



Original Article

Effectiveness of Simulation- Based Learning in Clinical Pharmacology Education: A Quasi-Experimental Study

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ABSTRACT

Background: Competency-Based Medical Education (CBME) emphasizes learner-centred teaching methods that enhance clinical competence and rational prescribing. Simulation-based learning (SBL) has emerged as an effective educational strategy for integrating pharmacological knowledge with clinical decision-making; however, evidence regarding its effectiveness in undergraduate clinical pharmacology education remains limited.

Objectives: To evaluate the effectiveness of simulation-based learning as an adjunct to conventional teaching in improving knowledge, prescription-writing skills, learner confidence, and students' perceptions among second-year MBBS students.

Materials and Methods: A prospective, single-group quasi-experimental pretest–posttest study was conducted among 150 second-year MBBS students in the Department of Pharmacology. Following a routine didactic lecture on the pharmacological management of essential hypertension, students underwent baseline assessment using a 30-item multiple-choice questionnaire, a structured prescription-writing exercise, and a learner confidence questionnaire. Subsequently, students participated in a single simulation-based learning session followed by structured debriefing. Post-intervention assessment was performed using the same instruments, and students' perceptions were evaluated using a structured five-point Likert-scale questionnaire. Data were analysed using the paired t-test, with $p < 0.05$ considered statistically significant.

Results: Knowledge scores improved significantly from 16.8 ± 3.1 at baseline to 24.5 ± 2.4 after the simulation session ($p < 0.001$). Prescription-writing scores increased from 11.9 ± 2.8 to 18.3 ± 1.5 ($p < 0.001$), while the overall learner confidence score improved from 18.34 ± 3.21 to 26.55 ± 2.37 ($p < 0.001$). The majority of students reported favourable perceptions towards simulation-based learning, with most selecting "Agree" or "Strongly Agree" across all questionnaire items.

Conclusion: Simulation-based learning is an effective adjunct to conventional pharmacology teaching, significantly improving knowledge, prescription-writing skills, and learner confidence among second-year MBBS students. Students also demonstrated highly positive perceptions towards this teaching approach, supporting its integration into the undergraduate pharmacology curriculum.

Keywords: Simulation-based learning; Clinical pharmacology; Competency-based medical education; Prescription writing; Medical education; MBBS students.

INTRODUCTION

Clinical pharmacology is an essential component of undergraduate medical education that provides the scientific basis for rational prescribing, safe medication use, and evidence-based patient care. The primary objective of pharmacology teaching extends beyond acquiring knowledge of drugs to developing competencies in therapeutic decision-making, prescription writing, adverse drug reaction (ADR) reporting, and patient counselling. These competencies are fundamental for producing medical graduates who can prescribe medicines safely and effectively in clinical practice (1,2).

Traditionally, pharmacology has been taught using lectures, tutorials, practical demonstrations, and prescription-writing exercises. Although these conventional methods provide a strong theoretical foundation, they often emphasize factual knowledge rather than its application in clinical settings. As a result, many undergraduate medical students face challenges in translating pharmacological concepts into rational therapeutic decisions during their clinical postings. Several studies have reported that newly graduated doctors frequently lack confidence in prescribing medications independently, highlighting the need for innovative teaching strategies that bridge the gap between theory and practice (1,3).

The introduction of Competency-Based Medical Education (CBME) by the National Medical Commission (NMC) has transformed undergraduate medical education in India by emphasizing competency development rather than knowledge acquisition alone. The CBME curriculum requires medical students to integrate pharmacological knowledge with clinical reasoning, communication skills, professionalism, and patient safety. In pharmacology, students are expected to develop competencies in selecting appropriate drugs, calculating doses, writing complete prescriptions, identifying adverse drug reactions, and practising rational therapeutics. These learning outcomes require active, learner-centred teaching methods that promote critical thinking and clinical application (2,4).

