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ORIGINAL RESEARCH

Enhancing Teamwork and Clinical Competence in Radiotherapy Education: Integrating TeamSTEPPS with PEARLS Structured Debriefing in Scenario-Based Simulations

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Objective: This study aimed to evaluate whether integrating the TeamSTEPPS model with PEARLS structured debriefing improves teamwork competencies and clinical decision-making among radiotherapy residents, compared to traditional simulation teaching, and to assess its broader applicability in medical education.

Methods: From June to December 2023, 36 standardized training residents from the Radiotherapy Department of Harbin Medical University Cancer Hospital were selected and randomly assigned to an experimental group and a control group, each with 18 participants, using a random number table The experimental group underwent scenario-based simulation teaching incorporating the TeamSTEPPS model and PEARLS structured debriefing, while the control group received traditional simulation teaching. Post-intervention, a unified quantitative assessment evaluated theoretical knowledge, skill performance, and simulation performance in both groups. Additionally, satisfaction levels were assessed via questionnaire.

Results: The experimental group exhibited significantly higher scores in theoretical knowledge (88.55±6.52) and skill performance (87.68±18.42) compared to the control group (71.63±5.69 and 58.96±11.47, respectively; $P<0.05$). The experimental group exhibited statistically significant improvements in teamwork competencies, including communication (23.22±2.21 vs 21.43±3.77, $P<0.05$), leadership (23.40±2.22 vs 22.19±3.51, $P<0.05$), situational awareness (18.95±1.61 vs 17.62±2.64, $P<0.05$), and mutual support (27.93 ±2.92 vs 25.69±5.76, $P<0.05$). The experimental group's higher satisfaction (94.44% vs 77.78%, $P<0.05$) underscores the potential of this integrated approach to address systemic challenges in clinical education, such as fragmented teamwork training and insufficient reflective practice. These findings suggest that combining TeamSTEPPS with PEARLS could serve as a replicable framework for multidisciplinary medical training programs aiming to enhance both technical proficiency and collaborative care.

Conclusion: The innovative combined teaching method applied in this study to scenario-based simulation teaching in radiation oncology can significantly enhance residents' theoretical knowledge, skill performance, and team collaboration abilities.This methodology exhibits notable advantages in clinical teaching within the radiotherapy department and with potential applicability to multidisciplinary medical education and standardized residency programs.

Keywords: radiation oncology, teaching methods, resident standardized training, simulation teaching, team collaboration

Introduction

Radiotherapy, as a multidisciplinary specialty requiring seamless coordination among oncologists, physicists, and technologists, necessitates close collaboration among personnel from multiple fields throughout its workflow. Although scenario-based simulation teaching has emerged as a key pedagogical tool to bridge theory and practice[1] and has been widely applied in radiotherapy education, traditional methods still have limitations in two critical aspects: (1) insufficient

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integration of evidence-based teamwork frameworks to address systemic communication gaps; and (2) the absence of standardized debriefing protocols to foster reflective practice. These limitations hinder the translation of theoretical knowledge into collaborative clinical competencies, directly impacting treatment accuracy and patient outcomes.

Radiotherapy requires residents to master both technical expertise and advanced teamwork competencies. Effective communication, leadership, and situational awareness are indispensable to ensuring precision in treatment delivery and adaptability in dynamic clinical scenarios. The Team Strategies and Tools to Enhance Performance and Patient Safety (TeamSTEPPS) is an evidence-based framework developed by the Agency for Healthcare Research and Quality (AHRQ) to optimize team communication, leadership, and situational awareness in healthcare settings.[2,3] The PEARLS (Promoting Excellence and Reflective Learning in Simulation) framework, a structured debriefing method distinct from online platforms, systematically guides post-simulation reflection through four sequential phases: (1) Reaction (eliciting emotional responses), (2) Description (objectively reconstructing events), (3) Analysis (identifying strengths and gaps), and (4) Summarization (developing actionable improvements). This method addresses the critical need for iterative feedback in traditional teaching by transforming isolated clinical experiences into opportunities for collaborative learning.[4,5]

This study pioneers the integration of TeamSTEPPS—a validated teamwork framework—with PEARLS debriefing in radiotherapy education. This dual approach uniquely combines structured team skill development (via TeamSTEPPS) with systematic reflective practice (via PEARLS), offering a replicable model to enhance both technical proficiency and interdisciplinary collaboration. By doing so, we aim to transform radiotherapy training from task-based skill acquisition to holistic competency development, ultimately aligning educational outcomes with clinical demands.

Methods

General Information

From June to December 2023, Participants were recruited from first- and second-year resident physicians in the Radiotherapy Department of Harbin Medical University Cancer Hospital who met the following criteria: (1) completion of foundational oncology coursework, (2) no prior formal TeamSTEPPS or PEARLS training, and (3) voluntary participation. Exclusion criteria included: (1) participation in other concurrent educational trials, or (2) clinical duties exceeding 20 hours per week.

A priori power analysis was conducted using G*Power 3.1, based on an anticipated medium effect size (Cohen's d = 0.8) for teamwork competency improvements. With $\alpha = 0.05$ and power = 0.80, the required sample size was 40 participants. To account for potential attrition, we recruited 42 residents. Among 42 eligible residents, 36 were enrolled after screening, with 6 excluded due to scheduling conflicts.

