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Application of flexible ureteroscope simulation training based on the PDCA quality cycle in urology clinical teaching

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Abstract

Background

Insufficient clinical exposure is a prevalent issue during undergraduate clerkship in urology. Worldwide, medical education has shifted from time-dependent training models to the competency-based medical education (CBME) framework, where simulation-based training plays a central enabling role.

Methods

Seventy-two fifth-year undergraduate medical students undergoing urological clerkship at the Second Hospital of Anhui Medical University were recruited between April and July 2026 and randomly assigned to either an experimental group receiving PDCA cycle-integrated flexible ureteroscopy simulation training or a control group with conventional teaching. All interns completed a theoretical examination and Mini-CEX assessment prior to their urology rotation. At the two-week mark of the clerkship, theoretical tests, Mini-CEX and DOPS evaluations were administered. In addition, questionnaires were distributed to collect students' feedback on the teaching modalities for the evaluation of their learning experience.

Results

All clerkship students in both groups were assessed prior to the urology rotation. There were no significant intergroup differences in scores of theoretical examinations and all Mini-CEX items ($p > 0.05$). Reassessments were conducted upon completion of the two-week rotation. Students in the experimental group achieved significantly higher scores in theoretical tests, all Mini-CEX domains and all DOPS items relative to the control group (all $p < 0.05$). Interns in the experimental group reported significantly better feedback regarding self-learning ability, improved confidence in clinical operations, learning initiative and motivation, teamwork competence and overall satisfaction compared with those in the control group (all $p < 0.05$).

Discussion

PDCA cycle-based flexible ureteroscopy simulation training effectively improves urology undergraduates' theoretical proficiency, clinical performance, operative skills and learning satisfaction. It offers a viable quality improvement strategy for standardized simulation training of urological undergraduate interns.

Introduction

Clinical attachments in urology demonstrate significant inconsistency across medical schools, with national audit data revealing that 20.1% of UK Foundation Year 1 (FY1) doctors reported no undergraduate clinical attachment in urology[1]. Cross-national surveys corroborate this deficit, as 63.4% of junior Portuguese doctors considered their exposure to urological pathology and procedures inadequate during medical school, while 33.3% reported no practical urology classes despite mandatory theoretical instruction[2]. In the United

States, only 5–17% of medical schools require urology clerkships, and 66% of students at one Canadian institution reported no curriculum exposure to urology[3]. Undergraduate students in most medical schools in China typically spend only two weeks training in urology, resulting in significantly insufficient clinical exposure. How to improve the practical skills of interns in urology is an urgent problem to be solved.

Endoscopic Surgery has become an indispensable and routine surgical approach in modern urology, primarily by utilizing the body's natural passages (urethra, ureter) to introduce endoscopes and delicate instruments into the urinary system for diagnosis and treatment under direct visualization[4]. Flexible ureteroscopy is currently a routine procedure in urology, used for the treatment of kidney stones, urothelial tumors, and other conditions[5, 6]. To improve the operative proficiency of residents in flexible ureteroscopy, numerous studies have demonstrated that training with a flexible ureteroscopy simulation system can significantly enhance their technical skills[7, 8]. Medical education for undergraduate interns differs from that for urology residents. Urology residency training requires improved standardization, enhanced learning flexibility, and gradual development of independent clinical competence. In contrast, urology education for medical students should provide more practical opportunities, offer targeted guidance, and help them master basic urological procedural skills[9]. The flexible ureteroscopy simulation system is a teaching device based on virtual reality or high-fidelity models, which can authentically replicate the anatomical structure of the human urinary system and the surgical procedure. Trainees can practice repeatedly in a risk-free environment. This immersive learning approach not only improves students' practical skills but also enhances their understanding of cases and ability to respond to intraoperative challenges[8]. The procedures covered all fundamental skills specified in the undergraduate urology internship syllabus, including aseptic technique and urethral catheterization. Combined with several technical characteristics of flexible ureteroscopy and the requirements of the undergraduate intern training syllabus, we decided to apply the flexible ureteroscopy simulation system to undergraduate practical teaching, aiming to help students master the basic procedural skills and clinical thinking ability in urology. To further improve teaching quality and effectiveness, a scientific and systematic teaching assessment system can be constructed by combining the PDCA (Plan-Do-Check-Act) cycle management model and introducing two evaluation tools: Mini-Clinical Evaluation Exercise (Mini-CEX) and Direct Observation of Procedural Skills (DOPS)[10].