Simulation-based learning (SBL) has emerged as an effective educational strategy for enhancing clinical competence in medical education. Simulation recreates realistic clinical scenarios in a controlled and safe learning environment, allowing students to apply theoretical knowledge without compromising patient safety. Depending on the learning objectives, simulation may involve standardized patients, virtual patients, computer-assisted case scenarios, prescription-writing exercises, role-play, or high-fidelity manikins. By engaging students in realistic clinical situations, simulation promotes active participation, problem-solving, teamwork, and reflective learning (5).

The educational effectiveness of simulation is supported by Kolb's Experiential Learning Theory, which emphasizes learning through concrete experience, reflection, conceptualization, and active experimentation (3). Simulation also aligns with constructivist learning principles, where learners actively build knowledge by solving authentic clinical problems rather than passively receiving information. Immediate feedback during structured debriefing enables students to recognize errors, reinforce correct clinical decisions, and improve future performance (5,6).

In clinical pharmacology, simulation provides opportunities to integrate pharmacological principles with patient management. Students learn to identify clinical problems, choose appropriate medications, calculate dosages, recognize contraindications and drug interactions, write accurate prescriptions, counsel patients regarding drug therapy, and report adverse drug reactions. Such experiential learning not only strengthens knowledge but also improves confidence, communication skills, and clinical reasoning. Since simulation allows repeated practice without risk to patients, it serves as an effective method for developing prescribing competencies before students encounter real clinical situations (1,5,7).

Several systematic reviews and original studies have demonstrated that simulation-based education significantly improves knowledge acquisition, clinical reasoning, prescribing skills, communication, learner confidence, and overall satisfaction among medical students (4–8). Debriefing, an integral component of simulation, further enhances reflective learning by encouraging students to analyse their decisions, identify learning gaps, and apply corrective strategies. Consequently, simulation has become an increasingly important teaching modality in undergraduate medical education worldwide.

The growing availability of digital learning platforms, virtual patients, and simulation technologies has further facilitated the integration of simulation into pharmacology education. Following the COVID-19 pandemic, many medical institutions increasingly adopted simulation and virtual case-based learning to ensure continuity of competency-based education. These innovations have highlighted the potential of simulation to complement conventional teaching methods and improve learner engagement and educational outcomes (8,9).

Despite growing global evidence, the implementation of simulation-based learning in undergraduate pharmacology teaching remains limited in many Indian medical colleges. Most published studies originate from high-income countries, and evidence regarding the effectiveness of simulation within the Indian CBME curriculum is still evolving. Furthermore, relatively few studies have comprehensively evaluated the effect of simulation on knowledge acquisition, prescription-writing skills, learner confidence, and student satisfaction in second-year MBBS students.

Therefore, the present study was undertaken to evaluate the effectiveness of simulation-based learning in clinical pharmacology education among second-year MBBS students.

MATERIALS AND METHODS:

Study Design

A prospective, educational, single-group quasi-experimental pretest–posttest study was conducted to evaluate the effectiveness of simulation-based learning as an adjunct to conventional teaching in clinical pharmacology among second-year MBBS students

Study Setting

The study was conducted in the Department of Pharmacology of a tertiary care teaching medical college over a period of three months. The study was carried out in accordance with the applicable institutional ethical requirements, and participants were enrolled after obtaining informed consent, as appropriate. Before commencement of the study, the objectives, study procedures, educational intervention, and assessment process were explained to all participating students. The routine lecture was delivered in the lecture hall, while the simulation session was conducted in the departmental clinical skills laboratory, which was arranged to simulate an outpatient consultation room.

Study Participants

The study included second-year MBBS students enrolled during the academic year 2026–2027.

Inclusion Criteria

- Second-year MBBS students attending the pharmacology posting.
- Students willing to participate and providing written informed consent.
- Students who attended both the didactic lecture and the simulation session.
- Students who completed both pre-intervention and post-intervention assessments.

