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A Multi-observer Study of the Effect of Including Point-of-care Patient Photographs with Portable Radiography: A Means to Reduce Wrong-Patient Errors

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Abstract

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Hospital errors are the third leading cause of deaths in the United States. Within radiology, an important source of error is a wrong-patient error, wherein one patient's imaging study may be placed in another patient's folder in the Picture Archiving and Communication System. Despite the current technique for using dual-identifiers for patient identification, wrong-patient errors continue to occur. One potential solution is to include a patient's facial photograph with their respective radiograph. To test this, a prospective radiologist observer study with simulated wrong-patient errors was conducted in the 2012 American Board of Radiology's Oral Examination setting. Patient radiographs and photographs were obtained in two cardiothoracic intensive care units at Emory University, Atlanta GA. A total of 30 patients contributed 166 simultaneously obtained radiograph-photograph combinations. Eighty-seven radiologists with varied experience participated. Each radiologist interpreted a unique, randomly chosen set of 10 radiographic pairs with or without photographs and containing up to 10% simulated wrong-patient errors. Sensitivity for error detection and time for interpretation of each pair was measured. Patient photographs increased sensitivity for error detection from 29% (8/28) to 82% (23/28) ($P < 0.001$). The odds ratio for error detection with photographs was 11.5 (95% CI: 3.5, 44.9). Observer qualifications, demographics, training or practice subspecialty did not influence sensitivity. Interpretation time medians (range) without and with photographs were 52 (22-19) and 61 (17-140) seconds, respectively ($P = 0.85$). The results indicate the addition of patient photographs significantly increased the identification of wrong-patient errors and offers a potential means to increase patient safety. While the introduction of patient photographs does not appear to significantly increase the interpretation time, further examination of the impact of including patient photographs on radiology workflow is an important next step.

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INTRODUCTION

The Institute of Medicine's Quality Report estimates that between 44,000 and 98,000 deaths annually may be attributed to medical errors (1). Within radiology, an important source of error is the wrong-patient error, wherein one patient's imaging study may be placed in another patient's folder in the Picture Archiving and Communication System (PACS). In an attempt to prevent wrong-patient errors, the Joint Commission's first specific requirement in its National Patient Safety Goals (NPSG) is that at least two identifiers are required while delivering healthcare (2). The two identifiers can be any combination of name, date of birth, social security number, hospital assigned number, or telephone number. While this technique is effective in a variety of clinical settings, wrong-patient errors continue to occur. For example, patients who may be unconscious, inebriated, and otherwise nonresponsive can make using these identifiers difficult. Furthermore, these errors may occur in high-throughput radiology settings such as cardiothoracic intensive care units (ICUs). In this setting radiographs are obtained with portable x-ray equipment and there are several potential points of potential failure. For example, upon completing a radiographic examination a technologist must successfully associate a patient's identifier (barcode on the patient's requisition order) with the x-ray image (barcode on the x-ray plate). The patient is then linked with the image when the study is uploaded to the PACS. If a technologist inadvertently associates the wrong patient in his/her stack of requisition orders, the new radiograph will be incorrectly associated with a different patient. By acquiring facial photographs at the point-of-care of medical imaging, an extrinsic identifier, the face, can serve as an identification mechanism used with medical imaging examinations to potentially offset such errors.

The primary hypothesis is that the use of point-of-care facial photographs obtained at the time of portable radiography increases radiologists' likelihood of detecting wrong-patient errors. The secondary hypothesis is that the effect of the use of photographs on the likelihood of detecting wrong-patient errors is modified by subspecialty, or years of experience. We also examined whether the introduction of photographs increases the interpretation time for radiologists. In this thesis these hypotheses are tested in the setting of a large observer study.