Objectives and methods

Study participants

From April 2026 to July 2026, we recruited 5-year clinical undergraduate students who interned in the Department of Urology, the Second Affiliated Hospital of Anhui Medical University, and randomly assigned them into an experimental group (PDCA cycle combined with flexible ureteroscopy simulation) and a control group (traditional teaching). According to the teaching schedule, 9–10 undergraduate clinical interns rotate into the Department of Urology every two weeks. The minimum required sample size was determined to be 36 cases per group, with a total of 72 cases. All interns who refused to sign the informed consent form were excluded from the study. Our study was approved by the Ethics Committee of The Second Affiliated Hospital of Anhui Medical University (approval number: YX2026-117).

Study methods

All interns were required to complete a two-week rotation in the Department of Urology to ensure balanced clinical competence. In the control group, tutors adopted traditional teaching methods combining weekly lectures and daily teaching rounds. All tutors had at least three years of clinical and teaching experience. Tutors selected typical patients from daily clinical cases. The experimental group received flexible ureteroscopy simulation teaching based on the PDCA quality cycle model[11].

Plan

At the initial teaching stage, Tutors developed detailed training plans according to the curriculum objectives. The training content shall be closely aligned with the internship curriculum for medical interns and differentiated from that for residents. To ensure the effectiveness and practicality of the teaching process, the entire teaching content is closely integrated with scenario simulation, aiming to bridge the gap between theoretical knowledge and clinical practice[12].

The specific teaching content is detailed as follows: The curriculum covers the core knowledge and procedural skills related to flexible ureteroscopy, including its working principle, indications and contraindications, preoperative preparation, and basic operational procedures. Regarding preoperative preparation, particular emphasis is placed on doctor-patient communication, which is delivered through scenario-based simulation. Trainees are required to work in pairs or groups to role-play different characters (e.g., attending physician, resident/intern, patient, and patient's family members), simulating real clinical scenarios such as explaining the surgical procedure, potential risks, and postoperative precautions to patients, answering patient's inquiries, and alleviating patient anxiety.

The basic operational procedure includes not only fundamental technical skills of flexible ureteroscopy (such as device assembly, ureteral catheterization, endoscope manipulation, and stone extraction) but also the cultivation of core clinical competencies. Specifically, strict attention is paid to the concept of asepsis, which runs through the entire operation, including standardized hand hygiene, disinfection and draping, and the prevention of iatrogenic infections.

Phased objectives were established: In the first week, teaching resources were arranged, including the allocation of simulation systems, grouping of trainees, and assignment of instructors, together with instruction on flexible ureteroscopy techniques and basic hands-on practice on simulators. In the second week, comprehensive training was conducted, covering case selection, preoperative preparation, simulated surgery, and other related components.

Do

During implementation, students performed simulated procedural training according to the established plan. Tutors primarily provided guidance and supervision to ensure that all students completed training as required. Meanwhile, students were encouraged to record problems and experiences during operations to support subsequent feedback.

Check

Student performance was evaluated using two assessment tools: Mini-CEX and DOPS. Mini-CEX was used to assess trainees' overall clinical competence, including history taking, physical examination, clinical reasoning, doctor-patient communication, and professionalism[13]. DOPS was specifically applied to assess the technical proficiency and procedural safety of specific clinical skills (e.g., flexible ureteroscopy and catheterization), by means of direct observation of the entire procedural workflow to gauge technical competence, aseptic awareness, and intraoperative emergency response[14]. Both assessments were conducted on-site by experienced clinical tutors.

