Section 1

1.1 Multiple-choice exam

To assess students' knowledge of emergency responses, CPR, and decision-making in emergency situations related to ACLS, a multiple-choice exam consisting of eight questions was developed, inspired by the European and American Heart Association guidelines for ACLS.[1–3] These questions cover topics such as medication administration, identifying shockable and non-shockable rhythms, and proper CPR techniques. The same set of questions was used for both the pre- and post-training simulations, with each question designed to measure changes in students' knowledge by addressing a different concept.

Table 1. Pre- and Post Training Simulation Multiple-Choice Exam:

Q1: Which medication is typically administered during ACLS for ventricular fibrillation or pulseless ventricular tachycardia after the third defibrillation? a) Atropine b) Amiodarone c) Adenosine d) Dopamine
Q2: Which of the following ECG rhythms is shockable? a) Ventricular fibrillation b) Sinus bradycardia c) Sinus rhythm d) Asystole
Q3: A 45-year-old patient becomes unconscious in the emergency department and shows no signs of normal breathing. What is the appropriate action? a) Clear the airway and give one breath every 6 seconds b) Start chest compressions immediately after checking the pulse for no more than 10 seconds c) Check the pulse for 20 seconds, then start chest compressions d) Administer intravenous fluids (e.g., Ringer's lactate)
Q4: According to the Advanced Cardiac Life Support (ACLS) protocol, what is the next step when a patient has a non-shockable rhythm after 2 minutes of cardiopulmonary resuscitation (CPR)? a) Cardioversion b) Administer epinephrine c) Administer amiodarone d) Endotracheal intubation
Q5: A 34-year-old patient collapses in the emergency department. What is the recommended ratio of chest compressions to ventilations during cardiopulmonary resuscitation (CPR)? a) 5:2 b) 30:2

c) 10:2 d) 20:2
Q6: Which of the following ECG rhythms is not shockable? a) Ventricular fibrillation b) Pulseless torsades de pointes c) Pulseless ventricular tachycardia d) Asystole
Q7: A 55-year-old patient presents to the emergency department with a blood pressure of 183/121 mmHg but shows no symptoms such as chest pain or neurological deficits. What is the most appropriate management for this patient? a) IV sodium nitroprusside b) Oral antihypertensives (e.g., captopril) c) Sublingual nitroglycerin d) Oxygen therapy and preparation for mechanical ventilation
Q8: A 60-year-old patient presents to the emergency department with a blood pressure of 230/124 mmHg, severe chest pain, and shortness of breath. What is the most appropriate first step in management? a) IV sodium nitroprusside b) Oral antihypertensives (e.g., captopril) c) Oral antihypertensives (e.g., methyldopa) d) Oxygen therapy and preparation for mechanical ventilation

1.2 Self-Assessment Questionnaire

We developed a questionnaire to investigate pharmacy students' self-assessment of their competence in emergency response and consultation skills related to medication-related emergencies, as well as their perceptions of simulation-based learning. The survey consisted of 10 statements with a 5-point Likert scale, where 1 represented "strongly disagree" and 5 represented "strongly agree". Statements 1-5 focused on recognizing and managing medication-related emergencies based on the patient's medication therapy, including identifying drug interactions, adverse effects, and performing emergency responses such as CPR. Statements 6-10 addressed the value of interprofessional collaboration and simulation-based learning, regarding their integration into clinical pharmacy education and their role in enhancing skills for handling medication-related emergencies. The self-assessment questionnaire was administered both before and after the training simulation to measure changes in students' self-assessment. Students were asked about their experience in managing medication-related emergencies in the relevant age group whether adult or pediatric. Additionally, they were asked whether they had completed any first aid courses. The template for the self-assessment questionnaire is provided in supplementary materials.

Table 2. Pre- and Post Training Simulation Self-Assessment Questionnaire

Q1: I feel able to identify medication-related emergencies in patients based on their medical history and condition.
Q2: I feel competent to address patients' concerns and questions related to their medication therapy.
Q3: I feel competent to make recommendations on drug therapy for patients of different ages.
Q4: I feel competent to perform cardiopulmonary resuscitation (CPR) in emergency situations.
Q5: I feel competent to recognize interactions and side effects during medication consultation.
Q6: I feel competent to interpret critical arrhythmias in cardiological emergencies.
Q7: I feel confident in collaborating with other healthcare disciplines, including medicine, to manage medication-related emergencies.
Q8: I feel competent to make critical decisions during Advanced Cardiac Life Support (ACLS) emergencies.
Q9:. Simulation training for managing medication-related emergencies should be incorporated into the clinical pharmacy curriculum.
Q10: I feel competent to handle medication-related emergencies in different patient age groups.

