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Enhancing CT and MRI Positioning Competency Through Virtual Simulation: A Prospective Educational Study

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ABSTRACT

Background: Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) positioning require a combination of theoretical knowledge and practical skills. Traditional teaching methods may offer limited opportunities for repeated hands-on practice.
Objective: To evaluate the effectiveness of virtual simulation-based training in improving CT and MRI positioning knowledge and practical competency among undergraduate radiography students.
Methods: A prospective pre-test and post-test educational intervention study was conducted among 30 undergraduate radiography students. Participants completed a four-week virtual simulation training program consisting of CT and MRI positioning modules. Knowledge was assessed using a 25-item multiple-choice questionnaire, while practical competency was evaluated through an Objective Structured Clinical Examination (OSCE)-based assessment within the simulation environment. Student perceptions regarding the learning experience were also collected using a structured questionnaire. Data were analyzed using descriptive statistics and paired t-tests, with statistical significance set at $p < 0.05$.
Results: All 30 participants completed the study. The mean knowledge score increased significantly from 13.8 ± 2.9 before training to 21.2 ± 2.1 after training ($p < 0.001$). Similarly, the mean practical competency score improved from 14.6 ± 3.2 to 23.4 ± 2.8 ($p < 0.001$). More than 90% of students reported increased confidence, improved understanding of CT and MRI positioning procedures, and satisfaction with the simulation-based learning experience. Most participants recommended the integration of simulation training into the radiography curriculum.
Conclusion: Virtual simulation-based training significantly improved both theoretical knowledge and practical competency in CT and MRI positioning among undergraduate radiography students. The findings support the incorporation of simulation-based learning as a valuable supplement to traditional radiography education.

Keywords: Virtual simulation, Radiography education, Computed tomography, Magnetic resonance imaging, Positioning competency.

INTRODUCTION

Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) are among the most advanced and widely utilized diagnostic imaging modalities in contemporary healthcare. These imaging techniques provide detailed anatomical and pathological information that assists clinicians in diagnosis, treatment planning, and patient management. The successful acquisition of high-quality CT and MRI images depends largely on the competence of radiographers, who are responsible for patient preparation, accurate positioning, protocol selection, image optimization, and adherence to safety standards.[1,2] Consequently, radiography education programs must ensure that students acquire not only theoretical knowledge but also practical competencies necessary for operating sophisticated imaging equipment and managing diverse clinical scenarios.[3] Traditional radiography education has historically relied on a combination of classroom instruction, laboratory demonstrations, and clinical placements to develop professional competence.[4] While these approaches remain fundamental to radiographer training, several challenges have emerged in recent years. Increasing patient workloads, limited scanner availability, concerns regarding patient safety, and restricted clinical placement opportunities can reduce students' exposure to advanced imaging procedures. [5,6] Furthermore, CT and MRI examinations often involve complex protocols and specialized positioning techniques that may not be encountered frequently during routine clinical rotations. As a result, many students experience difficulties in developing confidence and proficiency before entering professional practice. [7] The integration of simulation-based education into healthcare training has gained considerable attention as an innovative solution to these challenges. Simulation provides learners with opportunities to engage in realistic clinical scenarios within a controlled and risk-free environment.[8] Unlike conventional teaching methods, simulation-based learning allows repeated practice, immediate feedback, and experiential learning without compromising patient safety or workflow efficiency.[9] Educational theories suggest that active participation and deliberate practice significantly enhance knowledge retention, skill acquisition, and clinical decision-making abilities among healthcare learners.[10]

Recent technological advancements have led to the development of virtual simulation platforms specifically designed for medical imaging education. These software applications replicate CT and MRI environments, enabling students to perform virtual patient positioning, identify anatomical landmarks, select scanning parameters, and practice protocol planning. [11] Through interactive interfaces, learners can visualize imaging anatomy in multiple planes, understand scan coverage requirements, and appreciate the relationship between positioning accuracy and image quality. Such experiences may help bridge the gap between theoretical instruction and real-world clinical practice. [12] Several studies conducted in medical and allied health education have reported positive outcomes associated with simulation-based learning, including improved technical skills, enhanced learner confidence, reduced anxiety, and better preparedness for clinical responsibilities. [13]