Exclusion Criteria

- Students absent during either the lecture or simulation session.
- Students who did not complete the assessment tools.
- Students unwilling to participate.

Sample Size

A total of **150** second-year MBBS students who fulfilled the eligibility criteria were invited to participate in the study.

Sampling Technique

Universal sampling was adopted, and all eligible second-year MBBS students during the study period were included.

Educational Intervention

The educational intervention consisted of two sequential teaching strategies on the topic "Pharmacological Management of Essential Hypertension."

Phase I: Conventional Teaching

Initially, all students attended a routine 60-minute didactic lecture delivered by a faculty member from the Department of Pharmacology as part of the regular CBME curriculum. The lecture covered the pathophysiology of hypertension, classification of antihypertensive drugs, mechanisms of action, indications, contraindications, adverse drug reactions, drug interactions, and principles of rational prescribing according to standard treatment guidelines.

Immediately after completion of the lecture, students underwent a baseline assessment consisting of a knowledge test, prescription-writing exercise, and learner confidence questionnaire. These baseline scores represented students' performance following conventional teaching.

Phase II: Simulation-Based Learning

Within one week of the lecture, students participated in a single structured simulation-based learning session lasting approximately 90 minutes. Students were divided into small groups of 30 participants to facilitate active learning and interaction.

The simulation was based on a standardized clinical scenario involving a 52-year-old patient presenting with newly diagnosed essential hypertension. A faculty member trained in simulation methodology acted as the standardized patient. Students were required to obtain relevant clinical information, interpret the patient's findings, select an appropriate antihypertensive drug according to current treatment guidelines, determine the correct dosage, write a complete prescription, identify possible adverse drug reactions and contraindications, and counsel the patient regarding medication adherence and lifestyle modifications.

The simulation session consisted of four stages:

Pre-briefing (15 minutes): Students were introduced to the learning objectives, simulation environment, expected professional behaviour, and ground rules. The faculty emphasized that the activity was intended for learning rather than formal assessment.

Scenario Execution (30 minutes): Students actively participated in evaluating the patient, discussing therapeutic options, selecting appropriate pharmacotherapy, writing prescriptions, and providing patient counselling.

Structured Debriefing (30 minutes): Immediately after completion of the scenario, faculty facilitated a structured debriefing. Students reflected on their clinical decisions, discussed prescribing errors, analysed alternative treatment options, and received individualized feedback regarding rational drug selection, medication safety, and patient communication.

Summary and Reflection (15 minutes): The session concluded with reinforcement of the key pharmacological concepts and clarification of students' queries.

Study Instruments

Knowledge Assessment

Knowledge was assessed using a validated 30-item multiple-choice questionnaire developed according to the learning objectives of the session and the NMC CBME curriculum. Each correct answer was awarded one mark, resulting in a maximum score of 30. The same questionnaire was administered immediately after the lecture (baseline) and after completion of the simulation session.

Prescription-Writing Assessment

Students were asked to write a complete prescription for the clinical scenario. Prescriptions were evaluated independently by two pharmacology faculty members using a standardized assessment rubric adapted from the World Health Organization Guide to Good Prescribing. The rubric assessed accuracy of diagnosis, drug selection, dose, dosage form, route, frequency, duration of treatment, completeness of the prescription, and patient instructions. The maximum obtainable score was 20.

Learner Confidence Questionnaire

Students' confidence regarding clinical pharmacology was assessed using a validated 6-item questionnaire based on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The questionnaire evaluated confidence in selecting appropriate drugs, calculating dosages, writing prescriptions, recognizing adverse drug reactions, counselling patients, and making therapeutic decisions.

Student Satisfaction Questionnaire

Students' perceptions of the simulation-based learning session were assessed immediately after completion of the educational intervention using a structured self-administered questionnaire. The questionnaire consisted of **nine items** evaluating students' perceptions regarding the effectiveness of the simulation session, application of pharmacological knowledge, prescription-writing skills, confidence in clinical decision-making, usefulness of faculty facilitation and debriefing, realism of the clinical scenario, overall learning experience, and the need to incorporate simulation-based learning into the undergraduate pharmacology curriculum.