BACKGROUND

The National Quality Forum recognizes that wrong-patient errors may affect radiologic practice and, along with the Agency for Healthcare Research and Quality, specifically endorses implementation of a "standardized protocol to prevent mislabeling of radiographs" in its fact sheet of safe practices for better health care (3). Limited information exists in the published literature regarding mislabeled or misidentified patient errors. Gale and Gale (4) reported an error rate of 0.26% in 48,800 imaging examinations. Although such an error rate can lead to substantial problems in patient management, in fact, this study may under-report the true error rate. For instance, many errors are likely detected by technologists at the time of completing the imaging study. Such errors are generally unreported because the error can be corrected before the mismatch comes to the attention of a radiologist or a referring clinician. Other errors may not be detected at all because the body habitus of both patients in the mismatched pair may be similar.

There are no federal requirements to report adverse events and near misses in medical imaging (5). However, as of 2007, 26 states have been proactive in requiring hospitals and healthcare institutions to report such events including adverse events in radiology (6). One such system was initiated in 2004 by the Pennsylvania Patient Safety Authority (PSA). The PSA recently published (7) that it received 652 reports on radiology events in 2009: 30.1% (196 events) of the reported events were related to wrong-patient events preceded only by wrong procedures or tests at 50.0%. Of these 196 wrong-patient events, 47% (93 events) occurred in radiography. The report concluded that such errors "occur more frequently than healthcare providers and patients may realize" despite various quality improvement measures.

Schultz et al. (8) describe a Web-based radiology-specific patient safety reporting system at their institution, which recorded 19% (313 events) of reported events were related to patient identification over a two-year period. Patient identification was the second most common adverse event, with inappropriate examination coming in first at 26% (439 events). Of note, the reporting system required the reporting individual to be identified one year into the two-year observation period, which may have discouraged some users from reporting adverse events. At their institution the average annual volume was 930,000 examinations. Although patient misidentification occurred in only 0.017% of all imaging examinations, this is far from ideal.

A voluntary event reporting system for radiology at another institution in the United States identified 62 near misses over a two-year period and patient misidentification (16% of reported events, 10 events) was the third most common error (9). 65% of reported events were assigned maximum severity scores. Moreover in 73% of the reported events with the maximum severity score, there was no explicit step in the care chain that could have prevented assigning the worst outcome (9).

While the Joint Commission's first specific requirement in its National Patient Safety Goals (NPSG) requires two identifiers while delivering healthcare (2), these identifiers can be a problem in patients who may be unconscious, inebriated, and otherwise nonresponsive. The use of an extrinsic identifier (e.g., acquiring facial photographs at the point-of-care of medical imaging) may offer an alternative. This identifier will not replace standard identifiers where such identifiers can be obtained; however, in some cases of incapacitated patients, this may be the only identifier available.

In prior work (10), a system was developed that automatically obtains patient photographs simultaneously with portable chest radiographs. The system requires no input from the technologists and thus does not impact the workflow at this level. Complementing this system, a feasibility study was conducted wherein ten radiology fellows and junior faculty at the Emory University Department of Radiology and Imaging Sciences evaluated portable chest radiograph pairs both with and without the presence of photographs (11). Radiograph-photograph combinations were obtained from 27 patients admitted to two cardiothoracic ICUs at Emory University Hospital (EUH) over a three-month period.

A significant improvement was found in radiologists' sensitivity for detecting misidentification errors when facial photographs were introduced, 12.5% to 64% with the addition of photographs. Only one out of 10 readers was able to identify errors in the absence of photographs. This pilot study also confirmed that a computer-based user-interface for radiographic evaluation was readily accepted by radiologists who participated as observers in the study.

Guided by this feasibility study, the current study assesses whether the use of patient photographs improves the error detection capabilities of a large, diverse group of academic radiologists from various subspecialties and institutions who possess a range of experience levels.

METHODS

The study goal was to determine if the integration of patient point-of-care facial images affected a radiologists' ability to detect a wrong-patient error. The primary hypothesis was that the use of point-of-care facial photographs obtained at the time of portable radiography increases radiologists' likelihood of detecting wrong-patient errors. The secondary hypothesis was that the effect of the use of photographs on the likelihood of detecting wrong-patient errors is modified by: (a) whether subspecialty of the radiologist is cardiothoracic vs. non-cardiothoracic, or (b) whether the years of experience of the radiologist post-residency is greater or less than 10 years. Another goal was to examine the effect on interpretation time due to the introduction of patient photographs to radiologist workflow.

