in an active voice
EKG interpretation skills	1	1	1	3	1	Accept	
ACLS management skills	1	1	1	3	1	Accept	
Drug selection based on pharmacokinetics and pharmacodynamics	1	0	1	2	0.67	Revision	Should specify "drug selection" such as by pharmacokinetics and pharmacodynamics
Holistic care of a patient	1	1	1	3	1	Accept	
Satisfaction of the self-directed learning resources and the allocated time	1	1	0	2	0.67	Revision	It should also include the allocated time
Sample videos/medical team for pre-learning purposes	1	1	1	3	1	Accept	
Common EKG examples	1	1	1	3	1	Accept	
ACLS algorithms for pre-learning purposes	1	1	1	3	1	Accept	
The amount of time for preparation before class is appropriate	0	1	1	2	0.67	Revision	It should be more specific and include "is appropriate" in the clause
Satisfaction with the scenarios and equipment	1	1	1	3	1	Accept	
Number of scenarios	1	1	1	3	1	Accept	
The diversity of the scenarios	1	1	1	3	1	Accept	
The difficulty of the scenarios	1	1	1	3	1	Accept	
The duration of each scenario	1	1	1	3	1	Accept	
Satisfaction with the equipment	1	1	1	3	1	Accept	
Number of equipments	1	1	1	3	1	Accept	
The equipment is realistic	1	1	1	3	1	Accept	

The level of difficulty in handling the high-fidelity mannequin is appropriate	0	1	1	2	0.67	Revision	It should be more specific and include "is appropriate" in the clause
Teaching and learning manual	1	1	1	3	1	Accept	
Perception toward the SBL course							
Experience with the simulation benefits clinical practice	1	1	1	3	1	Accept	
The learner was able to utilize prior basic skills during the simulation	1	1	1	3	1	Accept	
The simulation course improves the learner teamwork skills	1	1	1	3	1	Accept	
The simulation course improves the learner communication skills	1	1	1	3	1	Accept	
The simulation course improves the learner critical thinking and decision-making skills	1	1	1	3	1	Accept	
The simulation course improves the learner clinical skills and competence	1	1	1	3	1	Accept	
The simulation course improves the learner practical skills	1	1	1	3	1	Accept	
The simulation course improves the learner EKG interpretation skills	1	1	1	3	1	Accept	
The simulation course improves the learner ACLS management skills	1	1	1	3	1	Accept	
The high-fidelity mannequin is realistic	1	1	1	3	1	Accept	
The learner enjoys simulation-based learning	1	1	1	3	1	Accept	
The use of simulation increased the learner motivation to learn	1	1	1	3	1	Accept	
Using simulation increased the learner interest in learning the subject.	1	1	0	2	0.67	Revision	It could be more concise and be in an active voice
Simulation-based learning should be incorporated into the curriculum	1	1	0	2	0.67	Revision	Be more specific. Such as should be "incorporated into the curriculum".