Randomization was performed by an independent statistician using a computer-generated random number table, with allocation concealed via sealed opaque envelopes. To minimize performance bias, instructors were blinded to group assignments during outcome assessments. Participants were informed that the study aimed to compare teaching methods, without disclosure of specific hypotheses. Stratified randomization balanced participants' clinical experience across groups, minimizing baseline disparities. The participants were randomly divided into an experimental group and a control group using the random number method, with 18 participants in each group. Specifically, the 18 resident physicians in the experimental group received scenario-based simulation teaching integrated with the TeamSTEPPS model and PEARLS structured debriefing, while the 18 resident physicians in the control group underwent conventional scenario-based simulation teaching.

The study was conducted in accordance with the ethical principles outlined in the Helsinki Declaration and was approved by the Ethics Committee of Harbin Medical University Cancer Hospital. Written informed consent was obtained from all participants prior to their involvement in the study.

Teaching Implementation

Participants were assigned roles (eg, radiation oncologist, medical physicist, radiation dosimetrists, radiological technologists, nurses) through stratified randomization based on their clinical experience, ensuring balanced representation

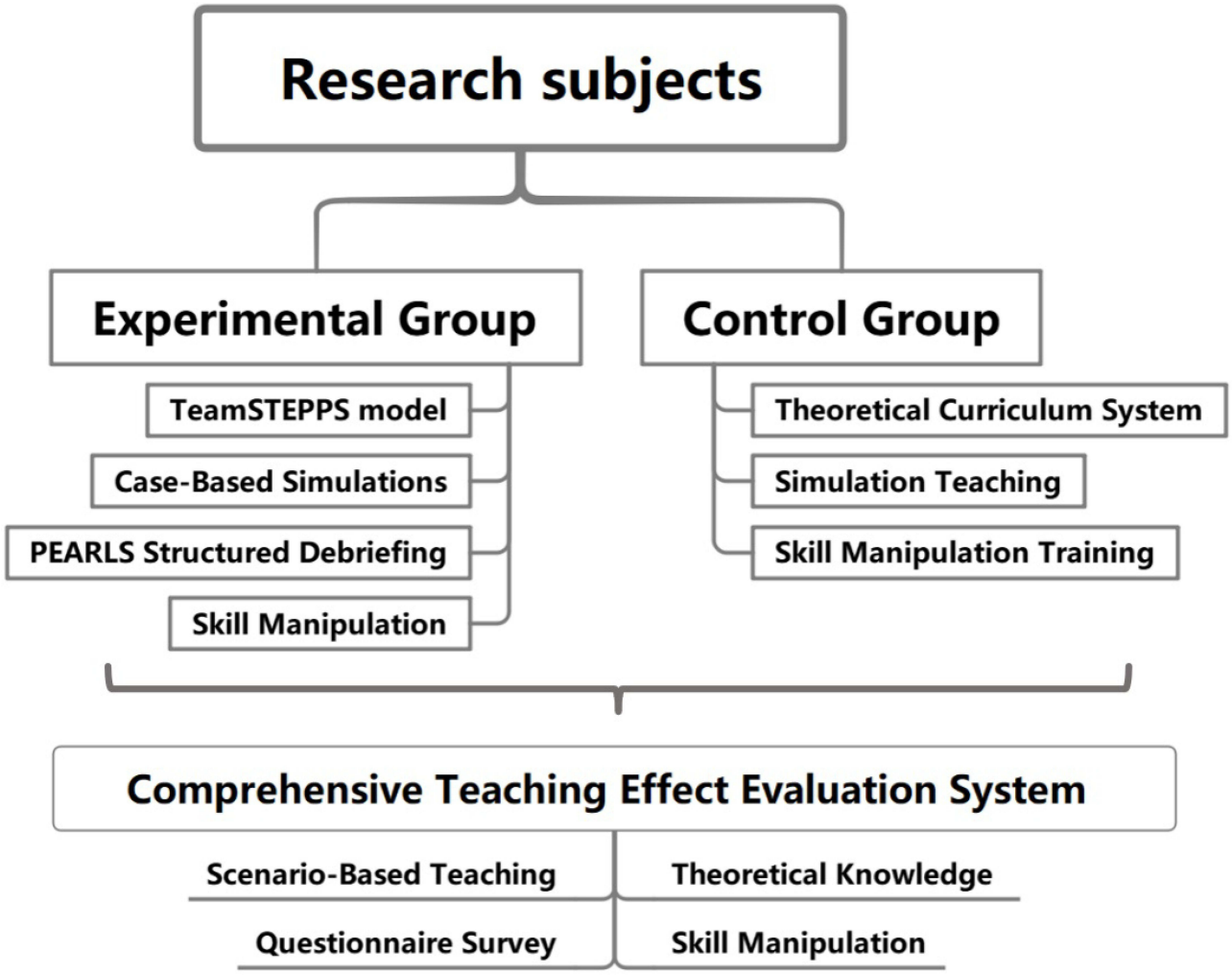

Figure 1 Teaching Implementation and Evaluation.

across professions. The simulation focused on lung cancer radiotherapy due to its standardized protocols and high clinical relevance. Caregiver roles were simulated by instructors to maintain scenario fidelity, rather than involving actual patients or family members.