Section 2.1 Study Procedure

Firstly, as shown in Figure 1, we recruited the students through an introductory seminar for pharmacy students within a two-week period. The seminar was held on a scheduled date and was conducted live, in which they were provided with detailed information about the study. The seminar covered background information on medication-related emergencies and the role of pharmacists in in-hospital emergency teams globally and in Germany, as well as high-/low-fidelity simulations. It also included a brief discussion on the basic principles of ACLS. Afterwards, information sheets and consent forms were handed to prospective students. Once the consent forms were signed, the students became eligible to participate in the study. The pharmacy students then completed a pre-training simulation on a scheduled date within a one-week period, which included a multiple-choice exam and a self-assessment questionnaire. Subsequently, for an additional week, we conducted HFS/LFS training including adult and pediatric emergency care scenarios for the four groups. The control groups received LFS training, which involved paper-based cases and CPR simulators, while the intervention groups were trained using HFS, integrated with software that allows physiological parameters to change in response to students' interventions. Finally, the pharmacy students completed a post-training simulation, which included an identical multiple-choice exam and self-assessment questionnaire.

Section 2.2 Student Characteristics

After voluntarily signing an informed consent form, 39 fourth-year pharmacy students participated in the study. Students were asked to indicate whether they had previously completed a first aid course and any prior experience managing medication-related emergencies in pediatric and adult age groups (e.g. in outpatient or inpatient hospitals). Table 3 presents the characteristics of pharmacy students for both the intervention and control groups.

Table 3. Characteristics of pharmacy students.

Pharmacy Students		Adult-Simulator (n = 20)		Pediatric-Simulator (n = 19)	
		Intervention (n = 10)	Control (n = 10)	Intervention (n = 9)	Control (n = 10)
	Mean (± SD)	25 (± 3.12)	24 (± 1.687)	26 (± 3.279)	25 (± 2.366)
Gender	Male, n (%)	4 (40%)	3 (30%)	3 (33%)	2 (20%)
	Female, n (%)	6 (60%)	7 (70%)	6 (67%)	8 (80%)
Experience in managing medication-related emergencies in pediatric and adult age groups (e.g., outpatient or inpatient hospitals)					
	Yes, n (%)	0 (0%)	1 (10%)	0 (0%)	1 (10%)
	No, n (%)	10 (100%)	9 (90%)	9 (100%)	9 (90%)
Completion of a first aid course					
Yes, n (%)		9 (90%)	10 (100%)	7 (78%)	10 (100%)
No, n (%)		1 (10%)	0 (0%)	2 (22%)	0 (0%)

Section 2.3 High- and Low Fidelity Simulators

For the purposes of training students' consultation and emergency response skills, two different types of fidelity simulators were used. All students practiced consultation skills to address issues encountered during simulation cases and were exposed to several medication-related emergency scenarios. The intervention group trained using high-fidelity simulators representing different age groups (adult HAL® S1000, pediatric S3005 Gaumard). These simulators provided realistic inpatient care scenarios and emergency cardiac situations by exhibiting physiological responses to students' interventions. Students could observe adverse symptoms and vital signs, such as respiratory movement and ECG readings, either physically on the simulator or through a displayed monitor. These functions allowed students to request further patient information and perform necessary actions. These high-fidelity simulators were controlled through software that included a microphone, which allows the instructor to communicate directly with the student and provide tailored interventions for the patient scenario. Furthermore, these simulators featured adjustable physiological parameters such as respiratory and heart rate, as well

as programmable CPR responses, that allow students to observe CPR effects on a displayed monitor. On the other hand, the control group used a low-fidelity simulator (ZOLL CPR-D demo kit) along with paper-based case scenarios. Patient information and vital parameters were initially provided on paper, while further information about the patient's history was verbally conveyed upon request by a faculty member acting as a family member. As the scenario escalated into a life-threatening cardiac event, students received supplementary paper-based information, including updated vital signs and clinical indicators such as ECG readings. This additional information was designed to allow students to respond and perform the necessary actions.

Section 2.4 Pre-Post Training Simulation Checklist

(A) Patient information
A.1 The student introduces him/herself to the patient by name and role.
A2 Confirms patient's identity (name, date of birth)
A2.1 The student asks the patient to provide his /her surname and first name.
A2.2 The student asks the patient to provide his/her date of birth to ensure accurate identification.
A3 History of Present Illness
A3.1 The student asks for further information about the patient's main concern.
A3.2 The student asks for further information about the timing of the symptoms (onset and duration).
A3.3 The student asks about any associated symptoms that the patient has noticed.
A3.4 The student assesses the patient's adherence to current medications.
A3.5 The student asks about any prescribed or over-the-counter medications that the patient is currently taking, which may not be listed in the patient sheet.
A3.6 The student assesses any abnormal lab values that may indicate risk.
A3.7 The student assesses the patient's vital signs.
A4. Personal and Social History **(student asks for further information about only one point depending on the case, other points are mentioned in the patient information sheet)**
A4.1 ask for information about tobacco. A4.2 ask for information about Alcohol. A4.3 ask for information about usual dietary practices. A4.5 ask for information about current physical activity. A4.6 ask for information about driving ability.

