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Case-Based Radiology Education In Interns: Comparing Learning And Retention Across Modalities

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Abstract

Aim: This study aimed to evaluate intern physicians' ability to interpret basic radiological imaging methods and to investigate the effect of a case-based training program on knowledge acquisition and retention.

Materials and Methods: In this prospective study, participants underwent a pre-test before training, a post-test after training, and a retention test four weeks later. Assessments were performed using direct radiography, ultrasound (US), computed tomography (CT), and magnetic resonance imaging (MRI) modalities. The data were statistically analyzed, and performance changes between modalities were examined.

Results: This study included 50 intern physicians enrolled in medical school. Of the participants, 40% (n=20) were male and 60% (n=30) were female. The median age was 24 years (interquartile range: 24-24). A statistically significant increase was found in all imaging modalities in the post-test results compared to the pre-test (direct radiography, US, CT: $p<0.001$; MRI: $p=0.019$). In the retention test, a statistically significant increase was observed in all modalities compared to the pre-test ($p=0.001$). However, when the post-test was compared with the retention test, no statistically significant difference was observed in direct radiography and US ($p=0.381$; $p=0.059$), while a statistically significant decrease was observed in CT and MRI ($p=0.006$; $p=0.001$).

Conclusion: Case-based training significantly improves interns' ability to interpret basic radiologic imaging modalities. While permanent learning was achieved primarily in direct radiography and basic US applications, loss of knowledge was observed in more complex modalities such as CT and MRI. Structuring training programs taking into account these differences may contribute to the development of clinical decision-making skills.

Keywords: Intern physician, radiology education, case-based learning, ultrasound, retention

Introduction

Radiologic imaging modalities are an indispensable part of the diagnosis and treatment process in the emergency department. Direct radiography, computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound (US) especially facilitate rapid decision-making in emergency patient management. However, many studies have shown that intern physicians feel inadequate in the interpretation and application of these imaging modalities. In a study by Glenn-Cox et al. (1), a large proportion of intern physicians reported that they did not receive adequate radiology training in the medical school curriculum and therefore experienced deficiencies in clinical practice. Similarly, Harthoorn et al. (2) emphasized that radiology education should be integrated more effectively into the curriculum, and restructuring teaching methods and content could increase students' acquisition of clinical skills. In addition, other studies in the field of radiology have demonstrated the positive relationship between students' attitudes, skills, and clinical competencies, indicating the need for more effective planning of educational processes (3).

In recent years, online or case-based learning methods have come to the forefront alongside traditional methods in clinical education (4). Case-based learning enables students to acquire

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knowledge through real clinical scenarios and to develop problem-solving and decision-making skills. Fromke emphasized that case-based learning is an effective and efficient teaching model, especially for new generation students (Gen Z and Millennial generation) (5). Sugi et al. (6) showed that the use of interactive case materials in radiology education enriches the learning process by increasing student participation. In addition, the new case-based and competency-oriented teaching format developed by Masthoff et al. (7) increased student motivation and supported skill acquisition. this study aimed to evaluate the effectiveness of a case-based theoretical and practical training program designed to improve the radiological interpretation and application skills of intern physicians. It also aimed to investigate its impact on short-term learning and long-term knowledge retention.

Materials and Methods

Study Design and Setting

This prospective study was conducted in a medical school within the scope of the Scientific and Technological Research Council of Türkiye (TÜBİTAK) 2209-A University Students Research Projects Support Program. Within the scope of the study, a case-based theoretical and practical training program on radiological imaging frequently encountered in the emergency department was implemented. The results of the pre-test, post-test, and retention test conducted after the training constituted the research data. This study was approved by the institutional review board and ethics committee of Recep Tayyip Erdoğan University in Türkiye (decision no: 2025/357, date: 31.07. 2025).