Act

Based on assessment results, the teaching team summarized and optimized the teaching process: High performing students were recognized and motivated to participate in more advanced simulation training. Teaching strategies were adjusted for common problems, such as adding targeted training for specific skills. The simulation case library was updated with more clinically realistic complex cases. The teaching plan was refined to form a continuously improved teaching closed loop.

Assessment methods

All interns completed the Mini-CEX before and after their urology rotation. In the Mini-CEX assessment, the supervisor evaluates interns by observing their history taking and physical examination performed on randomly selected non-surgical inpatients. All patients provided written informed consent. DOPS was administered at the end of the rotation. During the assessment, interns were required to perform standardized basic surgical procedures on a simulator, with one task randomly selected from urethral catheterization, disinfection and draping, suturing and knot-tying, and wound care. All assessments were conducted by two supervisors, and the average score was taken as the final result. The Mini-CEX evaluates clinical diagnostic and therapeutic competence across seven domains: history taking, physical examination, humanistic care, clinical judgment, counseling skills, organizational efficiency, and overall performance. A 9-point rating scale was used: scores 1–3 indicated below expectations (requiring frequent guidance), 4–5 indicated competent performance (independent core examinations without major omissions), 6–7 indicated proficiency (skillful identification of subtle signs and sound clinical reasoning), and 8–9 reflected exemplary performance (management of complex cases with outstanding teaching and humanistic care)[13]. The DOPS instrument included 11 procedural items: professional knowledge, informed consent, preoperative preparation, anesthetic management, technical skills, aseptic technique, teamwork, postoperative management, communication skills, professional conduct, and overall performance. DOPS also used a 3-tier 9-point scale: 1–3 (insufficient proficiency requiring intensive training), 4–6 (basic competence), and 7–9 (skilled performance with mentoring ability)[15]. A self-designed questionnaire based on a 5-point Likert scale was adopted in this study to assess interns' feedback on clinical teaching, ranging from 1 (strongly disagree) to 5 (strongly agree). All items were positively scored, with higher scores indicating more favorable evaluations from interns. The questionnaire consisted of five dimensions: self-learning ability, improved confidence in clinical operations, learning initiative and motivation, teamwork competence, and satisfaction.

Cronbach's coefficient of the questionnaire was 0.799, and the split-half reliability coefficient was 0.801, demonstrating satisfactory reliability. The Kaiser-Meyer-Olkin (KMO) coefficient was 0.822, and Bartlett's test of sphericity was $p < 0.001$, which confirmed adequate construct validity of the questionnaire.

Statistics

Statistical analyses were performed using SPSS 19.0 software. Quantitative data were tested for normality and expressed as mean ± standard deviation. Categorical data were presented as frequencies and percentages. Comparisons of quantitative data were performed using the t-test, and categorical data were compared using the chi-square test. Continuous variables that failed the normality test were expressed as median (25th percentile, 75th percentile) [M (P25, P75)]. The nonparametric Mann –Whitney U test was used for between-group comparisons of two independent groups, with a significance level of $\alpha = 0.05$. A p-value < 0.05 was considered statistically significant.

Results

Participant characteristics

A total of 72 undergraduate clinical interns were screened for eligibility. No interns were excluded or withdrew due to ineligibility, and they were subsequently randomized into two groups (Fig. 1). Mini-CEX and theoretical knowledge assessments were performed prior to grouping. All baseline characteristics are summarized in Table 1, and all variables were comparable between the two groups ($p > 0.05$, Table 1).

Table 1
Comparison of baseline data for all interns between the two groups

Variables	Control group (n = 36)	Experimental group (n = 36)	Statistic	P - value
Age, Mean ± SD (years)	22.61 ± 0.65	22.47 ± 0.74	t = 0.851	0.397
Gender, n (%)			χ^2=0.057	0.812
Female	16 (44.44)	15 (41.67)		
Male	20 (55.56)	21 (58.33)		
Theoretical score before rotation, Mean ± SD	71.00 ± 3.04	71.31 ± 2.89	t=-0.437	0.663
Mini- CEX score before rotation, Mean ± SD				
History taking	4.36 ± 0.62	4.35 ± 0.52	t = 0.103	0.918
Physical examination	4.48 ± 0.60	4.36 ± 0.60	t = 0.878	0.383
Humanistic care	4.28 ± 0.64	4.40 ± 0.63	t=-0.837	0.406
Clinical judgment	3.96 ± 0.61	4.04 ± 0.25	t=-0.754	0.453
Counseling skills	4.19 ± 0.55	4.26 ± 0.41	t=-0.609	0.544
Organizational efficiency	4.36 ± 0.46	4.50 ± 0.59	t=-1.122	0.266
Overall performance	4.65 ± 0.43	4.61 ± 0.52	t = 0.370	0.712