(B) Actions & Solutions
B1 Drug Interactions and Side Effects
B1.1 The student identifies possible drug-drug interactions/drug-related problems in the patient's medications.
B1.2 The student provides optimization recommendations related to point B1.1.
B2 Emergency Response
B2.1 The student immediately presses the emergency alarm button upon recognizing patient deterioration (unresponsive with abnormal or no respirations)
B2.2 The student opens the patient's airway by tilting the patient's head back and lifting the chin.

B2.3 The student begins performing chest compressions after confirming that the patient has no pulse within 10 seconds.
B2.4 The student places one hand on the lower half of the patient's breastbone and the other hand on top.
B2.5 The student performs a cycle of chest compressions followed by rescue breaths.
B2.6 The student is asked whether the defibrillator should be used in this case based on the patient's ECG.

(C) Behavioral Responses in Emergency Situations and Consultation
C.1 The student listens actively and allows the patient to complete statements.
C.2 The student uses open and closed questions when appropriate.
C.3 The student responds effectively to the patient's questions and concerns in an informative and reassuring way.
C.4 The student shows support and responds to the patient's feelings (angry/frustrated) and needs.
C.5 The student avoids scientific words (unnecessary jargon) and explains medical concepts in patient-friendly terms.
C.6 The student demonstrates confidence during the consultation, avoiding moments of silence and confusion.
C.7 The student responds effectively to the emergency, ensuring actions are taken within the designated time frame

Section 2.5 Training sessions

The training session started with a theoretical session conducted separately for Group A (adult, high-fidelity simulation), Group B (pediatric, high-fidelity simulation), Group C (adult, low-fidelity simulation), and Group D (pediatric, low-fidelity simulation), followed by a practical session for each study group. Both groups received the same theoretical training, which covered various medication consultation models such as the Medication-Related Consultation Framework (MRCF), [4] the roles of pharmacists in hospital emergency teams, and the principles ACLS, including ACLS algorithms and commonly used medications. The practical sessions involved four training cases for adult and pediatric patients, focusing on taking the patient's medical history and applying ACLS emergency response techniques, including alerting the emergency response team, performing CPR, and recognizing life-threatening cardiac arrhythmia. Students are divided into pairs, with each pair rotating roles. In each case, the first student takes the patient's history and activates the emergency alarm, while the second student performs CPR. Each pair works on two cases, rotating roles to ensure understanding of both tasks. Each intervention group trained using either an adult or pediatric patient simulator, while each control group worked with paper-based cases and a low-fidelity simulator. In the intervention groups, all **students** communicated directly with the high-fidelity simulator, with two faculty members either remotely controlling the simulator or acting as a family member to respond to the **student**. Various emergency scenarios were simulated in the HFS groups by dynamically altering the simulator's physiological symptoms and vital parameters displayed on a monitor using customized simulator software. In contrast, **students** in the LFS groups received all patient information in paper-based format, including vital signs, lab values, and ECG result. Once the emergency began, **students** received follow-up paper-based information related to the escalating scenario, regardless of their initial actions. This was because the scenario was pre-scripted to escalate based on the patient's condition, ensuring standardized escalation and consistent information for all students.

Section 3.1 Overestimation Proportion across intervention (HFS) and control (LFS) groups

Overestimation was defined as students who rated themselves above 3 (above the median) on the self-assessment questionnaire with a 5-point Likert scale and scored below 4 on the multiple-choice exam (e.g., failed the exam). To assess this, the total number of students in HFS and LFS groups for adults and pediatrics was recorded. the median self-assessment score (for students with self-assessment > 3), and the median multiple-choice exam score (for students scoring < 4) were calculated. The number of students who met both criteria (self-assessment > 3 and multiple-choice exam score < 4) was then determined, and the overestimation proportion was calculated as the percentage of students who overestimated their performance in each group. This section presents the overestimation proportion across the HFS and LFS groups for both adult and pediatric cases It includes the total number of students in each group, the median self-assessment score (calculated as the median of all students' self-assessment scores, representing those who rated themselves above 3 on the self-assessment questionnaire), and the median multiple-choice exam score (calculated as the median of all students ' exam scores, representing those who scored below 4 on the multiple-choice exam). Students who met both criteria — self-assessment score > 3 and multiple-choice exam score < 4 — were classified as overestimated students. The overestimation proportion was then calculated as the percentage of students in each group who overestimated their performance.

Section 3.2 Multiple Choice Exam Scores

Table 5. Pre- and Post Training Simulation- Multiple-Choice Exam Scores:

	Adult-Simulator		Pediatric-Simulator	
	Intervention-HFS Mean (± SD)	Control-LFS Mean (± SD)	Intervention-HFS Mean (± SD)	Control-LFS Mean (± SD)
Pre-Training Score	3.70 (0.95)	3.00 (0.94)	3.22 (1.39)	2.80 (1.87)
Post-Training Score	7.10 (1.10)	5.90 (1.85)	7.22 (1.30)	5.70 (1.34)
Score Difference	3.40 (1.17)	2.90 (1.79)	3.60 (2.01)	2.92 (2.28)
p-Value intergroup	0.212		0.294	

References:

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