In radiography education, simulation has been shown to support the development of positioning skills, radiation safety awareness, and patient communication competencies.[14] However, despite the increasing adoption of simulation technologies, evidence specifically evaluating virtual CT and MRI simulation software remains relatively limited, particularly in undergraduate radiography programs.[15] Given the growing demand for competent imaging professionals and the increasing complexity of advanced diagnostic imaging procedures, there is a need to evaluate innovative educational approaches that can enhance student learning outcomes. Therefore, the present study aimed to assess the effectiveness of virtual simulation software in improving CT and MRI positioning knowledge, practical competency, and confidence among undergraduate radiography students. The findings may contribute to the development of evidence-based educational strategies and support the integration of simulation technologies into radiography curricula.

MATERIALS AND METHODS

Study Design: This study employed a prospective pre-test and post-test educational intervention design to evaluate the effectiveness of virtual simulation software in improving CT and MRI positioning knowledge and practical competency among undergraduate radiography students.

Study Participants: A total of 30 undergraduate radiography students were recruited through convenience sampling. Participants were enrolled in the Bachelor of Medical Radiology and Imaging Technology (BMRIT) program and had completed introductory coursework in radiographic anatomy, conventional radiography, and imaging physics before participation in the study.

Inclusion Criteria

- Undergraduate radiography students currently enrolled in the BMRIT program.
- Completion of basic radiographic positioning and anatomy courses.
- Willingness to participate and provide informed consent.
- Availability to attend all simulation training sessions and assessments.

Exclusion Criteria

- Students who had previously undergone formal CT or MRI simulation-based training.
- Students absent during either the pre-test or post-test assessment.
- Incomplete questionnaire responses or practical assessment records.

Ethical Considerations: Ethical approval for the study was obtained from the Institutional Ethics Committee. Participation was voluntary, and written informed consent was obtained from all participants before enrollment. Confidentiality and anonymity of participants were maintained throughout the study.

Virtual Simulation Software: The intervention utilized a virtual CT and MRI simulation platform designed to replicate real-world imaging environments. The software provided interactive modules that allowed students to perform virtual patient positioning, identify anatomical landmarks, select scanning protocols, adjust scan parameters, and evaluate image coverage. The platform included three-dimensional anatomical visualization and simulated clinical scenarios commonly encountered in CT and MRI departments.

Educational Intervention: Participants underwent a structured simulation-based training program for four weeks. The training consisted of two sessions per week, with each session lasting approximately 90 minutes. Faculty members supervised all activities and provided guidance when necessary.

Simulation-Based Training Program: Participants underwent a structured four-week virtual simulation training program focusing on CT and MRI positioning procedures. The training modules included CT Brain, CT Paranasal Sinuses, CT Cervical Spine, CT Chest, CT Abdomen and Pelvis, as well as MRI Brain, MRI Cervical Spine, MRI Lumbar Spine, MRI Knee Joint, and MRI Shoulder Joint examinations. During the sessions, students practiced patient positioning, anatomical landmark identification, scan range selection, protocol planning, safety procedures, and image quality evaluation. Repeated practice was encouraged to enhance skill acquisition and confidence.

Knowledge Assessment: Theoretical knowledge was assessed using a structured questionnaire consisting of 25 multiple-choice questions related to CT and MRI positioning. The questionnaire evaluated participants' understanding of anatomical landmarks, patient positioning principles, imaging protocols, safety considerations, scan planning, and image acquisition techniques. Each correct response was awarded one mark, with a maximum obtainable score of 25.

Practical Competency Assessment: Practical skills were evaluated through an Objective Structured Clinical Examination (OSCE)-based assessment conducted within the virtual simulation environment. Students performed simulated positioning tasks and were assessed on positioning accuracy, anatomical landmark identification, protocol selection, scan range planning, and workflow efficiency. Performance in each domain was scored using a five-point rating scale, with higher scores indicating greater competency.

