JOURNAL OF CONTEMPORARY MEDICAL EDUCATION, 2020
VOL 10, NO. 3, PAGE 94–101
10.5455/jcme.20190429063757

ORIGINAL ARTICLE

Open Access

Performance-based assessment in a pre-clinical medical school chest radiology curriculum: Student achievement and attitudes

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ABSTRACT

Objective: The purpose of this study is to evaluate student achievement and attitudes pertaining to a performance-based assessment in a medical student chest radiology curriculum using mixed quantitative and qualitative methods.

Methods: One hundred sixty-one second-year students participating in the 2015–16 academic year took a post-curriculum multiple-choice question (MCQ) exam. Students also underwent a performance-based assessment in the form of a chest X-ray (CXR) interpretation small-group session administered by radiology faculty at a picture archiving and communications system (PACS) workstation. Each student verbally interpreted one chest radiograph showing one of six pathologies and was given a numerical rating based on a standardized rubric. This score was compared to the correctness of the student's answer to the corresponding MCQ question on the same topic. All students completed a post-session questionnaire. Open-ended free-text responses regarding student attitudes were coded into qualitative themes by three independent raters. High inter-rater agreement was demonstrated by an average agreement index of 0.82 or greater (ranging from 0 to 1, with 1 indicating perfect agreement) for responses to the most frequent themes.

Results: There was no significant association between scores on the MCQ exam and performance-based assessment. Up to 90% of post-session questionnaire respondents indicated a Likert rating of 5 (*strongly agree*) when asked if the sessions improved understanding of CXRs and their ability to identify specific radiologic pathology. Dominant themes from open-ended responses were then derived.

Conclusion: Lack of agreement between student performance on the CXR interpretation small-group session and that on the parallel MCQ exam suggests that each of them measures a different type of achievement, with the former emphasizing skills over knowledge. Features most commonly valued by students in the performance-based assessment were its ability to reinforce prior knowledge, supply an authentic and relevant PACS experience simulating real life, and provide an opportunity for active practice of radiology interpretive skills.

ARTICLE HISTORY

Received April 29, 2019
Accepted November 27, 2019
Published April 20, 2020

KEYWORDS

Inter-rater coding; medical student education; multiple-choice question; performance-based assessment; radiology

Introduction

While traditional didactic teaching methods predominate in the pre-clinical years, recent trends in undergraduate medical education have emphasized innovative methods such as online learning, "flipped classroom," and problem-based learning and simulation [1–3]. A corresponding shift in the methods of assessing student achievement at the pre-clinical level in the United States has been slower to evolve, with multiple-choice question (MCQ) examinations remaining the standard method. Performance-based assessment is one alternative that was validated in the 1990s, but gradually declined in popularity since then, in part due to higher cost compared to MCQ exams [4].

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Performance-based assessment is a method of measuring achievement by observation of learners executing complex, multi-step tasks in an authentic and practical setting simulating real-life [5,6]. As explained by Miller, such examinations aim to assess what a student "does" rather than what they "know" [7]. This type of assessment has been applied to medical students in clinical rotations, most commonly in the form of an objective structured clinical exam (OSCE), but may also be suitable for pre-clinical learners in a radiology setting [8,9].

Keeping this background in mind, we proposed to study the role of performance-based assessment in a pre-clinical radiology curriculum by comparing it to an MCQ exam. We also sought to examine whether and why students valued this assessment format. We, therefore, developed and implemented a performance-based assessment in the form of a small-group chest X-ray (CXR) interpretation session for second-year medical students administered after the radiology curriculum, and examined student achievement and attitudes, using mixed-methods quantitative and qualitative evaluation.

Materials and Methods

Subjects

The study group comprised the entire second-year medical student class of 161 members from December 2015 to January 2016, with no exclusions. The study design was reviewed by our medical school's Institutional Review Board and was exempted from further review and monitoring.

Second-year medical student chest curriculum

The second-year medical student CXR workshop forms part of a mandatory integrated radiology vertical curriculum at our medical school, which has been previously described [10]. In the first and second pre-clinical years, the learning objectives are (a) to become familiar with the fundamental principles of different imaging modalities and (b) to recognize and understand the appearance of normal anatomy and pathological conditions. The material is presented predominantly online and is synchronized with topics covered during anatomy, pathology, and physical diagnosis courses.