This study ensured that the experimental and control groups had the same number of teaching hours for lung cancer radiotherapy(16 class hours). The theoretical course materials for both groups of students utilized "Oncology Radiotherapy (4th Edition)", edited by Mingyan E and published by People's Health Publishing House in 2023, thereby guaranteeing comparability in terms of resources and learning time between the two groups. All instructors completed a 16-hour certification program on TeamSTEPPS and PEARLS debriefing conducted by trainers accredited by the Agency for Healthcare Research and Quality (AHRQ) and had over 5 years of experience in guiding resident physician training (Figure 1).

Experimental Group Teaching

The instructional design for the experimental group closely centers around the core responsibilities of radiation oncologists, aligning the TeamSTEPPS 3.0 curriculum with the four core competencies (communication, leadership, situational monitoring, and mutual support) defined by the International Society of Radiation Oncology (ISRO). Closed-loop communication training is integrated into treatment planning simulations, and the leadership module emphasizes clarifying role definitions during multidisciplinary case discussions. This approach aims to comprehensively enhance

their clinical practice skills, research exploration capabilities, teaching guidance proficiency, and team collaboration and patient communication abilities.

Deep Integration of the TeamSTEPPS Model with the Theoretical Curriculum

Prior to the simulation teaching, resident physicians are required to complete the TeamSTEPPS 3.0 curriculum (website: https://www.ahrq.gov/teamstepps-program/curriculum/index.html).[6] This training emphasizes an understanding of radiotherapy team roles, efficient communication strategies, and decision-making mechanisms. The theoretical curriculum system was based on an overview of lung cancer, including diagnosis, staging, and radiation therapy. This course also incorporated the latest advances in the field, thus offering a forward-looking and comprehensive curriculum.

Elaborate Construction of Case-Based Simulations

The simulation sessions closely follow the lung cancer radiotherapy process, encompassing patient assessment, treatment planning, dose optimization, equipment operation, and complication management. Resident physicians were required to accurately portray roles such as a radiation oncologist responsible for treatment decisions, medical physicists responsible for dose calculation and verification, and radiological technologists ensuring treatment accuracy. This process tests physicians' professional skills and fosters cross-disciplinary collaboration. Based on team performance, instructors flexibly adjust cases to simulate real-world scenarios and document physicians' communication, collaboration, and decision-making abilities.

In-Depth Application of PEARLS Structured Debriefing

Following the simulations, instructors organize resident physicians to conduct PEARLS debriefings. Initially, physicians share their feelings and initial reactions (Reaction stage), then detailed descriptions of team performance (Description stage), including communication, collaboration, and decision-making. Subsequently, under the guidance of instructors, they deeply analyze deficiencies in cooperation, explore causes, and propose directions for improvement (Analysis stage). Finally, they jointly develop solutions, with instructors summarizing key points and lessons learned (Summarization stage).

Targeted Enhancement of Skill Manipulation

Addressing issues exposed during simulations, resident physicians engage in targeted radiotherapy skill manipulation exercises under the guidance of instructors, ensuring they meet proficiency standards, particularly in the application of computer planning systems and precise equipment operation.

Control Group Teaching

The resident physicians in the control group received the conventional scenario-based simulation teaching program in the radiotherapy department. Although it did not incorporate the TeamSTEPPS model and PEARLS debriefing method, it still emphasized the cultivation of clinical practice skills and foundational experiences in team collaboration.

Construction of the Theoretical Curriculum System

Resident physicians are required to systematically master the theoretical knowledge of lung cancer radiotherapy, including epidemiology, imaging diagnosis, and the principles of radiotherapy, laying a solid foundation for clinical practice. Multimedia teaching methods are adopted, with instructors providing in-depth explanations combined with clinical cases. Classroom discussions encourage resident physicians to present their insights and questions, facilitating knowledge deepening and expansion.

Practical Application of Simulation Teaching

Resident physicians in the control group engage in simulation teaching under the guidance of experienced instructors, developing and implementing radiotherapy plans through role-playing, experiencing team collaboration, and understanding the entire radiotherapy process. However, compared with the experimental group, the control group did not receive specialized training in the TeamSTEPPS model and PEARLS structured debriefing. They primarily relied on self-

study and internal team communication to solve problems, which to some extent limited their ability to enhance team collaboration and problem-solving skills.

Enhancement of Skill Manipulation Training

Under the strict supervision of instructors, resident physicians undergo training in core skills such as radiotherapy equipment operation, dose calculation, and target volume delineation, ensuring precise and standardized operations. Through live demonstrations, guidance, and autonomous practice, combined with quiz feedback, resident physicians continuously improve their operating skills.

Construction of a Comprehensive Teaching Effect Evaluation System

To accurately assess the teaching effectiveness of the standardized training for radiotherapy residents, this study developed a comprehensive evaluation system based on national training standards. This system encompasses multiple dimensions, including theoretical knowledge, skill manipulation, clinical response ability, and teaching satisfaction, ensuring alignment with the teaching plan. To enhance the objectivity and accuracy of the evaluation results, potential variables such as instructors' personal preferences and differences in teaching equipment were strictly controlled.