Student Perception Questionnaire: Following completion of the training program, participants completed a self-administered questionnaire to evaluate their perceptions of simulation-based learning. Responses were recorded using a five-point Likert scale ranging from strongly disagree to strongly agree. The survey assessed confidence in CT and MRI positioning, ease of software use, perceived educational effectiveness, overall satisfaction, and recommendations for integration of simulation training into the radiography curriculum.

Data Collection Procedure: Data collection was performed in two phases. Before the intervention, all participants completed baseline knowledge and practical competency assessments. Following the four-week simulation training program, the same assessments were repeated to evaluate changes in performance. Student perception data were collected immediately after completion of the post-intervention assessment.

Outcome Measures: The primary outcome measure was the improvement in CT and MRI positioning knowledge and practical competency following virtual simulation-based training. Secondary outcomes included student confidence, perceived usefulness of the simulation software, satisfaction with the educational experience, and acceptance of simulation-based learning as a component of radiography education.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 26.0. Descriptive statistics were used to summarize participant characteristics and assessment outcomes. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Differences between pre-test and post-test scores were analyzed using the paired t-test, with a p-value of less than 0.05 considered statistically significant.

RESULT

A total of 30 undergraduate radiography students participated in the study and completed both the pre-intervention and post-intervention assessments, resulting in a completion rate of 100%. No participants were excluded from the final analysis. All students successfully completed the four-week virtual simulation-based training program consisting of CT and MRI positioning modules. The theoretical knowledge assessment consisted of 25 multiple-choice questions evaluating CT and MRI positioning principles, anatomical landmark identification, protocol selection, scan planning, and safety considerations. Comparison of pre-test and post-test scores demonstrated a marked improvement in knowledge following completion of the virtual simulation training program. The mean pre-test knowledge score was 13.8 ± 2.9 out of 25, which increased to 21.2 ± 2.1 following the intervention. The mean improvement in knowledge score was 7.4 points, corresponding to a 53.6% increase from baseline. Paired t-test analysis demonstrated that the improvement was statistically significant ($t = 12.84$, $p < 0.001$).

Table 1. Comparison of Knowledge Assessment Scores

Assessment	Mean ± SD	Mean Difference	t-value	p-value
Pre-test	13.8 ± 2.9			
Post-test	21.2 ± 2.1	7.4	12.84	<0.001

Practical Competency Assessment: Practical competency was evaluated using an OSCE-based assessment within the virtual simulation environment. Students were assessed on positioning accuracy, anatomical landmark identification, protocol selection, scan range planning, and workflow efficiency. The mean overall practical competency score increased from 14.6 ± 3.2 before training to 23.4 ± 2.8 after completion of the simulation program. The observed improvement of 8.8 points represented a substantial enhancement in practical performance. Statistical analysis demonstrated a highly significant difference between pre-test and post-test scores ($t = 14.27$, $p < 0.001$).

Table 2. Comparison of Practical Competency Scores

Assessment	Mean ± SD	Mean Difference	t-value	p-value
Pre-test	14.6 ± 3.2			
Post-test	23.4 ± 2.8	8.8	14.27	<0.001

Domain-Wise Practical Competency Performance: Improvements were observed across all assessed domains of CT and MRI positioning competency. The greatest gains were observed in positioning accuracy and anatomical landmark identification.

Table 3. Domain-Wise Practical Competency Scores

Competency Domain	Pre-test Mean ± SD	Post-test Mean ± SD	Percentage Improvement
Positioning Accuracy	2.7 ± 0.7	4.4 ± 0.5	62.9%
Anatomical Landmark Identification	2.6 ± 0.8	4.5 ± 0.5	73.1%
Protocol Selection	2.9 ± 0.7	4.3 ± 0.6	48.3%
Scan Range Planning	3.0 ± 0.8	4.4 ± 0.5	46.7%
Workflow Efficiency	3.4 ± 0.7	4.6 ± 0.4	35.3%

Student Perceptions of Simulation-Based Learning: All participants completed the post-intervention perception questionnaire. Responses indicated a highly positive attitude toward virtual simulation-based learning. Twenty-eight students (93.3%) agreed or strongly agreed that simulation training improved their understanding of CT and MRI positioning procedures. Twenty-seven students (90.0%) reported increased confidence in performing positioning tasks, while 29 students (96.7%) found the software easy to use. Additionally, 28 students (93.3%) believed that simulation training enhanced their learning experience and should be incorporated into the radiography curriculum. Overall, 29 students (96.7%) stated that they would recommend simulation-based training to future radiography students.