Study Design and Research Subjects

This prospective study was approved by Emory University's Institutional Review Board. Full, written informed consent was obtained from either the subjects recruited into the study, or from one of their family members authorized to provide consent.

The data were gathered from two cardiothoracic ICUs using a convenience sampling method between August 5, 2011 and November 8, 2011.

For each patient recruited into the study, radiograph-photograph combinations were obtained when portable radiographs were ordered for clinical indication by the referring services. A total of 41 patients were recruited into the study; however 11 of these patients had only one radiograph-photograph combination, and thus the final study cohort consisted of 30 patients (Table 1). These patients each provided a variable number of radiograph-photograph combinations, from which image pairs were generated as discussed below.

Data Acquisition and Case Selection

Photographs were obtained with a 5-megapixel camera on an Apple iPhone 4 (Apple Inc., Cupertino, CA), and were converted from JPEG into the Digital Imaging and Communication in Medicine (DICOM) format. This color photograph was then stitched together with the corresponding radiograph, with the photograph measuring approximately ¼ the size of the radiograph (Fig. 1).

Anonymized study pairs were generated by combining two sequential radiographs from the same patient, i.e., a current radiograph and the most recent previous radiograph were presented as a pair of images to the reader for interpretation. When more than two radiographs existed for the same patient, every two consecutive images were paired (Fig. 2). No radiograph appeared in two different pairs.

Display Workstation Environment

ClearCanvas Workstation Community Edition (ClearCanvas Inc., Toronto, Ontario, Canada)—a Free and Open-Source Software DICOM viewer was used for the study. The viewer provided capabilities for image manipulations, such as zoom, pan, and invert, among others. The open source nature of the software allowed development of custom modules necessary for study. ClearCanvas workstation software was loaded on two individual workstations running Microsoft Windows 7, with dual 21” LCD displays. The following three application functions were developed:

- The Observer Demographics function allowed the observer to enter demographic information, such as name, age, and specialization, and loaded images automatically from a predetermined worklist.

- The Review Study Component function presented the observer with a popup window containing a questionnaire at the end of each pair reviewed (Fig. 3). The Review Study Component also included a timer, which recorded the interpretation time per image pair. Once an observer completed the evaluation for the current image pair, the responses were saved to a database and the next image in the worklist was presented automatically.
- After the final (10th) study was presented, the Post-Study Questionnaire function was accessed by the "Next Study" button (Fig. 4). Depending on whether the images presented to the observer were with or without pictures, the Post-Study Questionnaire function generated questions accordingly.

Observer Study Design

The observer study was also performed with approval from Emory University's Institutional Review Board and with permission from the American Board of Radiology (ABR). The study was performed at the ABR Oral Examination setting in Spring 2012. Oral board examiners, who are all board certified, representing all radiologic subspecialties, from all over the United States, and one international observer from Australia, were recruited to participate in the observer study over a four-day period. Observers were informed during their oral examination orientations that the study was to evaluate radiologist performance in interpreting portable chest radiographs. Observers were not informed that some of them would read radiographs with photographs and some would read them without photographs, nor were they informed that simulated wrong-patient errors could be introduced into the sets of cases that they would be interpreting. Written sheets of information regarding the study were provided to the observers, and an observer's presence at the research study center was considered to represent consent to participate in the study.

Each of the observers participated in the study during a 20-minute break between administering oral examinations. Observers were randomly assigned to interpret a set of 10 pairs of cases with or without concomitantly obtained photographs. To avoid any reader learning or memory effects, the ten pairs were chosen starting with the pool of 83 pairs without replacement for each set. A block randomization procedure was followed with each block containing 12 sets of cases (6 without photographs and 6 with photographs). In each of the first five blocks, three randomly selected error pairs were introduced randomly into three of the sets without photographs, and three randomly selected error pairs were introduced randomly into three of the sets with photographs. That is, three of the observers in this block who read sets without photographs each saw a single error pair, while the other three observers did not. Similarly, three of the observers in this block who read sets with photographs each saw a single error pair, while the other three observers did not. To enrich the study population, for the remaining blocks, one error pair was randomly introduced into all 12 sets, so that each observer, whether interpreting with or without photographs, saw exactly one error pair randomly interspersed within their 10 pairs of cases.

