Effectiveness of a Multidimensional Formative Assessment Model Integrating Mini-CEX and DOPS on Enhancing Clinical Competency of Medical Imaging Interns

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Abstract: Objective: To investigate the effectiveness of an integrated Mini-CEX/DOPS formative assessment model in enhancing clinical competency of medical imaging interns. Methods: A quasi-experimental study enrolled 96 interns into an experimental group (n=48, integrated model) and control group (n=48, traditional assessment) from January 2024 to December 2025. Outcomes included competency scores, OSCE pass rates, and satisfaction. Results: The experimental group showed significantly higher scores in all six competency domains ($P<0.05$), higher OSCE pass rate (95.83% vs. 79.17%, $P=0.014$), and greater satisfaction (93.75%). Conclusion: The integrated model effectively enhances clinical competency through structured continuous feedback and self-directed learning.

***Keywords*:** Mini-CEX; DOPS; formative assessment; medical imaging; clinical competency

1. Introduction

Medical imaging is indispensable to modern clinical practice, requiring professionals with technical proficiency, clinical reasoning, patient communication, and professional judgment [1]. The clinical internship is pivotal for translating theoretical knowledge into practical competence [2]. Traditionally, assessment has relied on summative methods such as end-of-rotation examinations, which emphasize memorization over reasoning and provide limited feedback [3,4]. This encourages surface learning strategies rather than deep competency development [5].

Competency-based medical education (CBME) shifts focus from time-based training to outcome-based achievement [6,7]. Central to CBME is workplace-based assessment (WBA) in authentic clinical settings [8]. The Mini-Clinical Evaluation Exercise (Mini-CEX) and Direct Observation of Procedural Skills (DOPS) are two extensively validated WBA instruments [9]. Mini-CEX evaluates clinical encounters across history-taking, reasoning, communication, and professionalism with immediate feedback [10,11]. DOPS complements this by focusing on procedural skill observation [12,13].

Lörwald et al. demonstrated favorable effects of both instruments in a systematic review [9]. Wang et al. reported that combined Mini-CEX/DOPS significantly improved general practitioner training [14]. Sharma et al. confirmed Mini-CEX feasibility in undergraduate training [15]. However, most studies have focused on internal medicine or surgery rather than medical imaging, and few have examined integrated longitudinal models. This study developed and evaluated a multidimensional formative assessment model integrating Mini-CEX and DOPS within an OBE framework for medical imaging interns.

2. Methods

2.1 Study Design and Ethical Approval

This study employed a quasi-experimental controlled design with pre-test and post-test measurements, conducted from January 2024 to December 2025 at the Department of Medical Imaging of a university-affiliated tertiary teaching hospital. Ethical approval was obtained from the Institutional Review Board. All participants provided written informed consent, and the study adhered to the Declaration of Helsinki.

2.2 Participants and Grouping

Ninety-six medical imaging interns were enrolled. Inclusion criteria comprised: (1) full-time undergraduate medical imaging students in their clinical internship year, (2) completion of all prerequisite coursework, (3) voluntary consent, and (4) no prior clinical internship experience. Exclusion criteria included: (1) withdrawal before completion, (2) prolonged absence exceeding two weeks, and (3) concurrent participation in other educational interventions. Interns entering January 2024–December 2024 formed the control group (n = 48); those entering January 2025–December 2025 formed the experimental group (n = 48). Both cohorts followed identical rotation schedules and were supervised by the same faculty members to minimize confounding variables.

2.3 Intervention

2.3.1 Control Group

Traditional Assessment Model. The control group received the conventional assessment model: (1) a mid-rotation written examination covering imaging physics, anatomy, pathology recognition, and equipment operation, (2) an end-of-rotation practical examination in which interns performed one randomly assigned imaging procedure scored by global rating checklist, and (3) a subjective clinical performance evaluation by the supervising radiologist based on general impressions of attendance, attitude, and participation. Feedback was provided only upon request and was not systematically structured. Results were used primarily for summative grading purposes.

2.3.2 Experimental Group

Integrated Mini-CEX/DOPS Formative Assessment Model. The experimental group received the integrated model, developed through four phases guided by outcome-based education (OBE) principles. In Phase 1, an expert panel of eight senior radiologists and medical education specialists established 42 core competency indicators across six domains through a modified Delphi process: (1) imaging technique and equipment operation, encompassing patient positioning, parameter selection, and image acquisition across radiography, CT, MRI, and ultrasonography, (2) image quality assessment and optimization, covering diagnostic adequacy evaluation and artifact correction, (3) clinical reasoning and diagnostic thinking, addressing integration of clinical information with imaging findings, (4) patient communication and care, including informed consent, anxiety management, and contrast agent safety counseling, (5) radiation protection and safety compliance, encompassing ALARA principles and contrast reaction management, and (6) professional conduct and interdisciplinary collaboration.