Participant Selection and Data Collection

A total of 62 intern physicians studying in a medical school, who were in the internship period, did not have a shift or outpatient clinic/service shift at the hospital on the dates of the study, and were able to participate in all sessions uninterruptedly during the training were invited to the study. Four of the intern physicians missed their theoretical training, two missed their practical training, two missed the pre-test, one missed the post-test, and three missed the retention test. As a result, out of the intern physicians were excluded, and 50 who completed all training and evaluation processes were included in the study.

Prior to the training, a questionnaire including demographic information, subjective perceptions of skills and attitudes towards radiology, and a 10-question case-based multiple-choice pre-test was administered to the participants. After the completion of the training, the 10-question post-test and questionnaire were reapplied which were prepared at equivalent content and difficulty level. To evaluate the retention of learning, a retention test consisting of 28 questions was conducted 1 month after the training. All data were recorded using a standard data coding template and converted into a format suitable for analysis.

Training Program and Content

The training program was planned for two days. On the first day, case-based theoretical training were held. In this context, lectures titled "The Importance of Direct Radiography", "Commonly Missed Direct Radiography Examples", "Computed Tomography with All Sections", "Common Pathological Computed Tomography Cases", "US, the Shining Star of Recent Years", "Common Ultrasound Case Examples" and "Magnetic Resonance imaging Reading Principles and Case Examples" were presented. In the theoretical sessions, each topic was explained through case examples of common pathologies encountered in the emergency department.

On the second day, hands-on practical training were held to improve the participants' skills in the use of US. Four stations were created in this context: "Trauma US — the Focused Assessment with Sonography in Trauma (FAST) and the extended FAST (eFAST)", "hepatobiliary US", "Doppler US", and "US-Guided Interventional Procedures (vascular access, venipuncture, central venous catheter placement)". At each station, the training sessions were supported by visual materials, video recordings, and live model applications. The training program was conducted in an integrated structure, aiming to provide both theoretical knowledge and practical skills.

All theoretical and practical training sessions were conducted by emergency medicine specialists who had completed at least five years of professional experience. For the US practice sessions, two instructors were selected, who had both attended and successfully completed a basic US course approved by professional emergency medicine associations. Both had at least five years of experience in point-of-care ultrasound (PoCUS), with an average of 250 US examinations per year.

Data Collection Tools and Measurements

The data collection process in the study consisted of three main components: a demographic and subjective assessment questionnaire, case-based knowledge tests (pre-test and post-test), and a retention test.

Questionnaires: In the questionnaires administered before and after the training, participants' gender, age, grade level, the specialty they planned to choose in the future, their subjective evaluation of the type, duration, and adequacy of their previous radiology education, their self-initiated learning activities, and their perception of their skills in interpreting imaging methods were questioned. In the questionnaires administered after the training, additional questions were included regarding the scientific adequacy of the program, its appropriateness in terms

of duration, the level of experience gained, and the imaging technique in which improvement was achieved. Likert-type scales were also used to assess the effect of the training program on the participants' ability to interpret or apply different imaging modalities. Accordingly, the participants were asked to respond on a five-point scale before and after the training program for direct radiography, CT, and MRI, by selecting "definitely can interpret, can interpret, undecided, cannot interpret, definitely cannot interpret" and for US by selecting definitely can apply, can apply, undecided, cannot apply, definitely cannot apply. Thus, an attempt was made to measure whether there was a change in individual perceptions resulting from the training.

Pre-test and post-test: Both tests consisted of 10 questions and were prepared at a similar level of difficulty. The questions were organized in a case-based multiple-choice format based on four direct radiographs, 3 CT, 2 US, and 1 MRI image. The pre-test was administered just before the start of the training, and the post-test was administered after the completion of the training. In tests, the number of correct answers was evaluated based on both total score and modality (direct radiography, CT, US, MRI).

Retention test: It was administered 1 month after the completion of the training and consisted of 28 questions. The questions were prepared in a case-based multiple-choice format including eight direct radiographs, nine CT, seven US, and four MR images. With this test, the long-term retention of the information obtained from the training was evaluated.