Comparison of intern performance after rotation

After rotation, theoretical examination, Mini-CEX and DOPS assessments were conducted. Both the theoretical scores and Mini-CEX ratings of the two groups of interns were significantly improved compared with those before rotation ($p < 0.001$, Table 2).

Table 2
Intra-group comparisons of theoretical scores and Mini-CEX scores pre- vs post-rotation for two groups of interns

Variables	Control group (n = 36)		Statistic (intra-group)	*P* - value (intra-group)	Experimental group (n = 36)		Statistic (intra-group)	*P* - value (intra-group)
	Pre-rotation	Post-rotation			Pre-rotation	Post-rotation		
Theoretical score, Mean ± SD	71.00 ± 3.04	79.22 ± 1.94	t=-18.377	< 0.001	71.31 ± 2.89	81.75 ± 2.05	t=-19.251	< 0.001
Mini- CEX score, Mean ± SD								
History taking	4.36 ± 0.62	7.10 ± 0.29	t=-23.389	< 0.001	4.35 ± 0.52	7.25 ± 0.30	t=-31.196	< 0.001
Physical examination	4.48 ± 0.60	7.08 ± 0.33	t=-22.759	< 0.001	4.36 ± 0.60	7.31 ± 0.32	t=-24.373	< 0.001
Humanistic care	4.28 ± 0.64	7.06 ± 0.33	t=-26.618	< 0.001	4.40 ± 0.63	7.26 ± 0.37	t=-23.737	< 0.001
Clinical judgment	3.96 ± 0.61	7.04 ± 0.28	t=-26.742	< 0.001	4.04 ± 0.25	7.21 ± 0.32	t=-50.269	< 0.001
Counseling skills	4.19 ± 0.55	7.01 ± 0.30	t=-27.676	< 0.001	4.26 ± 0.41	7.22 ± 0.33	t=-33.739	< 0.001
Organizational efficiency	4.36 ± 0.46	6.97 ± 0.31	t=-27.266	< 0.001	4.50 ± 0.59	7.21 ± 0.30	t=-26.990	< 0.001
Overall performance	4.65 ± 0.43	7.03 ± 0.29	t=-29.463	< 0.001	4.61 ± 0.52	7.24 ± 0.28	t=-23.910	< 0.001

After rotation, the theoretical score of the experimental group was 81.75 ± 2.05, and that of the control group was 79.22 ± 1.94, with a significant difference ($p < 0.05$, Table 3). Following clinical rotation, Mini-CEX assessments demonstrated that interns in the experimental group exhibited significantly superior clinical competence compared with those in the control group across all domains: history taking (control group:7.10 ± 0.29 vs. experimental group: 7.25 ± 0.30, $p < 0.05$, Table 3), physical examination (control group: 7.08 ± 0.33 vs. experimental group: 7.31 ± 0.32, $p < 0.05$, Table 3), humanistic care (control group: 7.06 ± 0.33 vs. experimental group: 7.26 ± 0.37, $p < 0.05$, Table 3), clinical judgment (control group: 7.04 ± 0.28 vs. experimental group: 7.21 ± 0.32, $p < 0.05$, Table 3), counseling skills (control group: 7.01 ± 0.30 vs. experimental group: 7.22 ± 0.33, $p < 0.05$, Table 3), organizational efficiency (control group: 6.97 ± 0.31 vs. experimental group: 7.21 ± 0.30, $p < 0.05$, Table 3), and overall performance (control group: 7.03 ± 0.29 vs. experimental group: 7.24 ± 0.28, $p < 0.05$, Table 3).