In Phase 2, standardized Mini-CEX and DOPS instruments were adapted for medical imaging. The Mini-CEX evaluated seven dimensions: (1) patient interview and history-taking, (2) physical assessment and patient preparation, (3) clinical reasoning and examination justification, (4) communication skills, (5) professionalism, (6) efficiency and organization, and (7) overall clinical competence, each rated on a nine-point Likert scale (1–3: below expectations; 4–6: meets expectations; 7–9: exceeding expectations). Eighteen DOPS forms were developed covering plain radiography positioning, CT scanning with contrast protocols, MRI scanning with safety screening and sequence management, ultrasonographic examinations, and fluoroscopic procedures. Each DOPS assessed indication knowledge, informed consent, technical performance, post-procedural management, communication, and overall procedural competence.

In Phase 3, all 12 clinical supervisors completed a standardized four-hour training workshop covering formative assessment theory, Mini-CEX/DOPS instrument use, calibration exercises with standardized video recordings, and feedback delivery techniques. Inter-rater reliability was assessed using intraclass correlation coefficients (ICCs $\geq$ 0.75 required). In Phase 4, the model was implemented throughout the 12-month internship. Each intern completed a minimum of two Mini-CEX and two DOPS assessments per four-week rotation, totaling at least 24 of each annually. Each assessment was immediately followed by a 5–10 minute structured feedback session in which the assessor highlighted strengths, identified areas for improvement, and collaboratively developed an action plan. Interns completed self-reflection forms documenting perceived performance, key learning points, and improvement strategies. All data were recorded in a digital portfolio system generating longitudinal competency progression charts for both interns and supervisors.

2.4 Outcome Measures

The primary outcome was the composite clinical competency score assessed at baseline (week 1) and conclusion (week 48) using a 42-item instrument (five-point Likert scale; maximum 210 points; Cronbach's $\alpha = 0.89$). Secondary outcomes included: (1) a standardized 12-station OSCE at internship completion (pass threshold: 60%), (2) intern satisfaction via a 15-item questionnaire on a five-point Likert scale, and (3) assessor satisfaction and perceived feasibility.

2.5 Statistical Analysis

Analyses were performed using SPSS 26.0. Continuous variables were expressed as mean ± SD and compared using independent and paired t-tests. Categorical variables were compared using chi-square or Fisher's exact test. Cohen's d was calculated for effect sizes. $P < 0.05$ (two-tailed) was considered statistically significant.

3. Results

3.1 Baseline Characteristics

All 96 interns completed the study. Baseline characteristics showed no significant between-group differences (Table 1).

Table 1. Baseline characteristics

Characteristic	Experimental (n=48)	Control (n=48)	t/χ^2	P
Age (years)	22.35±1.02	22.19±0.98	0.792	0.430
Gender (M/F)	21/27	23/25	0.170	0.680
GPA	3.42±0.31	3.38±0.29	0.652	0.516
Baseline score	118.52±14.37	116.85±15.21	0.554	0.581

3.2 Post-Intervention Competency Scores

The experimental group achieved significantly higher scores across all six domains (Table 2). Largest effect sizes were in clinical reasoning (d=1.06) and communication (d=0.94). Total score: 178.63±12.84 vs. 158.42±15.39 ($P<0.001$, d=1.42).

Table 2. Post-intervention competency scores

Domain (max 35)	Experimental	Control	t	P	d
Imaging technique	30.25±3.18	27.13±4.02	4.226	<0.001	0.86
Image quality	29.81±3.45	26.58±4.28	4.076	<0.001	0.83
Clinical reasoning	30.48±2.97	25.94±5.31	5.149	<0.001	1.06
Communication	30.15±3.12	26.71±4.15	4.590	<0.001	0.94
Radiation safety	29.44±3.56	26.85±3.92	3.393	0.001	0.69
Professionalism	28.50±3.78	25.21±4.45	3.900	<0.001	0.80
Total (max 210)	178.63±12.84	158.42±15.39	6.956	<0.001	1.42

3.3 Within-Group Changes

Both groups improved significantly (Table 3). The experimental group showed greater improvement (60.11±10.52 vs. 41.57±12.86, $P<0.001$).