All test questions were developed collaboratively by three emergency medicine specialists with at least five years of clinical experience and active involvement in undergraduate radiology and US education. The content validity of the questions was ensured through consensus among the educators, focusing on common emergency radiology scenarios. To guarantee equivalence of difficulty and scope between the pre-test and post-test, the questions were constructed using identical learning objectives, similar case complexity, and parallel distributions of imaging modalities. The retention test questions were independently reviewed and validated by two external emergency medicine educators, to confirm that they assessed the same level of knowledge and comprehension without reproducing identical cases.

Statistical Analysis

All analyses were performed in Jamovi version 1.6 statistical software (The Jamovi Project, 2021, Computer Software, version 1.6, Sydney, Australia). Continuous variables were expressed as mean ± standard deviation or median interquartile range (IQR). Categorical variables were expressed as number (percentage, %). In modality-based learning outcome and retention assessments, the percentage of correct answers for the relevant modality was calculated. Pre-tests, and post-tests retention tests were compared using paired Student's t-test when parametric assumptions were met, and Wilcoxon signed-rank test, when parametric assumptions were not met. In all statistical analyses, p values <0.05 were considered significant.

Results

A total of 50 intern physicians were included in the study. Of the participants, 40% (n=20) were male, and 60% (n=30) were female. The median age was 24 years (IQR: 24-24), and the age distribution of the participants was relatively homogeneous. Urology (12%, n=6), emergency medicine (10%, n=5), cardiology (8%, n=4), and psychiatry (8%, n=4) were the most frequently considered specialties in career choices. Of the participants, 46% (n=23) reported previous didactic radiology training, 30% (n=15) had case-based training experience, and 92% (n=46) had attempted self-learning. The median values for didactic training time and case-based training time were 0 hours (IQR: 0-10) and 0 hours (IQR: 0-2), respectively. Basic demographic information is shown in Table 1.

Figure 1 shows the pre- and post-training self-assessment results of the intern physicians. While 50% of the participants stated that they could interpret direct radiographs before the training, this rate increased to 98% after the training. In US: while 74% of the participants answered "I cannot" or "I am undecided" before the training, 64% stated that they could perform the application after the training. In CT, while only 28% thought that they could interpret before the training, 80% stated that they could interpret after the training. In magnetic resonance interpretation, while 50% of the participants were undecided before the training, 52% stated that they could interpret, after the training. In general evaluation, most of the participants reported that the training made a significant contribution, especially in the fields of direct radiography and US (Figure 1).

The pre-test and post-test performances of the intern physicians participating in the study are presented in Table 2. According to the post-test results, a significant increase was found in all imaging modalities: direct radiography ($p<0.001$), US ($p<0.001$), CT ($p<0.001$), and MRI ($p = 0.019$). Similarly, in Table 3, where the results of the pre-test and retention test were compared, a significant improvement was observed in all modalities ($p=0.001$ for all). In Table 4, where post-test and retention test performances were evaluated, no significant difference was found between the direct radiography and US results ($p=0.381$, $p=0.059$, respectively). In contrast, a significant difference was found in CT and MRI ($p=0.006$, $p=0.001$, respectively). These data revealed that case-based training provided more permanent learning, especially in direct radiography and US applications.