Table 3
Comparison of scores data for all interns between two groups after rotation

Variables	Control group (n = 36)	Experimental group (n = 36)	Statistic	P - value
Theoretical score after rotation, Mean ± SD	79.22 ± 1.94	81.75 ± 2.05	t=-5.372	< 0.001
Mini-CEX score after rotation, Mean ± SD				
History taking	7.10 ± 0.29	7.25 ± 0.30	t=-2.185	0.032
Physical examination	7.08 ± 0.33	7.31 ± 0.32	t=-2.902	0.005
Humanistic care	7.06 ± 0.33	7.26 ± 0.37	t=-2.517	0.014
Clinical judgment	7.04 ± 0.28	7.21 ± 0.32	t=-2.343	0.022
Counseling skills	7.01 ± 0.30	7.22 ± 0.33	t=-2.802	0.007
Organizational efficiency	6.97 ± 0.31	7.21 ± 0.30	t=-3.248	0.002
Overall performance	7.03 ± 0.29	7.24 ± 0.28	t=-3.093	0.003
DOPS score after rotation, Mean ± SD				
Professional knowledge	7.04 ± 0.32	7.29 ± 0.37	t=-3.066	0.003
Informed consent	7.00 ± 0.29	7.25 ± 0.33	t=-3.416	0.001
Preoperative preparation	6.96 ± 0.28	7.14 ± 0.28	t=-3.024	0.003
Anesthetic management	6.94 ± 0.44	7.15 ± 0.23	t=-2.493	0.015
Technical skills	7.01 ± 0.25	7.17 ± 0.29	t=-2.368	0.021
Aseptic technique	6.93 ± 0.32	7.21 ± 0.32	t=-3.658	< 0.001
Teamwork	7.07 ± 0.27	7.23 ± 0.30	t=-2.452	0.017
Postoperative management	6.90 ± 0.26	7.08 ± 0.19	t=-3.350	0.001
Communication skills	7.08 ± 0.35	7.31 ± 0.38	t=-2.574	0.012
Professional conduct	7.01 ± 0.25	7.32 ± 0.32	t=-4.496	< 0.001
Overall performance	7.03 ± 0.29	7.22 ± 0.30	t=-2.773	0.007

Similarly, post-rotation DOPS assessments revealed that interns in the experimental group achieved significantly higher scores in surgical procedural competence than those in the control group, specifically in: professional knowledge (control group: 7.04 ± 0.32 vs. experimental group: 7.29 ± 0.37, $p < 0.05$, Table 3), informed consent (control group: 7.00 ± 0.29 vs. experimental group: 7.25 ± 0.33, $p < 0.05$, Table 3), preoperative preparation (control group: 6.96 ± 0.28 vs. experimental group: 7.14 ± 0.28, $p < 0.05$, Table 3),

anesthetic management (control group: 6.94 ± 0.44 vs. experimental group: 7.15 ± 0.23, $p < 0.05$, Table 3), technical skills (control group: 7.01 ± 0.25 vs. experimental group: 7.17 ± 0.29, $p < 0.05$, Table 3), aseptic technique (control group: 6.93 ± 0.32 vs. experimental group: 7.21 ± 0.32, $p < 0.05$, Table 3), teamwork (control group: 7.07 ± 0.27 vs. experimental group: 7.23 ± 0.30, $p < 0.05$, Table 3), postoperative management (control group: 6.90 ± 0.26 vs. experimental group: 7.08 ± 0.19, $p < 0.05$, Table 3), communication skills (control group: 7.08 ± 0.35 vs. experimental group: 7.31 ± 0.38, $p < 0.05$, Table 3), professional conduct (control group: 7.01 ± 0.25 vs. experimental group: 7.32 ± 0.32, $p < 0.05$, Table 3), and overall performance (control group: 7.03 ± 0.29 vs. experimental group: 7.22 ± 0.30, $p < 0.05$, Table 3).