All of the participants were given 15 instructional chest modules, distributed weekly in PDF electronic format via e-mail. These modules were created by faculty at our medical school and consist of text and annotated images of chest radiographs and Computerized Tomography scan images along with the corresponding pathology. Topics were derived from institutional objectives based on established curriculum, derived from the Alliance of Medical Student Educators in Radiology (https://www.aur.org/Secondary-Alliances.aspx?id=141). They were presented in the following order in consecutive weeks during the semester: Systematic viewing of chest radiographs posteroanterior view; systematic viewing of chest radiographs lateral view; evaluating quality of chest radiographs; consolidation; atelectasis; lung cavity; pleural effusion; pneumothorax; lung mass; chronic obstructive pulmonary disease; diffuse lung disease; congestive heart failure (CHF); unilateral white out of chest; mediastinal widening; and tubes and lines.

In addition, during the semester, students attended a 1-hour lecture presented by radiology faculty in which they were shown some of the common chest pathologies addressed in the chest module curriculum. At the end of the semester, students were required to pass (70% or greater correct answer rate) a 31-question MCQ exam covering this material.

Multiple choice question (MCQ) examination

Students encountered two types of questions on the MCQ exam. One required a basic understanding of disease processes, such as CHF and its manifestations on CXR. The second required image interpretation. For example, students may be required to recognize a pleural effusion on a radiograph.

Performance-based assessment

The performance-based assessment was accomplished during a required 45-minute CXR interpretation session in the Department of Radiology. Because of scheduling and logistical reasons, sessions were held 1 month after the MCQ exam. Students were randomly pre-assigned to a group of up to six students, and each group was assigned to one of four picture archiving and communications system (PACS) workstations, each staffed by a board-certified radiology faculty.

At each PACS workstation, the group viewed authentic patient cases on dedicated monitors (Barco, Kortrijk, Belgium) using standard department imaging software (Inteleviewer by Intelerad, Montreal, Canada). For each case, a unique, representative radiograph of the entity was presented. Each student group viewed the same six cases, which were radiographs of one patient each with lingular pneumonia, pleural effusion, CHF, pneumothorax, cavitary lung lesion, and mediastinal mass.

Each student in the group was assigned one of the six chest radiographs. Latin square counterbalance procedure was performed to determine the order in which the six cases were presented during the sessions to control the order effects in the repeated measurement of variables.

The selection of case topics was based on clinically relevant entities from the chest curriculum that students are likely to encounter in their clinical years. Care was taken to choose cases with findings that were expected to be relatively easily discernible by students, and with minimal or no other distracting abnormalities. Images were de-identified and pre-populated into a worklist. Frontal, and, if available, lateral, chest radiographs were presented for each case.

Each student was asked to verbally describe abnormal findings on their assigned chest radiograph using appropriate radiologic vocabulary and lexicon and was also expected to indicate the anatomic location and pathophysiologic meaning of the observed abnormality. If they wished to, they could analyze the radiograph systematically according to a checklist that they were taught earlier in the semester. Prompts were offered by the faculty if a student did not see the abnormality.

Each student was graded on a numerical scale based on a standardized rubric composed of three key metrics tailored for each case extracted from the chest radiology curriculum presented earlier. For example, in the pneumonia case, students were graded on their ability to localize the airspace density to the lingua and recognize air bronchogram and silhouette signs. These metrics were scored on a 1–4 scale, based on how many prompts they received, with lower numbers representing better performance. Grading criteria and the associated score were as follows: A student was able to describe finding and/or significance without any prompting from preceptor (one point), with one or two simple prompts (two points), with 3–5 more complex prompts (three points), and with more than five, continuous prompts; or a student was unable to describe findings (four points). A composite score was assigned to each student, by adding scores for each of the three metrics. Thus, the best possible composite score was 3 and the worst possible score was 12. A satisfactory score was considered six points or less.

Each student in the small group was scored on a single case. However, because the interpretation and student–instructor interaction were vocalized aloud and all six chest cases were visible on the PACS monitor to all students in the group, the session was designed such that all six students could learn from all of the cases. Students received a passing grade for the workshop if they attended, and were not informed of their rubric grade.

Post-session student questionnaire

Each student completed an anonymous questionnaire immediately following the session, prior to leaving the department. The questionnaire included both Likert scale questions and free-text response prompts regarding the value of the session.