Table 1. The volunteers' demographic data and baseline characteristics	
Characteristics	**All volunteers (n=50)**
Gender	
Male, n (%)	20 (40.0)
Female, n (%)	30 (60.0)
Age (years), median (IQR)	24 (IQR: 24-24)
Specialties considered in career preference	
Emergency medicine, n (%)	5 (10.0)
Family medicine, n (%)	2 (4.0)
Internal medicine, n (%)	2 (4.0)
Infectious diseases, n (%)	3 (6.0)
General surgery, n (%)	1 (2.0)
Eye diseases, n (%)	3 (6.0)
Thoracic surgery, n (%)	2 (4.0)
Public health, n (%)	1 (2.0)
Obstetrics and gynecology, n (%)	1 (2.0)
Cardiology, n (%)	4 (8.0)
Neurosurgery, n (%)	1 (2.0)
Orthopedics, n (%)	2 (4.0)
Pediatrics, n (%)	1 (2.0)
Psychiatry, n (%)	4 (8.0)
Medical genetics, n (%)	1 (2.0)
Anesthesia, n (%)	1 (2.0)
Dermatology, n (%)	3 (6.0)
Pulmonologist, n (%)	1 (2.0)
Plastic surgery, n (%)	1 (2.0)
Urology, n (%)	6 (12.0)
Child psychiatry, n (%)	1 (2.0)
Unknown, n (%)	4 (8.0)
Didactic education, n (%)	23 (46.0)
Didactic education (time), median (IQR)	0 (IQR: 0-10)
Case-based education, n (%)	15 (30.0)
Case-based education (time), median (IQR)	0 (IQR: 0-2)
Self-directed learning, n (%)	46 (92.0)
IQR: Interquartile Range (25p, 75p)	

Discussion

This study showed that after case-based theoretical training enriched with emergency cases and structured US practice, short-term cognitive acquisition increased significantly in all modalities for intern physicians. One month later, the data showed that the increase in direct radiography and US performance was maintained, while there was a partial decline in CT and MRI. The findings reveal that case-based learning strengthens basic interpretation and application skills by focusing on the clinical context and decision-making steps. This aligns with the approaches supported by case discussions, small group studies, and competency-based modules in the literature, especially in radiology education (5-7).

The significant and permanent gain in the US component may be associated with the enrichment of the training with visual materials as well as early and intensive practices, working in small groups, and using peer-supported or peer-educator models. In particular, abundant visual content, scenarios supported by videos, and applications on live mannequins make the learning process more concrete and permanent. Comprehensive reviews in recent years show that peer educators can achieve a level of proficiency close to that of the instructor in teaching activities. Appropriate preparation, audiovisual materials, and live applications contribute significantly to skill development, and short-session practices with frequent feedback significantly increase learning (8,9).

The modality-specific segregation seen in the retention window is also consistent with the trend in the literature: POCUS/basic US image acquisition and interpretation skills are significantly maintained at mid-term (6-8 weeks), whereas performance in more complex image acquisition/interpretation processes (e.g., cardiac windows, multistep slice analysis) fades more rapidly (10,11). These findings support the higher persistence observed for US and direct radiography in our study. Some studies have demonstrated that superficial vascular structures can be easily visualized via US by all physicians (12). Our training was designed at the basic US/POCUS level, and the evaluation questions were prepared within this framework, which may explain the retention success in US training. However, a similar retention may not be achieved in a training program targeting more advanced imaging windows or complex analyses.

Another implication is that learning should be distributed and reinforced over time. Systematic reviews focused on radiology education show that spaced learning, retrieval practice, and interleaving strategies can provide significant advantages in both short-term and long-term examinations, and that spaced digital education contributes to knowledge growth and behavioral change in health professions (13-15). Future studies should examine learning curves for CT/MRI with longitudinal designs involving intermittent reinforcement and repeated presentation of rare pathologies. To ensure long-term retention in CT and MRI imaging, incorporating periodic reinforcement and simulation-based case discussions is recommended. Integrating CT/MRI interpretation into longitudinal curricula, supported by spaced digital learning and structured feedback, may help sustain diagnostic accuracy and cognitive retention over time.