Interns' feedback on different teaching modalities after rotation

After completing the urology rotation, all interns completed a questionnaire survey to provide feedback on the teaching modality they had received. Mann-Whitney U test revealed that scores of self-learning ability, improved confidence in clinical operations, learning initiative and motivation, teamwork competence and overall satisfaction in the experimental group were significantly higher than those in the control group (all $p < 0.001$, Table 4).

Table 4
Comparison of feedback for all interns between two groups after rotation

Evaluation indicators	Control group [M (P25, P75)]	Experimental group [M (P25, P75)]	U - value	P - value
Self-learning ability	4 (3,4)	4 (4,5)	199.50	< 0.001
Improved Operative Confidence	4 (3,4)	5 (4,5)	179.50	< 0.001
Learning initiative and motivation	4 (3,4)	5 (4,5)	160.00	< 0.001
Teamwork Competence	4 (3,4)	5 (4,5)	214.50	< 0.001
Satisfaction	3.5 (3,4)	5 (4,5)	90.0	< 0.001

M, median; P25, 25th percentile; P75, 75th percentile; Inter-group differences were analyzed by Mann–Whitney U test, α = 0.05.

Discussion

Undergraduate urology internships are often limited by short rotation durations (e.g., only two weeks in most Chinese medical schools), insufficient clinical case exposure, and the high risk of iatrogenic injury associated with direct hands-on operation on patients, all of which hinder the effective cultivation of practical skills. Traditional teaching methods, relying primarily on lectures and ward rounds, tend to be passive and theoretical, making it difficult for interns to translate abstract knowledge into operational competence. Undergraduate education in urology requires standardization, flexibility and autonomy to adapt to the

continuously evolving healthcare environment. The integration of innovative approaches such as artificial intelligence, virtual learning and simulation training can improve the quality of medical education, facilitate the professional development of medical students, and address existing deficiencies in current education, including insufficient clinical exposure and inadequate technical skill training[16, 17]. Worldwide, medical education has shifted from time-dependent training models to the competency-based medical education (CBME) framework, where simulation-based training plays a central enabling role[18]. Based on the adoption of CBME principles, the European Association of Urology (EAU) has developed Stage 1 and Stage 2 training curricula for flexible ureteroscopy, serving as a framework for training and assessment of urological endoscopic skills[19]. These curricula have long been implemented in resident training. To this end, we introduced the flexible ureteroscopy simulation system into practical teaching for undergraduate interns. To enhance standardization and scientificity, the entire teaching procedure was designed in accordance with the PDCA cycle. At present, most studies on emerging teaching methods are constructed based on the PDCA cycle[20, 21].

The PDCA cycle divides the teaching process into four interrelated stages (Plan-Do-Check-Act), enabling targeted training, standardized implementation, scientific evaluation and continuous improvement[22]. In the planning phase, teaching contents are elaborately designed to align with the internship objectives of undergraduate students, which differ from resident training. Emphasis is placed on basic operational skills and scenario-based doctor-patient communication, which are essential for novice interns yet frequently neglected in conventional teaching. Such targeted design ensures the training is practical and accessible, avoiding overly complicated content beyond the learning capacity of undergraduates.

The implementation stage, flexible ureteroscopy simulation training serves as the core content. The flexible ureteroscopy simulation systems based on virtual reality or high-fidelity models can faithfully reconstruct the anatomical structures of the urinary system and standard surgical procedures, allowing interns to conduct repeated training in a risk-free environment[6, 7]. Such immersive training not only improves their proficiency in basic operational skills, but also consolidates their awareness of aseptic techniques, which constitutes a core requirement throughout the whole urological surgical training process. Unlike direct clinical practice, simulation training eliminates the pressure concerning patient safety. It enables interns to attempt operations, correct errors and optimize their skills without causing adverse clinical outcomes, which is particularly valuable for undergraduate interns with limited clinical experience. Our research results reveal that interns in the experimental group achieved significantly better performance than those in the control group in both clinical skills and communication abilities.