Table 3. Pre- vs. post-intervention total scores

Group	Pre	Post	Change	t	P
Experimental	118.52±14.37	178.63±12.84	60.11±10.52	39.56	<0.001
Control	116.85±15.21	158.42±15.39	41.57±12.86	22.39	<0.001

3.4 OSCE Performance

The OSCE pass rate was 95.83% vs. 79.17% ($\chi^2=6.095$, $P=0.014$). Mean scores: 82.35±7.62 vs. 73.48±9.85 ($P<0.001$). Station-level analysis showed significant advantages in communication, image interpretation, emergency management, and CT/MRI technique (Table 4).

Table 4. OSCE performance

Outcome	Experimental	Control	t/χ^2	P
Total score	82.35±7.62	73.48±9.85	4.935	<0.001
Pass rate	46(95.83%)	38(79.17%)	6.095	0.014
Communication	8.52±1.03	7.15±1.68	4.810	<0.001
Image interpretation	8.19±1.22	7.08±1.75	3.595	<0.001
Emergency management	7.85±1.35	6.73±1.92	3.310	0.001
CT/MRI technique	8.31±1.15	7.25±1.48	3.896	<0.001

3.5 Satisfaction

Overall, 93.75% of experimental interns rated the model as helpful vs. 62.50% in the control group (P<0.001). The experimental group reported higher satisfaction in feedback timeliness (91.67% vs. 41.67%), clarity of expectations (87.50% vs. 60.42%), and motivation (89.58% vs. 56.25%) (Table 5).

Table 5. Satisfaction (% agree/strongly agree)

Dimension	Experimental	Control	χ^2	P
Identified strengths/weaknesses	93.75%	54.17%	19.20	<0.001
Timely feedback	91.67%	41.67%	26.72	<0.001
Motivated to improve	89.58%	56.25%	13.50	<0.001
Clear expectations	87.50%	60.42%	9.26	0.002
Overall helpful	93.75%	62.50%	13.50	<0.001

4. Discussion

This study demonstrates that an integrated Mini-CEX/DOPS formative assessment model significantly enhances medical imaging interns' clinical competency. These findings are consistent with the broader literature. Gupta et al. concluded that formative tools including Mini-CEX and DOPS are essential to CBME [16]. Lee and Chiu emphasized that competency-based assessments should assist learners in progressing developmentally [17]. Our findings extend this evidence to medical imaging training.

The large effect sizes in clinical reasoning (d=1.06) and communication (d=0.94) are noteworthy. Traditional imaging assessment has prioritized technical skills over communication [18]. The Mini-CEX component required interns to conduct pre-procedural consultations and post-examination counseling under direct observation, which likely accounts for these improvements. This aligns with Jasemi et al. who found DOPS and Mini-CEX effective for clinical skills in a randomized trial [19].

Structured immediate feedback was central to improvements. Each assessment was followed by a collaborative feedback dialogue establishing improvement goals. Ritchie et al. found feedback most effective when timely and embedded within the learning process [20]. The digital portfolio system enhanced this by enabling longitudinal tracking. Barros et al. confirmed that portfolios promote critical thinking and self-directed learning [21]. The higher OSCE pass rate (95.83% vs. 79.17%) demonstrates learning transfer to standardized evaluation, consistent with Weissenbacher et al. [22].

The OBE-aligned design, with 42 competency indicators guiding assessment, ensured alignment between outcomes, activities, and evaluation. Chen et al. emphasized such alignment as critical for OBE effectiveness [23]. Höhne et al. noted that combining assessment methods compensates for individual limitations [24]. Regarding medical imaging specifically, H'ng et al. identified the need for improved assessment in radiology residency [25], and DOPS has been applied in radiography departments for competency engagement [26]. Our study extends these foundations to undergraduate imaging internship training.

The high satisfaction (93.75%) underscores formative assessment's motivational benefits. Branfield Day et al. found that learning-oriented assessment increased engagement [27]. Several limitations should be noted: the quasi-experimental design limits causal inference, the single-institution setting may limit generalizability, and long-term retention was not assessed. Future research should employ multi-center randomized trials with longer follow-up, and explore integration of AI-assisted assessment [28], programmatic assessment principles [29], and refined feedback modalities [30].

In conclusion, the integrated Mini-CEX/DOPS formative assessment model effectively enhances medical imaging interns' clinical competency through structured observation, immediate feedback, self-reflection, and longitudinal tracking within an outcome-based framework.

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