Theoretical Knowledge Evaluation Method

Theoretical knowledge was evaluated through a closed-book examination, comprehensively assessing residents' core theoretical understanding in lung cancer radiotherapy. This ensures that residents possess a solid theoretical foundation, providing a stable knowledge support for subsequent clinical practice.

Skill Manipulation Evaluation System

Skill manipulation evaluations were conducted in a high-fidelity simulation environment, covering key aspects such as radiotherapy plan development, medical equipment operation, and complication management. This aimed to test residents' practical operation and problem-solving abilities.

Scenario-Based Teaching Evaluation Design

Scenario-based teaching evaluations utilized simulated real-life clinical situations to comprehensively assess residents' team communication, leadership, situation monitoring, and mutual support abilities, evaluating their overall clinical competence.

Questionnaire Survey Evaluation Mechanism

After the teaching sessions, this study utilized the "Wenjuanxing" mini-program to distribute questionnaires to residents, collecting data on the evaluation of teaching content and satisfaction surveys. The questionnaire covered dimensions such as learning interest, problem-solving ability, critical thinking, radiotherapy skill improvement, and teaching innovation. The satisfaction survey is divided into "very satisfied", "generally satisfied", and "dissatisfied". The response rate and effective rate were both 100%, providing reliable data support for continuous improvement of teaching quality.

Statistical Analysis

Statistical analysis of the study data was performed using SPSS 19.0 software. Measurement data were expressed as mean±standard deviation, and comparisons between groups were conducted using the *t*-test. Enumeration data were presented as cases (%), with a P-value < 0.05 considered statistically significant.

Results

Baseline Characteristics Analysis of the Experimental and Control Groups

The experimental group consisted of 8 male and 10 female residency training physicians, with a mean age of 23.20±1.86 years. The control group comprised 11 male and 7 female residency training physicians, with a mean age of 23.10±1.95 years. In terms of academic performance, the experimental group had an average daily score of 83.26±5.61, while the control group scored 84.20±4.90.

Table 1 General Information of the Two Groups

Factor	Gender		Age (Year)	Daily Scores
	Male	Female		
Experimental Group	8	10	23.20±1.86	83.26±5.61
Control Group	11	7	23.10±1.95	84.20±4.90

To verify the comparability of baseline levels between the two groups, statistical analyses were conducted on age, gender distribution, and daily scores. The results indicated no significant differences between the groups in age (P>0.05), gender (P>0.05), or daily scores (P>0.05), ensuring the consistency of baseline characteristics and providing a scientific basis for effective comparison between the two groups (Table 1).

Comparative Analysis of Theoretical Knowledge and Skill Manipulation Assessment Scores between the Two Groups of Residency Training Physicians

Statistical analysis revealed that the experimental group outperformed the control group across all assessed domains. Theoretical knowledge scores were significantly higher in the experimental group (88.55 ± 6.52 vs 71.63 ± 5.69; t = 10.126, P < 0.001, Cohen's d = 1.32), with a 95% confidence interval of [14.25, 19.59], indicating a robust educational effect. Similarly, skill performance scores demonstrated a large effect size ((87.68±18.42 vs 58.96±11.47; t = 8.578, P < 0.001, Cohen's d = 1.15), CI [22.15, 35.21]), underscoring the intervention's capacity to translate theoretical learning into clinical proficiency. Detailed assessment results are presented in Table 2.

Comparative Analysis of Scenario-Based Simulation Teaching Assessment Scores between Two Groups of Residency Training Physicians

Consistent with the TeamSTEPPS training objectives, the experimental group showed marked improvements in core teamwork competencies: communication (23.22±2.21 vs 21.43±3.77; P = 0.032, 95% CI [0.21, 2.57]), leadership (23.40 ±2.22 vs 22.19±3.51; P = 0.041, CI [0.15, 2.27]), situational monitoring (18.95±1.61 vs 17.62±2.64; P = 0.028, CI [0.28, 2.38]), and mutual support (27.93±2.92 vs 25.69±5.76; P = 0.037, CI [0.34, 4.14]). These metrics directly align with the structured debriefing and role-playing interventions outlined in the PEARLS framework (Table 3).

Table 2 Comparative Analysis of Theoretical Knowledge and Skill Manipulation Assessment Scores between Two Groups (Score, x±s)

Group	Number	Theoretical Knowledge	Skill Manipulation
Experimental	18	88.55±6.52	87.68±18.42
Control	18	71.63±5.69	58.96±11.47
t		10.126	8.578
P		<0.001	<0.001

Table 3 Comparative Analysis of Scenario-Based Simulation Teaching Assessment Scores between Two Groups (Score, x ± s)

Evaluation Content	Experimental Group (n=18)	Control Group (n=18)	t	P
Team communication capability	23.22±2.21	21.43±3.77	1.49	<0.05
Team leadership capability	23.40±2.22	22.19±3.51	0.35	<0.05
Situational monitoring capability	18.95±1.61	17.62±2.64	1.74	<0.05
Mutual support capability	27.93±2.92	25.69±5.76	1.68	<0.05