In the checking phase, the Mini-CEX and DOPS were adopted to conduct comprehensive and objective assessments of interns' performances, which compensated for the deficiency of standardized evaluation in traditional undergraduate urological teaching. The combination of the two assessment tools enables the evaluation of overall clinical competence and specific technical skills, providing a more holistic picture of interns' progress than single-dimensional assessment[22]. Our results demonstrated that interns in the experimental group obtained statistically significantly higher scores in all domains of Mini-CEX and DOPS than those in the control group, indicating that the PDCA-based simulation teaching mode effectively improved learners' clinical thinking and operational proficiency. Notably, the experimental group also achieved greater progress in doctor-patient communication and humanistic care. Such competencies have attracted

increasing attention in modern medical education yet are difficult to cultivate via conventional lecture-based teaching. These improvements can be attributed to scenario-based doctor-patient communication simulations designed in the planning stage, which allow interns to engage in role-playing and foster empathy in a controlled environment. Scenario simulation is a scenario-based teaching approach. It constructs highly realistic clinical scenarios to enable learners to practice authentic clinical workflows safely. This immersive experience effectively cultivates learners' active thinking, clinical decision-making and doctor-patient communication skills[12].

The Act stage, which optimizes the teaching process based on assessment results, forms the iterative improvement loop of the PDCA model. This iterative improvement ensures that the teaching model remains dynamic and effective, rather than a static program, which is crucial for adapting to the continuously changing healthcare environment. Questionnaires distributed to interns demonstrated that this model yielded superior performance relative to the control group in improving self-learning ability, improved confidence in clinical operations, learning initiative and motivation, teamwork competence and overall satisfaction. These results further confirmed the acceptability and effectiveness of this model-active participation in simulation training and targeted feedback likely enhance intern engagement and motivation, which in turn improves learning outcomes.

Our findings demonstrate the value of simulation training in practical urological education, and integration of PDCA cycle management into this training can improve the quality of medical education. The novelty of the present study lies in its focus on undergraduate interns- a group that has received less attention in previous simulation-based teaching research compared with residents. Unlike residents, undergraduate interns have limited clinical experience and require more basic, targeted training to build foundational skills and clinical thinking. Our study tailors the PDCA-simulation model to the specific needs of undergraduate interns, emphasizing basic procedural skills, scenario-based communication, and gradual skill development, which fills the gap in undergraduate urology teaching research.

Despite encouraging findings, this study presents several acknowledged limitations. First, it was performed at a single center, restricting result generalizability. Multicenter trials with larger cohorts are warranted to confirm the efficacy of the PDCA-based simulation model in varied educational and clinical scenarios. Second, follow-up was confined to a two-week urology rotation. Long-term monitoring is needed to verify persistent skill gains and sustained clinical performance improvement. Further research should refine training schemes to boost learning efficiency.

In conclusion, the application of flexible ureteroscopy simulation teaching based on the PDCA cycle management model effectively improves theoretical performance, clinical competence, procedural skills, and teaching satisfaction of undergraduate urology interns. This model addresses the key deficiencies of traditional undergraduate urology teaching, including insufficient clinical exposure, passive learning, and lack of standardized assessment, and provides a systematic, feasible, and sustainable approach to enhance undergraduate urology education quality.

Abbreviations

CBME
Competency-based medical education
DOPS
Direct Observation of Procedural Skills
EAU
European Association of Urology
Mini-CEX
Mini-Clinical Evaluation Exercise
PDCA
Plan-Do-Check-Act

Declarations

Ethics approval and consent to participate

The study was approved by the Ethical Institutional Review Board of The Second Affiliated Hospital of Anhui Medical University, and written informed consent was obtained from all study participants. We obtained written informed consent from all patients and implemented all procedures under the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Author Contribution

DW, DD and XS designed the study. DW, DD, XS, ZZ, WS, ZL, WZ, EL, SX, XSu and XC performed the teaching intervention and assessment. JG and ZL collected the data. YH, DZ and WY analyzed the data. DW, JG and YH drafted the manuscript. All authors reviewed the manuscript and approved the final version.