In this study, 50 intern physicians participated, representing diverse specialty interests including emergency medicine, internal medicine, surgery, and psychiatry. Although participants reported a wide range of specialty preferences, no statistically significant difference was found between these preferences and the learning outcomes in radiology education. However, students planning to specialize in clinically dynamic disciplines such as emergency medicine or internal medicine may have higher

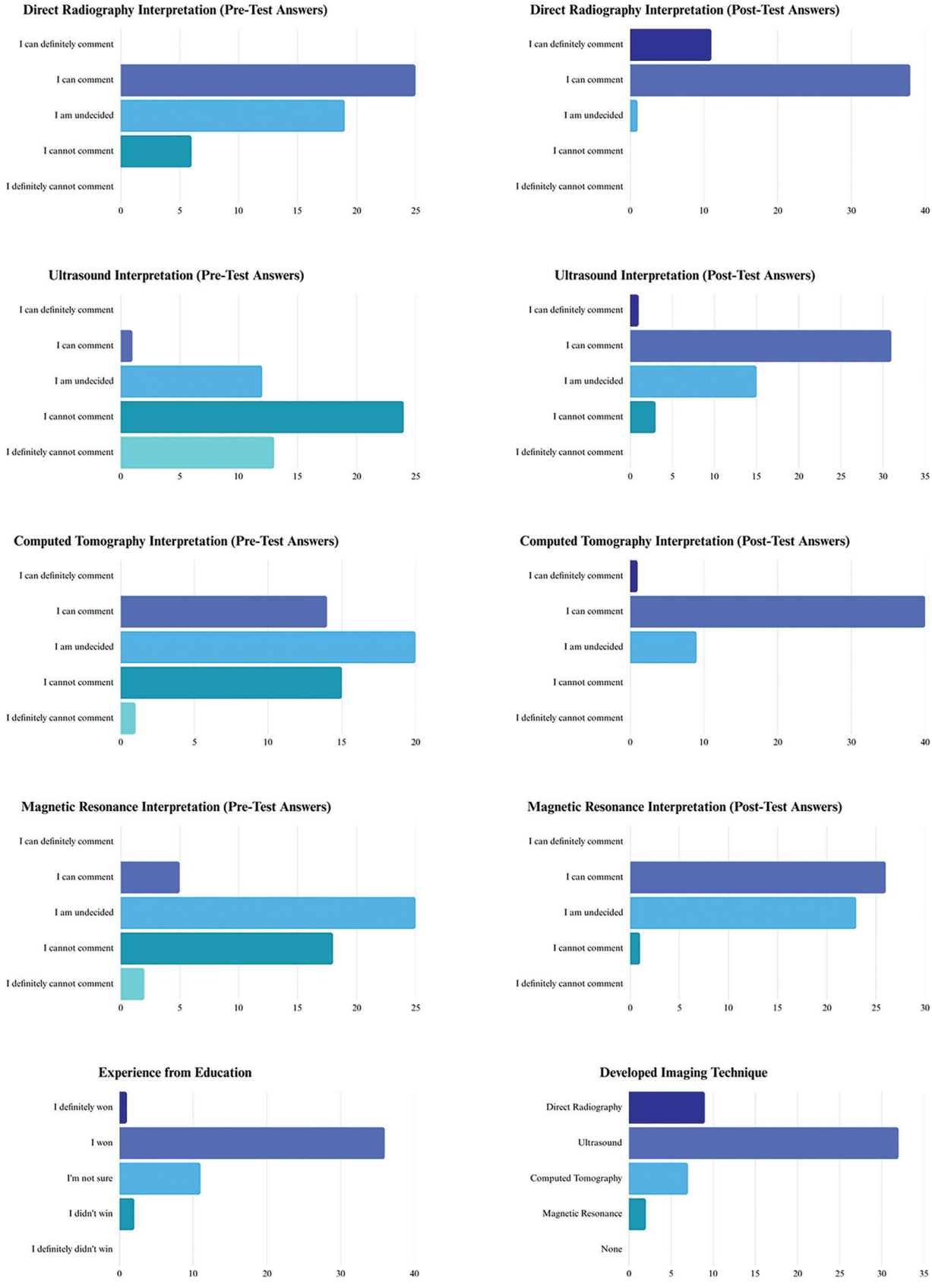

Figure 1. Graphical visualization volunteers' responses

Table 2. Pre- and post-test average score statistics			
Radiological method	**Pre-test**	**Post-test***	**p-value**
Direct radiography (%), median (IQR)	25 (IQR: 25-50)	75 (IQR: 50-75)	**0.001**
Ultrasound (%), median (IQR)	0 (IQR: 0-0)	100 (IQR: 100-100)	**0.001**
Computed tomography (%), median (IQR)	33.3 (IQR: 33.7-66.7)	100 (IQR: 66.7-100)	**0.001**
Magnetic resonance (%), median (IQR)	(IQR: 0-100)	100 (IQR: 0-100)	**0.019**
*: Correct answer percentage, IQR: Interquartile range (25p, 75p)			

Table 3. Pre- and persistence test average score statistics			
Radiological method	**Pre-test**	**Persistence test***	**p-value**
Direct radiography (%), median (IQR)	25 (IQR: 25-50)	75 (IQR: 50-75)	**0.001**
Ultrasound (%), median (IQR)	0 (IQR: 0-0)	85.7 (IQR: 71.4-96.4)	**0.001**
Computed tomography (%), median (IQR)	33.3 (IQR: 33.7-66.7)	77.8 (IQR: 66.7-77.8)	**0.001**
Magnetic resonance (%), median (IQR)	0 (IQR: 0-100)	100 (IQR: 75-100)	**0.001**
*: Correct answer percentage, IQR: Interquartile range (25p, 75p)			

Table 4. Post- and persistence test average score statistics			
Radiological method	**Post-test***	**Persistence test***	**p-value**
Direct radiography (%), median (IQR)	75 (IQR: 50-75)	75 (IQR: 50-75)	0.381
Ultrasound (%), median (IQR)	100 (IQR: 100-100)	85.7 (IQR: 71.4-96.4)	0.059
Computed tomography (%), median (IQR)	100 (IQR: 66.7-100)	77.8 (IQR: 66.7-77.8)	**0.006**
Magnetic resonance (%), median (IQR)	100 (IQR: 0-100)	100 (IQR: 75-100)	**0.001**
*: Correct answer percentage, IQR: Interquartile range (25p, 75p)			