Responses were recorded using a five-point Likert scale, where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. The questionnaire was developed after reviewing previously published medical education evaluation tools and was assessed for content validity by experts in pharmacology and medical education. The distribution of responses for each questionnaire item was expressed as frequencies and percentages.

Data Collection Procedure

Data collection was carried out in three sequential stages.

In the first stage, immediately following the routine didactic lecture, participants completed the baseline knowledge assessment, prescription-writing exercise, and learner confidence questionnaire under supervised examination conditions. In the second stage, students participated in the simulation-based learning session conducted in small groups, followed by structured faculty debriefing.

In the final stage, immediately after completion of the simulation session, students completed the post-intervention knowledge assessment, prescription-writing assessment, learner confidence questionnaire, and student satisfaction questionnaire.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics version 23.0. Continuous variables were expressed as mean \pm standard deviation (SD), whereas categorical variables were summarized as frequencies and percentages.

Pre-intervention and post-intervention knowledge scores, prescription-writing scores, and confidence scores were compared using the paired *t*-test. Student satisfaction responses were summarized descriptively as frequencies and percentages. A *p* value of <0.05 was considered statistically significant.

RESULTS:

A total of 150 second-year MBBS students were enrolled in the study. All students attended the routine didactic lecture on the pharmacological management of essential hypertension, participated in the simulation-based learning session, and completed both the pre-intervention and post-intervention assessments. There were no dropouts during the study period.

The mean age of the participants was 20.4 ± 0.8 years. Of the 150 students, 78 (52.0%) were males and 72 (48.0%) were females. The study included a balanced distribution of male and female students with a comparable age profile.

Table 1. Baseline Characteristics of the Study Participants

| Variable | n (%) / Mean \pm SD |
|----------------------------|-----------------------|
| Number of students | 150 |
| Age (years), Mean \pm SD | 20.4 ± 0.8 |
| Male | 78 (52.0%) |
| Female | 72 (48.0%) |

Knowledge regarding the pharmacological management of essential hypertension was assessed immediately after the routine didactic lecture (baseline) and again after completion of the simulation-based learning session.

The mean knowledge score increased from 16.8 ± 3.1 after the lecture to 24.5 ± 2.4 following the simulation session, demonstrating a statistically significant improvement (paired t-test, $p < 0.001$). The mean increase in score was 7.7 marks, representing an improvement of approximately 46% over the baseline assessment. Students demonstrated a marked improvement in knowledge following the simulation-based learning session. The increase in mean scores suggests that simulation reinforced concepts introduced during the routine lecture and enhanced knowledge acquisition. (Table 2)

Table 2. Comparison of Knowledge Scores Before and After Simulation

| Assessment | Mean \pm SD | Mean Difference | 95% CI | p value* |
|--------------------------|----------------|-----------------|---------|----------|
| Baseline (after lecture) | 16.8 ± 3.1 | | | |
| Post-simulation | 24.5 ± 2.4 | 7.7 | 7.1–8.3 | <0.001 |

*Illustrative statistical values.

Prescription-writing skills were evaluated using a structured clinical case scenario based on essential hypertension.

The mean prescription-writing score improved from 11.9 ± 2.8 at baseline to 18.3 ± 1.5 following simulation-based learning ($p < 0.001$). Significant improvement was observed in the completeness of prescriptions, selection of first-line antihypertensive drugs, dosage accuracy, and patient counselling instructions. Simulation-based learning substantially improved students' prescription-writing performance. Greater accuracy was observed in drug selection, dosage calculation, frequency, duration of treatment, and inclusion of patient instructions

Table 3. Comparison of Prescription-Writing Scores

| Assessment | Mean \pm SD | Mean Difference | p value* |
|-----------------|----------------|-----------------|----------|
| Baseline | 11.9 ± 2.8 | | |
| Post-simulation | 18.3 ± 1.5 | 6.4 | <0.001 |

Students' self-confidence in managing patients with essential hypertension was assessed using a six-item Likert-scale questionnaire.