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Data Availability

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

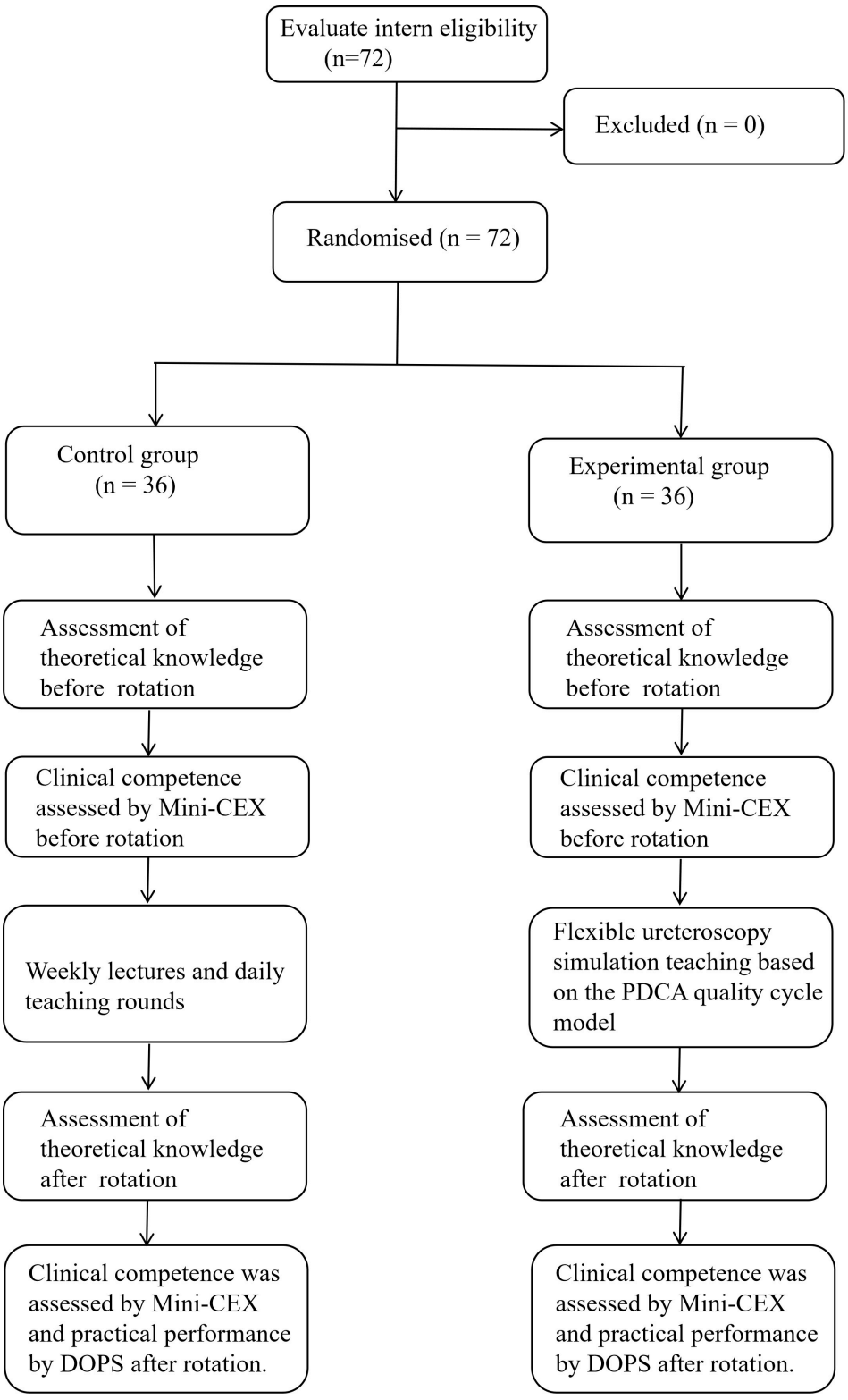


Figure 1

Flowchart of the overall study design.

Supplementary Files

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- Table1.docx
- Table2.docx
- Table3.docx
- Table4.docx
- Questionnaire.docx