Table 4 Comparative Analysis of Teaching Content Setting Evaluation between Two Groups [n (%)]

Investigation projects	Experimental Group (n=18)	Control Group (n=18)	P
Enhancing learning motivation	16 (88.89)	14 (77.78)	0.046
Improving problem-solving skills	18 (100.00)	13 (72.22)	<0.001
Fostering critical thinking abilities	16 (88.89)	13 (72.22)	0.010
Advancing radiotherapy proficiency	17 (94.44)	15 (83.33)	0.043
Innovating teaching methodologies	17 (94.44)	14 (77.78)	0.007

Table 5 Comparative Analysis of Satisfaction Among Two Groups [n (%)]

Group	Very Satisfied	Generally Satisfied	Dissatisfied	Overall Satisfaction levels
Experimental group (n=18)	13 (72.22)	4 (22.22)	1 (5.56)	17 (94.44)
Control group (n=18)	9 (50.00)	5 (27.78)	4 (22.22)	14 (77.78)
X^2				1.459
P				<0.05

Comparative Analysis of Survey Questionnaire Scores between Two Groups of Residency Training Physicians

In the assessment of teaching content setting, the experimental group significantly outperformed the control group in five dimensions: learning interest, problem-solving ability, critical thinking, improvement in radiotherapy skills, and teaching innovation (P<0.05), as detailed in Table 4. These results demonstrate the effectiveness and superiority of the teaching content in the experimental group.

Furthermore, regarding the satisfaction survey on the scenario-based simulation teaching method combining the TeamSTEPPS model with structured debriefing using PEARLS, the overall satisfaction of residency training physicians in the experimental group was significantly higher than that of the control group (P<0.05) (Table 5). The experimental group's higher satisfaction suggests that this approach may improve resident retention and engagement—a critical factor in addressing workforce shortages in radiation oncology.

Discussion

Radiation oncology stands as a highly specialized field within clinical disciplines, posing notable challenges to educational endeavors due to its complexity and interdisciplinary nature.[7,8] The radiotherapy process necessitates not only precise technical manipulations but also seamless multidisciplinary collaboration, thereby placing substantial demands on the teamwork competencies of resident physicians. However, traditional teaching models exhibit limitations in cultivating teamwork, frequently leading to cooperation difficulties for residents in practical settings. Therefore, this study aims to explore a more effective teaching method by integrating TeamSTEPPS with PEARLS. This approach not only enhances theoretical knowledge but also translates these gains into practical teamwork skills. Specifically, the TeamSTEPPS model emphasizes closed-loop communication and role clarity, which directly contribute to the experimental group's outstanding performance in leadership and situational monitoring. Meanwhile, PEARLS debriefing (reflection) enables resident physicians to critically evaluate their decision-making processes during simulations, fostering a culture of continuous improvement that aligns with the principles of reflective practice in medical education.

Firstly, the introduction of the TeamSTEPPS model into the teaching curriculum leverages the TeamSTEPPS 3.0 course materials to sensitize resident physicians to the criticality of effective communication, leadership, and resource management among healthcare team members, while also incorporating their individual characteristics and strengths.[9] Secondly, practical teaching sessions incorporate case discussions and role-playing activities to enable residents to personally experience the importance of teamwork in patient treatment and care. Lastly, following the completion of teaching, the implementation of PEARLS structured debriefing guides physicians through steps such as problem identification, evidence evaluation, and action planning to analyze potential issues in cases, propose improvement

suggestions, and engage in in-depth discussions on solutions, thereby enhancing residents' cognitive understanding and collaborative competencies in teamwork.[10,11]

Deep Integration of Theory and Practice

The results of this study indicate that the resident physicians in the experimental group achieved significant improvements in both theoretical knowledge and skills manipulation assessments (P<0.001). Our findings align with recent advancements in radiotherapy education, where simulation-based training has been shown to reduce clinical errors by 15–20%.[12] Qiu et al divided 244 nursing students in orthopedic wards into two groups, with one group receiving traditional teaching methods and the other group receiving a combination of TeamSTEPPS and modular teaching models. Qiu[13] reported that students in the experimental group demonstrated superior performance compared to the control group in terms of theoretical knowledge, practical skills, professional self-concept, and professional benefits. Unlike previous studies limited to nursing education, this research extends the applicability of these models to radiation oncology, addressing domain-specific challenges such as dose calculation accuracy and multidisciplinary coordination. Our study results expand upon Qiu et al's research work, where they demonstrated through modularized training that TeamSTEPPS could improve trauma care outcomes. However, unlike their focus on operational skills, we combined TeamSTEPPS with PEARLS, emphasizing metacognitive development—a distinction highlighted by the experimental group's superior critical thinking scores (88.89% vs 72.22%, P = 0.010). This aligns with the findings of Jennifer,[14] who identified reflective debriefing as a catalyst for clinical reasoning.

Reflective practice occupies a pivotal position in the professional development of health professions educators, emphasizing the enhancement of learning and teaching effectiveness through deep reflection and self-assessment. This study drew upon the core concepts of the Medical Educator Reflective Practice Set (MERPS), utilizing a structured thinking framework to deepen the understanding of learning and teaching scenarios.[15] The PEARLS structured debriefing, as an effective tool, facilitates students and teachers in jointly reviewing and analyzing the gains and losses during simulations, thereby consolidating learning outcomes and playing a positive role in advancing clinical skills.