intrinsic motivation and engagement during case-based imaging training, as radiologic interpretation directly contributes to their future clinical decision-making processes.

In the assessment dimension, it is emphasized that standardized and comparable assessment tools are still limited in US education; multiple-choice knowledge tests and self-assessment forms are frequently used. Objective structured clinical exams directed objective procedural skills/objective structured assessment of ultrasound skills (OSAUS) like frameworks that measure practical competence objectively and observationally need more systematic integration (8). In this context, the pre-, post-, and retention-knowledge exams used in our study are effective. It is recommended to add performance-based measures with structured practice stations (e.g., FAST/eFAST OSAUS checklists) at a later stage.

Study Limitations

The main limitations of the study are the single-center design, sample size, and the presence of a subjective perception component in the questionnaire items. In addition, the retention assessment was conducted only one month after the training, which does not allow for definitive conclusions about long-term knowledge retention. Given the partial decline observed in CT and MRI performance, it is possible that this decrease will further progress over longer follow-up periods (e.g., 6 months or 1 year).

Conclusion

The data obtained show that the case-based and practice-oriented mixed curriculum, in the emergency department context, significantly enhances short-term learning and provides high retention in direct radiography and US in one month.

Ethics

Ethics Committee Approval: This study was approved by the institutional review board and ethics committee of Recep Tayyip Erdoğan University in Türkiye (decision no: 2025/357, date: 31.07. 2025).

Informed Consent: Patients' consent was obtained from the patients before starting the study.

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Footnotes

Authorship Contributions

Surgical and Medical Practices: İ.A., Ö.B., Concept: İ.A., D.H., O.K., Design: M.M.Y., A.B.Ş., H.A., Data Collection or Processing: İ.A., E.G., Analysis or Interpretation: İ.A., Literature Search: İ.A., Writing: İ.A., Ö.B.

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