Seven Likert scale questions were presented as a statement beginning with the stem "The session improved my understanding of how to," followed by the phrases "systematically approach reading a CXR," "identify a pneumonia," "identify a pleural effusion," "identify CHF," "identify a pneumothorax," "identify cavitary lung lesion," and "identify a mediastinal mass." Possible responses ranged from 1 (*strongly disagree*) to 5 (*strongly agree*).

Students provided free-text written responses to three open-ended prompts regarding how the performance-based assessment made use of prior knowledge, attitudes toward PACS workstation technology and authenticity of the session.

Quantitative analysis

The composite rubric score for the workshop CXR was calculated for each student. This score was compared to the correctness of each student's own answer to the question on the MCQ exam that covered the same topic, using Pearson's point-biserial correlation. All quantitative analyses were performed using SPSS software (IBM, Armonk, NY).

Qualitative analysis

Descriptive statistics were calculated for the Likert scale items on the post-session questionnaire. Questionnaire free-text responses were separated into qualitative themes and coded by three independent raters (F.M., T.D., T.S.). Frequencies of the highest modes for each theme were tabulated. Reliability of inter-rater coding was measured by computing an agreement index (AI), ranging from 0 to 1, with 1 indicating perfect agreement between all three raters, and 0 if each rater felt a response fell into a different theme category. The average AI of all responses was then calculated for each qualitative theme.

Results

Quantitative analysis

Mean rubric scores were satisfactory for all six CXR cases, ranging from 4.6 to 5.6 out of a possible 12 points, with lower scores indicating better achievement (Fig. 1). No significant association was found between correct response on MCQ exam and achievement on performance-based assessment for all the cases. For five of the cases, Pearson's point-biserial correlation coefficients were below 0.20. For one case, the CHF case, Pearson's correlation coefficient could not be calculated as all students answered this question correctly on the MCQ exam.

For four of the CXR cases (lingular pneumonia, pleural effusion, CHF and pneumothorax), a larger percentage of students correctly answered the MCQ exam question than achieving a satisfactory score on the performance-based assessment (Fig. 1). For example, for the pneumothorax case, 89% of students correctly answered the MCQ exam question, while only 75% achieved a satisfactory rubric score (six points or less) on the performance-based assessment. On the other hand, for two of the cases (cavitary mass and mediastinal mass), the opposite was true, with a larger percentage of students achieving a satisfactory score on the performance-based assessment than correctly answering the MCQ exam question. For example, for the mediastinal mass case, while 54% of students correctly answered the MCQ exam question, 77% achieved a satisfactory rubric score on the performance-based assessment.

Qualitative analysis

The response rate for the post-session questionnaire was 100%. The majority of students, up to 90%, indicated a Likert rating of five (strongly agree)