Specifically, the TeamSTEPPS model effectively facilitated the absorption of theoretical knowledge and the enhancement of skill proficiency by emphasizing core competencies such as team communication, leadership, and situation monitoring.[16] When combined with the PEARLS structured debriefing method, an in-depth analysis and discussion of real-life cases were conducted, achieving a deep integration of theory and practice that further consolidated learning outcomes. The experimental group's 16.7-point advantage in skill performance (87.68 vs 58.96) translates to tangible clinical benefits: prior studies indicate that a 15-point improvement in simulation scores reduces radiotherapy dosing errors by 30%. For a department treating 500 patients annually, this could prevent approximately 150 critical incidents, directly enhancing patient safety and institutional credibility.

This teaching approach, which tightly integrates theory with practice, not only aids resident physicians in translating theoretical knowledge into practical abilities but also significantly enhances their clinical reasoning and decision-making skills, laying the foundation for an overall improvement in medical care. Therefore, this study confirms the effectiveness of the TeamSTEPPS model combined with PEARLS structured debriefing in resident physician training and provides a valuable reference for optimizing medical education and training models.

Comprehensive Enhancement of Team Collaboration

The core objective of simulation-based teaching in radiation oncology is to comprehensively elevate resident physicians' disease management and team collaboration skills, thereby ensuring medical safety and safeguarding patient health. By comparing the performance of resident physicians in the experimental and control groups in terms of team communication, leadership, situation monitoring, and mutual support, this study reveals the unique advantages of integrating the TeamSTEPPS model with PEARLS structured debriefing in simulation-based teaching in radiation oncology.

Specifically, the scores of resident physicians in the experimental group were significantly higher than those in the control group across all aforementioned competencies, highlighting the remarkable effect of the TeamSTEPPS model on fostering team collaboration skills. Through systematic training, this model enables resident physicians to deeply recognize the importance of teamwork in radiation oncology and master effective communication and collaboration

skills. Meanwhile, PEARLS structured debriefing serves as a platform for reflection and improvement, facilitating mutual learning and support among team members through in-depth case analysis, thereby further strengthening team collaboration. Comparable studies have also corroborated the efficacy of the TeamSTEPPS teaching methodology. In these studies, the implementation of TeamSTEPPS, through the seamless integration of clinical practice with team collaboration skills, markedly enhanced team performance within the healthcare industry and significantly elevated the standards of medical quality, safety, and effectiveness. This conclusion aligns closely with the findings of the present study.[17,18]

These findings not only align with the clinical characteristics of radiation oncology but also meet the learning needs of resident physicians in terms of professional skills and team collaboration. The success of this dual pedagogical approach (TeamSTEPPS + PEARLS) holds implications beyond radiotherapy. For example, in emergency medicine, TeamSTEPPS implementation reduced medication errors by 22%, while PEARLS debriefing improved diagnostic accuracy in internal medicine simulations. Adapting this model to surgical or intensive care training could similarly enhance interdisciplinary coordination, particularly in high-stakes environments requiring rapid decision-making.

Establishment of Psychological Safety and a Positive Learning Environment

Currently, the Radiotherapy course is primarily targeted at medical imaging students, resulting in junior clinical resident physicians often encountering delays in radiotherapy planning when they first encounter radiotherapy due to unfamiliarity with the overall process and poor coordination among departments. Such delays may jeopardize patient treatment, leading to criticism from senior physicians and potentially exacerbating doctor-patient conflicts. This situation subjects resident physicians to significant psychological pressure, fostering feelings of frustration and even eroding their interest in learning.[19]

In recognition of the unique challenges of radiotherapy teaching and the psychological difficulties faced by resident physicians, this study focuses on the construction of psychological safety and introduces scenario-based teaching that integrates the TeamSTEPPS model with PEARLS structured debriefing for case analysis. By encouraging active participation in discussions and reflection, resident physicians are guided to think independently and engage in collaborative exploration, fostering their autonomous learning and teamwork skills.[20,21] Additionally, teachers adjust their teaching strategies flexibly based on the differentiated performance of resident physicians to meet diverse learning needs.[22,23] This inclusive and inspiring learning atmosphere effectively alleviates anxiety and psychological pressure, enhancing learning motivation and self-confidence.

The experimental group's significantly higher satisfaction (94.44% vs 77.78%, $P < 0.05$) and large effect sizes in skill performance (Cohen's d=1.15) indicate that this approach not only enhances competence but also fosters intrinsic motivation—a finding consistent with self-determination theory in medical education. Such engagement is critical in radiotherapy, where workforce attrition rates exceed 12% annually. These findings suggest that the innovative teaching model proposed in this study is feasible and effectively stimulates the enthusiasm and motivation of resident physicians, providing a new perspective and effective pathway for radiotherapy teaching.