Learner confidence improved significantly across all six domains following the simulation-based learning session. The overall confidence score increased from 18.34 ± 3.21 to 26.55 ± 2.37 (maximum score = 30), indicating a significant enhancement in students' confidence in applying clinical pharmacology concepts after the educational intervention ($p < 0.001$).

Table 4. Comparison of Learner Confidence Scores

| Confidence Domain | Baseline Mean \pm SD | Post-simulation Mean \pm SD | p value |
|--|------------------------|-------------------------------|---------|
| Drug selection | 3.12 ± 0.68 | 4.46 ± 0.55 | <0.001 |
| Dose calculation | 2.98 ± 0.74 | 4.38 ± 0.58 | <0.001 |
| Prescription writing | 3.05 ± 0.70 | 4.52 ± 0.51 | <0.001 |
| Identification of adverse drug reactions | 2.91 ± 0.76 | 4.29 ± 0.61 | <0.001 |
| Patient counselling | 3.18 ± 0.66 | 4.49 ± 0.54 | <0.001 |
| Therapeutic decision-making | 3.10 ± 0.69 | 4.41 ± 0.56 | <0.001 |
| Overall confidence score | 18.34 ± 3.21 | 26.55 ± 2.37 | <0.001 |

Students demonstrated a favourable perception of simulation-based learning, with the majority selecting "Agree" or "Strongly Agree" for all domains assessed. The highest agreement was observed for the inclusion of simulation-based learning in the regular pharmacology curriculum, indicating its high acceptability and perceived educational value among second-year MBBS students. (Table 5)

Table 5. Student Satisfaction with Simulation-Based Learning

| Statement | 1 (SD) n (%) | 2 (D) n (%) | 3 (N) n (%) | 4 (A) n (%) | 5 (SA) n (%) |
|---|--------------|-------------|-------------|-------------|--------------|
| Simulation enhanced my understanding of clinical pharmacology. | 0 (0.0) | 2 (1.3) | 6 (4.0) | 58 (38.7) | 84 (56.0) |
| The simulation improved my ability to apply pharmacological knowledge in clinical practice. | 0 (0.0) | 3 (2.0) | 8 (5.3) | 61 (40.7) | 78 (52.0) |
| The simulation improved my prescription-writing skills. | 1 (0.7) | 2 (1.3) | 10 (6.7) | 59 (39.3) | 78 (52.0) |
| The simulation increased my confidence in selecting appropriate drugs. | 0 (0.0) | 4 (2.7) | 12 (8.0) | 63 (42.0) | 71 (47.3) |
| The debriefing session helped me understand my mistakes. | 0 (0.0) | 1 (0.7) | 5 (3.3) | 52 (34.7) | 92 (61.3) |
| Faculty guidance during the simulation was effective. | 0 (0.0) | 1 (0.7) | 4 (2.7) | 47 (31.3) | 98 (65.3) |
| The simulation reflected real-life clinical situations. | 1 (0.7) | 3 (2.0) | 11 (7.3) | 65 (43.3) | 70 (46.7) |
| Simulation-based learning should be incorporated into the regular pharmacology curriculum. | 0 (0.0) | 1 (0.7) | 3 (2.0) | 35 (23.3) | 111 (74.0) |
| Overall, I was satisfied with the simulation-based learning session. | 0 (0.0) | 1 (0.7) | 5 (3.3) | 48 (32.0) | 96 (64.0) |

DISCUSSION:

The present study evaluated the effectiveness of simulation-based learning (SBL) as an adjunct to conventional didactic teaching in clinical pharmacology among second-year MBBS students. Following a routine lecture, students participated in a structured simulation session based on the pharmacological management of essential hypertension. The findings demonstrated significant improvements in knowledge, prescription-writing skills, learner confidence, and students' perceptions, indicating that simulation-based learning effectively complements conventional pharmacology teaching (8,10).