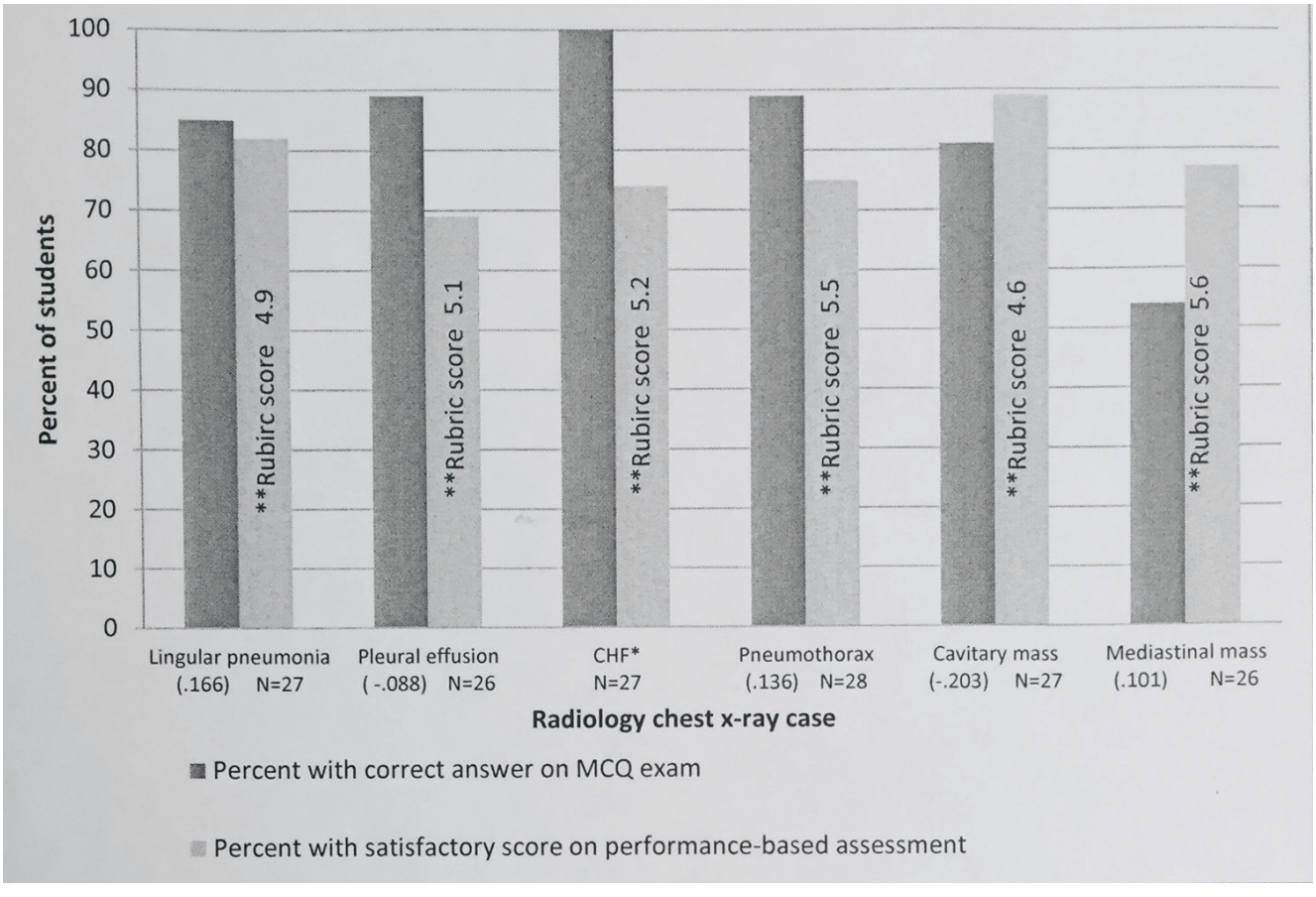

Figure 1. Student scores on MCQ compared to performance-based assessment. Graph depicting percent of students who answered MCQ correctly compared to those who achieved a satisfactory score on performance-based assessment for each of six radiology CXR cases. Point bi-serial Pearson's coefficients correlating the two sets of scores are displayed in parentheses. CHF = congestive heart failure. MCQ = multiple-choice question. *N* = total number of students who were scored on this case for both MCQ and performance-based assessment. *Pearson's correlation coefficient could not be calculated for the CHF case given that all students answered this question correctly on the MCQ exam. ** Mean rubric score on performance-based assessment, with scores of 6 or less considered satisfactory

when asked if sessions improved their understanding of specific aspects of CXR interpretation: Systematic approach to CXRs (73%), and how to identify specific pathology of mediastinal widening (80%), CHF (81%), pneumothorax (83%), pleural effusion (84%), pneumonia (84%), and cavitary lesion (90%).

The most common themes emerging from inter-rater coding of free-text responses to open-ended prompts in the questionnaire supported these findings and are shown in Table 1. High level of agreement in theme coding between the raters was demonstrated by agreement indices for top-rated responses of 0.82 or greater. Responses are reported as percentage frequency calculated as the number of students indicating this specific theme, divided by the total number of students answering the question. Because not all students answered all of the questions, the total number of students was less than 161 and ranged from 125 to 151. Students reported that their prior knowledge of specific radiographic signs and systematic checklist helped them in interpreting CXRs (42% and 32%, respectively), and also that they valued being able to reinforce this knowledge and improve their use of the checklist during the session (28% and 24%, respectively). Examples of student comments supporting these themes included: "The systematic approach helped in discussing the CXR out loud with group," "I was able to recognize a meniscus sign as an indication of pleural effusion," "Connecting cardiomegaly to pulmonary edema," and "Was able to understand mediastinal shift and its importance."

Other common themes demonstrated that students valued using the PACS during the assessment, specifically being able to manipulate images on PACS (27%), to see high-quality images (24%), and to participate in an authentic, relevant activity simulating real life (18%). Examples of student comments supporting these themes included: "More realistic to a hospital setting and gave us the ability to learn how to magnify," and "I was able to see how a radiologist approaches the system and can alter the view of the CXR."