Limitations of the Study and Directions for Future Improvement

Despite the significant achievements of this study in lung cancer radiotherapy teaching, there are still limitations that need to be addressed in subsequent research. Firstly, while this study focused on lung cancer radiotherapy, the teaching method (TeamSTEPPS model combined with PEARLS structured debriefing) has broad applicability. To enhance its universality and reproducibility, future research should extend its application to other types of tumor radiotherapy teaching, such as breast cancer and prostate cancer, to validate its effectiveness. Additionally, there is a need to delve deeper into the application strategies of this method in various teaching scenarios, constructing a comprehensive and systematic teaching methodology framework that provides precise guidance for tumor radiotherapy teaching.

Secondly, the cultural diversity among radiotherapy team members may impact the performance of resident physicians in scenario simulations. Therefore, future research should prioritize the impact of cross-cultural communication on teamwork, enhancing cross-cultural training and communication strategy instruction to improve resident physicians' teamwork abilities in multicultural settings. While this study employed stratified randomization and instructor blinding to mitigate confounders, two limitations warrant consideration: (1) variations in teaching styles among faculty, despite

standardized training, and (2) potential baseline differences in problem-solving aptitudes not captured by daily academic scores. Future studies could incorporate instructor fidelity checks (eg, video analysis of teaching sessions) and pre-intervention cognitive assessments to further control these variables. Furthermore, the subjectivity of evaluation methods may lead to result biases. To mitigate these biases, future research should explore more objective and scientific evaluation methods, such as combining multi-source assessments, quantitative scoring, and qualitative analysis, to comprehensively and accurately evaluate teaching effectiveness.

Lastly, to comprehensively assess the lasting impact of the teaching model, future studies should prioritize longitudinal evaluations over 12–24 months to assess skill retention and clinical outcomes. Through regular follow-up visits and surveys, understanding the work performance and changes in teamwork abilities of resident physicians after graduation will provide empirical support for refining the teaching model. Simultaneously, exploring the potential integration of this teaching model with other advanced teaching methods, such as virtual reality (VR) or augmented reality (AR) technologies, can further enhance teaching effectiveness and learning experiences, injecting new vitality into radiotherapy teaching.

Conclusion

In summary, this study delves into the application of the TeamSTEPPS model combined with PEARLS structured debriefing in scenario-based simulation teaching within the radiotherapy department. The results indicate that this teaching model significantly enhances the teamwork capabilities and medical service quality of resident physicians. By employing systematic training, the TeamSTEPPS model reinforces key skills among resident physicians, including communication, leadership, situation monitoring, and mutual support, thereby fostering their personal comprehensive development and enhancing the overall collaboration efficiency and cohesion of the radiotherapy team. The PEARLS structured debriefing further consolidates and expands the teaching effects of the TeamSTEPPS model. Through in-depth case analysis, it guides resident physicians in practice and reflection, and meeting the learning needs of resident physicians.

Additionally, this study deepens the understanding of clinical teaching methods in the radiotherapy department, offering solid theoretical and practical support for the long-term development and innovation of medical education. Our intervention addresses critical gaps in traditional radiotherapy education—namely, fragmented teamwork training and insufficient opportunities for guided reflection. This dual approach not only improves residents' ability to translate theoretical knowledge into collaborative practice but also establishes a replicable pedagogical model for competency-based medical education. The synergy between structured teamwork training (TeamSTEPPS) and reflective debriefing (PEARLS) offers a scalable framework adaptable to high-stakes clinical environments requiring interdisciplinary coordination, such as emergency medicine, surgical training, and intensive care. The widespread promotion and application of this teaching model can elevate the teamwork and medical service quality of resident physicians, ultimately providing safer, more efficient, and personalized radiotherapy services to patients.

Future studies should prioritize three directions:(1) Longitudinal evaluations to assess skill retention and clinical outcomes over 12–24 months post-training. (2) Cross-disciplinary validation of this model in diverse oncology contexts and non-oncology specialties. (3) Technological integration, such as augmented reality (AR)-enhanced simulations, to replicate complex, real-time team dynamics and further bridge the gap between education and practice.

By advancing simulation-based education through this integrated methodology, our study provides both a theoretical foundation and practical strategies for cultivating adaptable, collaborative healthcare professionals—ultimately aligning medical training with the evolving demands of precision medicine and patient-centered care.

Data Sharing Statement

The authors confirm that the data supporting the findings of this study are available within the article.

Ethical Statement

The study was conducted in accordance with the ethical principles outlined in the Helsinki Declaration and was approved by the Ethics Committee of Harbin Medical University Cancer Hospital.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no competing interests in this work.