Table 4. Student Perception of Simulation-Based Training (n = 30)

Statement	Agree/Strongly Agree n (%)
Improved understanding of CT and MRI positioning	28 (93.3)
Increased confidence in positioning procedures	27 (90.0)
Software was easy to use	29 (96.7)
Enhanced overall learning experience	28 (93.3)
Should be included in radiography curriculum	28 (93.3)
Would recommend to other students	29 (96.7)

DISCUSSION

The present study evaluated the effectiveness of virtual simulation-based training in improving CT and MRI positioning knowledge and practical competency among undergraduate radiography students. Following the four-week intervention, significant improvements were observed in both theoretical and practical assessments. The mean knowledge score increased from 13.8 ± 2.9 before training to 21.2 ± 2.1 after training, representing a 53.6% improvement. Similarly, the mean practical competency score increased from 14.6 ± 3.2 to 23.4 ± 2.8, demonstrating a substantial enhancement in students' positioning and protocol-selection skills. These findings indicate that simulation-based education can effectively support the development of essential competencies in CT and MRI imaging. The improvement in knowledge scores suggests that the virtual simulation platform enhanced students' understanding of anatomical landmarks, positioning principles, scan planning, and imaging protocols. The interactive nature of simulation allows learners to repeatedly perform procedures and receive immediate feedback, facilitating active learning and knowledge retention. The observed gain of 7.4 points in the knowledge assessment highlights the potential of simulation to complement traditional classroom teaching. Practical competency also improved significantly following the intervention. The mean practical score increased by 8.8 points, indicating better performance in positioning accuracy, anatomical landmark identification, protocol selection, and workflow management. The greatest improvements were observed in positioning accuracy and anatomical landmark identification, which are critical skills for obtaining diagnostic-quality CT and MRI examinations. Repeated practice within a risk-free environment likely contributed to these positive outcomes. [16-20]

Student perception findings further supported the effectiveness of the training program. More than 90% of participants reported that the simulation software improved their understanding of CT and MRI positioning, increased their confidence, and enhanced their overall learning experience. Additionally, 93.3% of students recommended the inclusion of simulation-based learning within the radiography curriculum, demonstrating strong acceptance of this educational approach. The findings of this study are consistent with previous reports indicating that simulation-based education enhances technical skills, clinical preparedness, and learner confidence in medical imaging programs. [21-25] Virtual simulation provides a standardized learning environment that enables students to practice procedures repeatedly without concerns related to patient safety, radiation exposure, or equipment availability. Despite the positive outcomes, several limitations should be acknowledged. The study included only 30 participants from a single institution, which may limit the generalizability of the findings. Furthermore, the absence of a control group prevented direct comparison with conventional teaching methods. Future studies involving larger multicenter samples and long-term follow-up assessments are needed to determine whether the observed improvements are sustained over time.

CONCLUSION

The findings of this study demonstrate that virtual simulation-based training is an effective educational approach for improving CT and MRI positioning knowledge and practical competency among undergraduate radiography students. Significant improvements were observed in both theoretical knowledge and practical performance following the four-week training program, accompanied by high levels of student confidence and satisfaction. Virtual simulation provides a safe, standardized, and interactive learning environment that facilitates skill development without the limitations of clinical exposure. Therefore, the integration of simulation-based training into radiography curricula may enhance student preparedness and contribute to improved clinical competence in advanced imaging modalities.

DECLARATIONS

Ethics Approval and Consent to Participate: The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Ethics Committee of the participating institution. Written informed consent was obtained from all participants prior to their inclusion in the study.

Consent for Publication: Not applicable.

Availability of Data and Materials: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing Interests: The authors declare that they have no competing interests.

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