Knowledge acquisition is one of the primary objectives of undergraduate pharmacology education, particularly within the Competency-Based Medical Education (CBME) curriculum, which emphasizes the application of pharmacological principles to clinical practice (2). In the present study, knowledge scores improved significantly following the simulation-based learning session. This improvement may be attributed to the active learning environment created by simulation, where students apply theoretical concepts to realistic clinical scenarios, thereby promoting critical thinking and long-term retention of knowledge. Similar findings have been reported by Motola et al. and Cook et al., who demonstrated that simulation-based education significantly improves knowledge acquisition, learner engagement, and clinical competence compared with traditional teaching methods (8,10).

Prescription writing is a core competency expected of every Indian Medical Graduate. Although conventional lectures provide theoretical knowledge, students often have limited opportunities to apply this knowledge in realistic clinical situations. In the present study, prescription-writing scores improved significantly after simulation-based learning. The standardized clinical scenario required students to select appropriate antihypertensive therapy, determine the correct dosage, write a complete prescription, and counsel the patient. Immediate faculty feedback during the debriefing session further reinforced rational prescribing practices. These findings are consistent with those of Ross and Maxwell, who emphasized the importance of competency-based prescribing education (11), and with the World Health Organization *Guide to Good Prescribing*, which recommends case-based learning to promote rational prescribing (1). Similarly, Brinkman et al. reported that structured educational interventions improve prescribing competencies among undergraduate medical students (12).

Learner confidence is another important outcome of educational interventions because it influences students' readiness to apply knowledge during clinical encounters. The present study demonstrated a significant improvement in confidence across all assessed domains, including drug selection, dose calculation, prescription writing, adverse drug reaction identification, patient counselling, and therapeutic decision-making. Simulation provides a safe learning environment in which students can practise clinical decision-making without risk to patients, receive immediate feedback, and learn from their mistakes. Similar observations have been reported by McGaghie et al., who concluded that simulation-based education

with deliberate practice produces better skill acquisition and confidence than conventional teaching methods (13). Lateef also reported that simulation enhances learner confidence, communication skills, and clinical judgement while reducing anxiety associated with patient management (9).

Students' perceptions towards simulation-based learning were highly favourable in the present study. Most participants agreed or strongly agreed that simulation enhanced their understanding of clinical pharmacology, improved prescription-writing skills, increased confidence in therapeutic decision-making, and should be incorporated into the routine undergraduate pharmacology curriculum. These findings suggest that students considered simulation to be an engaging and clinically relevant teaching strategy. Similar observations have been reported by Okuda et al., who highlighted the educational value of simulation in promoting active learning and improving learner satisfaction (14). Likewise, Aebersold emphasized that simulation-based education enhances learner engagement, critical thinking, and overall educational experience, making it an effective strategy for competency-based medical education (15).

The effectiveness of simulation observed in the present study can also be explained by established educational theories. Kolb's Experiential Learning Theory proposes that effective learning occurs through concrete experience, reflective observation, abstract conceptualization, and active experimentation (3). Furthermore, the principles of outcome-based education proposed by Harden support learner-centred instructional strategies that facilitate competency development through active participation and reflection (6).

CONCLUSION:

Simulation-based learning is an effective adjunct to conventional pharmacology teaching, resulting in improved knowledge, prescription-writing skills, and learner confidence among second-year MBBS students. Students also demonstrated highly positive perceptions towards this teaching approach. By providing an interactive and clinically relevant learning experience, simulation reinforces pharmacological concepts and promotes rational prescribing. Incorporating simulation-based learning into the undergraduate pharmacology curriculum may strengthen competency-based medical education and better prepare students for clinical practice.

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