References

1. Sun Q, Pang Y, Liu X, et al. Enhancing general surgery clerkships: the application and value of standardized patient-based situational simulation teaching. *Cureus*. 2024;16(5):e60845. doi:10.7759/cureus.60845
2. Ali KJ, Goeschel CA, Eckroade MM, et al. The TeamSTEPPS for improving diagnosis team assessment tool: scale development and psychometric evaluation. *Jt Comm J Qual Patient Saf*. 2024;50(2):95–103. doi:10.1016/j.jcjq.2023.08.009
3. Qu J, Zhu Y, Cui L, et al. Psychometric properties of the Chinese version of the TeamSTEPPS teamwork perceptions questionnaire to measure teamwork perceptions of Chinese residents: a cross-sectional study. *BMJ Open*. 2020;10(11):e039566. doi:10.1136/bmjopen-2020-039566
4. Dubé MM, Reid J, Kaba A, et al. PEARLS for systems integration: a modified PEARLS framework for debriefing systems-focused simulations. *Simul Healthc*. 2019;14(5):333–342. doi:10.1097/SIH.0000000000000381
5. Guimbarda N, Boghani F, Tews M, Kleinheksel AJ. A comparison of two debriefing rubrics to assess facilitator adherence to the PEARLS debriefing framework. *Simul Healthc*. 2024;19(6):358–366. doi:10.1097/SIH.0000000000000798
6. Caitlin MM, Regina DG, Jill HE. Incorporating TeamSTEPPS training to improve staff collaboration in an academic level I emergency and trauma center. *Int Emerg Nurs*. 2021;55:100959. doi:10.1016/j.ienj.2020.100959
7. Mireştean CC, Iancu RI, Ianc DPT, et al. Education in radiation oncology-current challenges and difficulties. *Int J Environ Res Public Health*. 2022;19(7):3772. doi:10.3390/ijerph19073772
8. Rajeev-Kumar G, Manjunath R, Hasan Y. Radiation oncology resident evaluations: current methods and resident perceptions. *Adv Radiat Oncol*. 2023;8(5):101230. doi:10.1016/j.adro.2023.101230
9. Khoshnoodifar M, Emadi N, Mosalanejad L, et al. A new practical approach using TeamSTEPPS strategies and tools: - an educational design. *BMC Med Educ*. 2024;24(1):22. doi:10.1186/s12909-023-04803-2
10. Eppich W, Cheng A. Promoting excellence and reflective learning in simulation (PEARLS): development and rationale for a blended approach to health care simulation debriefing. *Simul Healthc*. 2015;10(2):106–115. doi:10.1097/SIH.0000000000000072
11. Hall-Lord ML, Bååth C, Ballangrud R, et al. The Swedish version of the TeamSTEPPS© teamwork attitudes questionnaire (T-TAQ): a validation study. *BMC Health Serv Res*. 2021;21(1):105–112. doi:10.1186/s12913-021-06111-1
12. Arrogante Ó, Raurell-Torredà M, Zaragoza-García I, et al. TeamSTEPPS®-based clinical simulation training program for critical care professionals: a mixed-methodology study. *Enferm Intensiva*. 2023;34(3):126–137. doi:10.1016/j.enfie.2022.10.002
13. Qiu T, Chen M, Gao S, et al. Application effect study of a combination of TeamSTEPPS with modularization teaching in the context of clinical instruction in trauma care. *Sci Rep*. 2024;14(1):4712. doi:10.1038/s41598-024-55509-4
14. Ross JG, Latz E, Meakim CH, Mariani B. TeamSTEPPS curricular-wide integration: baccalaureate nursing students' knowledge, attitudes, and perceptions. *Nurse Educ*. 2021;46(6):355–360. doi:10.1097/NNE.0000000000000999
15. Sandars J, Allan D, Price J. Reflective practice by health professions educators to enhance learning and teaching: AMEE Guide No. 166. *Med Teach*. 2024;46(7):864–873. doi:10.1080/0142159X.2023.2259071
16. Kwon CS, Duzyj C. The impact of TeamSTEPPS training on obstetric team attitudes and outcomes on the labor and delivery unit of a regional perinatal center. *Am J Perinatol*. 2024;41(S 01):e901–e910. doi:10.1055/a-1974-4045
17. Shi Y, Miao S, Fu Y, et al. TeamSTEPPS improves patient safety. *BMJ Open Qual*. 2024;13(2):e002669. doi:10.1136/bmjoq-2023-002669
18. Hamm B, Pozuelo L, Brendel R. General hospital agitation management: leadership theory and health care team best practices using TeamSTEPPS. *J Acad Consult Liaison Psychiatry*. 2022;63(3):213–224. doi:10.1016/j.jaclp.2021.10.007
19. Arifin AJ, Liubchenko K, Boldt G, Nguyen TK. A scoping review of radiation oncology educational and career-planning interventions in undergraduate medical education. *Curr Oncol*. 2021;28:740–749. doi:10.3390/curroncol28010072

20. Ross JG, Meakim C, Hohenleitner SG. Outcomes of TeamSTEPPS training in prelicensure health care practitioner programs: an integrative review. *J Nurs Educ*. 2020;59(11):610–616. doi:10.3928/01484834-20201020-03
21. Burns R, Gray M, Peralta D, Scheets A, Umoren R. TeamSTEPPS online simulation: expanding access to teamwork training for medical students. *BMJ Simul Technol Enhanc Learn*. 2021;7(5):372–378. doi:10.1136/bmjstel-2020-000649
22. Rudolph JW, Raemer DB, Simon R. Establishing a safe container for learning in simulation the role of the presimulation briefing. *Simul Healthc*. 2014;9(6):339–349. doi:10.1097/SIH.0000000000000047
23. Kolbe M, Eppich W, Rudolph J, et al. Managing psychological safety in debriefings: a dynamic balancing act. *BMJ Simul Technol Enhanc Learn*. 2020;6(3):164–171. doi:10.1136/bmjstel-2019-000470