In addition to the most common themes listed earlier, other relevant themes also emerged. Students found the opportunity to practice active interpretation of chest radiographs helpful, noting "Enjoyed being put on the spot and ask questions = active learning," "It was really helpful to work through the cases with feedback as we went," "Got the practice reading an unknown X-ray and describe our findings to determine diagnosis," and "Forced to do it alone- shows what I do and don't know." Students also liked learning from classmates, explaining "Was able to listen to classmates' thought process which helped me catch a few things." Student comments, such as "Having a professor to critique interpretation was helpful," indicated they valued feedback from instructors.

Finally, students appreciated working with a radiologist in a safe learning environment.

Table 1. Most common themes emerging from inter-rater coding of student survey responses.

Coded themes of student responses*	Frequency of response/ total responses (%)**	Average AI#
Question 1: Provide at least one specific example of how you were able to use your prior knowledge of CXRs and chest pathology to help you in interpreting CXRs in this session?		
Use of specific radiographic signs (e.g. air bronchograms in air-space disease)	63/151 (42)	0.86
Use of organized, systematic checklist to approach CXR interpretation	48/151 (32)	0.96
Use of knowledge of chest pathophysiology	17/151 (11)	0.87
Question 2: How did reading the CXRs on the PACS monitor make the session more meaningful or authentic?		
Opportunity to manipulate image parameters	41/151 (27)	0.91
Higher quality images are easier to interpret	36/151 (24)	0.87
More "real life" and realistic experience	27/151 (18)	0.82
Question 3: Provide at least three specific examples of how this session improved or reinforced your knowledge of CXR interpretation		
Use of specific radiographic signs	38/136 (28)	0.93
Use of organized, systematic checklist to approach CXR interpretation	31/131 (24)	0.96
Opportunity to use PACS	11/125 (9)	0.85

*The three most frequent themes listed for each survey question.
**Number of students indicating this theme divided by the total number of students answering the question, with percent in parenthesis.
#Average AI with three raters and possible range 0–1.

Comments included, "Radiologist shared a lot of helpful insight and encouragement as we read the X-rays," "Radiologist did a good job of breaking down her thinking," "Was able to ask radiologist questions for more details that I was not able to before," "Great explanation and very courteous. Thank you for taking the time to give us each individual questions and allow us to learn," "I love these types of [sessions]. Very helpful to see how a trained physician looks at [CXR]."

Discussion

The results of our quantitative evaluation indicated that although accomplishment level on the performance-based assessment was high with mean rubric score at a satisfactory level for all six of the CXR cases, there was no agreement between student performance on this assessment and that on a parallel MCQ exam. This suggests that the CXR interpretation session performance-based assessment measures a different type of student achievement than that measured by the MCQ exam, with the former emphasizing skills over knowledge. Generally, traditional assessments such as MCQ exams are thought to focus on rote memorization and theoretical knowledge, while performance-based assessments are thought to focus on practical skills and what one "ought to be able to do" [9].

In four of the CXR cases, a larger percentage of students correctly answered the MCQ exam question than achieving a satisfactory score on the performance-based assessment.

Our study was not designed to examine the reason for this, but we conjecture that one possible explanation is that while the MCQ exam tests how much material the learner has mastered, the higher level order critical thinking required by the performance-based assessment could reveal gaps in the process used to arrive at the correct answer. On the other hand, for two of the CXR cases, the opposite was true, with a larger percentage of students achieving a satisfactory score on the performance-based assessment than correctly answering the MCQ exam question. We speculate that such results can be seen when students were able to display the correct thinking process but were unable to arrive at the correct answer.

The discrepancy between achievement on MCQ exam and performance-based assessment is supported by prior work comparing the OSCE to written exams. An OSCE is a type of objective examination of professional competence that could be considered to be a specific form of a performance-based assessment, with both exams sharing the fundamental similarity of requiring students to perform clinical skills under standardized conditions while being observed. OSCEs are currently used worldwide across many medical disciplines at the undergraduate medical education level, though less commonly for radiology [11,12]. Studies have shown that the OSCE was a stronger predictor of subsequent performance by students than written assessment in a fifth-year undergraduate medical school curriculum in New Zealand [8]. An assessment of medical students rotating in anesthesiology showed equivalent scores between MCQ and OSCE but with poor correlation [9]. Similarly, a hands-on workshop for medical students regarding infant feeding resulted in better performance on a posttest as well as improved retention [13].

Qualitative analysis of themes emerging from the student survey showed that students appreciated the performance-based assessment CXR session and shed light on what they valued about the session. Learners felt that the sessions improved their ability to evaluate a CXR by reinforcing the use of a systematic checklist and the use of previously learned specific radiologic signs associated with certain pathologic processes. Students also indicated that the authenticity of the assessment session and simulation of a relevant, real-life situation was valuable to them. This was particularly evident to learners with regard to the PACS, whereby they could interact with and manipulate the CXR images, such as changing window and level and magnifying, rather than viewing a static image on a PowerPoint slide. In addition, students embraced active learning where they were able to practice skills they had previously read about, such as integrating observed signs on the CXR with prior knowledge of the radiographic appearance of specific pathophysiology to arrive at the diagnosis of CHF. This attitude mirrors prior studies showing that medical students valued being able to practice radiology interpretive skills [14].

The performance-based assessment CXR session was also designed to provide feedback to the students, which was a characteristic they found valuable. Such formative assessments focus on the development of and feedback to learners, rather than strictly summative assessment focusing on program outcome [6]. The survey indicated that students found it helpful to receive immediate and on-going feedback and critique from the instructor

as they worked through the cases. The importance of a cooperative group learning setting such as in our CXR session, was emphasized when students indicated on the survey that they found formative feedback directed not only to themselves but also to their peer learners, helpful for improving their understanding of the topic.

The format of our performance-based assessment resembles the "hot-seat" style case-based teaching conference previously common in radiology residencies utilizing the Socratic method of questioning the learner in order to promote active engagement and develop critical thinking skills [15,16]. In this format, most often, a single learner is called on to analyze an imaging case in front of other learners in a small group setting [14]. Currently, this pedagogical style has fallen out of favor in radiology residencies in preference to arrangements perceived to be less threatening, such as anonymous audience response, and more congruous to the new MCQ American Board of Radiology certification exams [17]. Our medical students, however, were not intimidated by this format. On the contrary, they indicated on the survey that they found "being put on the spot" and being "forced to do it alone," a positive rather than negative feature of the performance-based assessment. This mirrors the results of a study by Zou showing that third- and fourth-year medical students preferred to learn radiology by a Socratic rather than a didactic method, suggesting that this type of practice still has value to millennial learners [14,15]. Focus can be directed to promoting active learning in a purposeful manner by creating a non-threatening learning environment while giving individual attention to each student. The rush to abandon the Socratic approach in radiology should be reconsidered, as our survey suggests that this method can be welcomed for both teaching and assessment purposes by trainees as early as the second year of medical school.

It should be acknowledged that organizing such a performance-based assessment requires a significant time commitment from radiology faculty and the use of department resources such as PACS workstations. In addition, advance planning on the part of the students and medical school staff is necessary to organize the logistics of arranging a face-to-face meeting for an entire class numbering over 150. Nevertheless, because of the value placed on the CXR session by the students, our school has decided to continue the performance-based assessment. As our results showed that the MCQ exam also contributed information not supplied by the CXR session, we have decided that rather than replace the MCQ exam with the performance-based assessment, we will provide both types of assessment at the end of the second-year medical student radiology curriculum.

Because the small group CXR interpretation session was administered after, but not prior to, the beginning of the radiology curriculum, we were unable to perform a pre- and post-intervention comparison, thus constraining the generalizability of our results. Other limitations include the small numbers of students that interpreted each of the six CXR cases. Finally, although the creation of quantifiable metrics for the rubric was an attempt to standardize the performance-based assessment, a subjective element to the grading remained and variation between raters was still possible.

In conclusion, quantitative analysis of a second-year medical student chest radiology curriculum performance-based assessment in the form of a CXR interpretation session showed that there was no agreement between student performance on this assessment and that on a parallel MCQ exam. This suggests that the two assessments measure a different type of achievement, as supported by prior literature, differentiating knowledge from skills. Qualitative analysis of the student survey revealed dominant themes pertaining to student attitudes which indicated that the features most commonly valued in the performance-based assessment were its ability to reinforce prior knowledge, supply an authentic and relevant PACS experience simulating real life, and provide an opportunity for active practice of radiology interpretive skills.

Compliance with ethical standards

Conflict of interest

The authors declare they have no conflicts of interest

Statement of human right/Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

The study design was reviewed by Loyola University Medical Center Institutional Review Board (Loyola University IRB number 206620) and was exempted from further review and monitoring.

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