Initially, demographic information was collected from all observers using the custom-built Observer Demographics function. Observers were all given identical instructions. Each was asked to treat the session like a true clinical setting and interpret pairs of chest radiographs and provide only the information that they would normally provide in a real world set of portable cases (Fig. 3). The observers were randomly assigned to one of the two workstations based on availability. One of two study team members was always present with the observer to assist with any questions. A study team member demonstrated the software controls for window level, reset, inversion, next study, etc. For each case, the observer had to interpret the current portable radiograph in comparison with a temporally prior radiograph and asked to answer the four questions in Fig. 3, which were provided by the Review Study Component in the form of a popup window. For the first three questions, the software only allowed the observer to click on radio buttons for the possible choices. The last question was a free-text question that allowed observers to enter any additional information that they thought might be clinically relevant or interesting.

Since observers were not informed about the possibility of errors, the last free-text response was introduced in an attempt to capture possible observation of a wrong-patient error without leading the observer. Most observers who identified mismatches made a note of the mismatch in the response to this free-format question. Some observers, who identified a mismatched image pair, notified a team member presuming a software error. They were asked to make a note on the questionnaire's "Other Comments" section and to proceed with the rest of the study.

Once an observer answered the four questions, the next case was automatically shown to them. The time spent on each case pair in the set was recorded; however, the time spent on the first case was not used for statistical analysis since most observers used the first case to get accustomed to the workstation controls and reading process.

At the end of their set of 10 cases, the Post-Study Questionnaire function asked observers who interpreted studies with photographs to complete a survey with the questions shown in Fig. 4. Again, three of the four questions only allowed them to select between choices, while one (Question 3) allowed a free-text response. Observers who interpreted studies without photographs were asked to choose "yes" or "no" for the questions: "Did you notice any mismatch errors in your list?"

At the end of each observer's session, the purpose of the study was revealed and the observer was requested not to disclose it to other potential observers to maintain study integrity.

Data Analysis

Continuous data are reported as means or medians, where appropriate, and categorical variables are reported as frequencies with percentages. The two-tailed χ^2 test was used to compare error detection rates without and with photographs. Logistic regression was used to analyze the univariate association of a predictor with the likelihood of detecting a wrong-patient error. Predictors included current subspecialty in cardiothoracic radiology and current specialties that are expected to be competent in interpreting chest radiographs, experience level (experience > 10 years vs. experience ≤ 10 years), gender, age category (age > 45 vs. age ≤ 45), and fellowship in cardiothoracic radiology. More specifically, experience level greater than 10 years post-residency was considered experienced. Similarly, age greater than 45 years was used since the average age of residency completion is 35 years. Therefore, 10 years post-residency results in an average age of 45 years. The imaging specialties of abdominal, cardiothoracic, interventional, musculoskeletal and general radiology were considered as observers expected to be competent in reading portable chest radiographs.

An odds ratio was computed to compare the occurrence of finding an error given the variable of interest. The corresponding P-value for the regression coefficient and 95% confidence interval was also obtained. To test for effect modification, logistic regression on outcome of detecting a wrong-patient error with photograph-predictor pairs with an interaction term was also used.

The Student t-test was performed on log-transformed observer interpretation time to compare the average times taken by readers who interpreted radiographs without and with photographs. The corresponding P-value for the regression coefficients and 95% confidence intervals were also obtained. For all statistical tests, a P-value of ≤ 0.05 was considered to indicate a significant difference. All statistical analyses were performed using JMP Pro 10 software (SAS Institute Inc., Cary, NC, USA)

RESULTS

Data Generation

A total of 166 chest radiographs along with photographs were obtained. Some ambiguous chest/abdominal radiographs from the set were eliminated resulting in 83 pairs of radiographs. Error pairs were generated by randomly pairing radiographs from two different subjects. For generating each error pair, one patient was randomly selected and then one radiograph from that patient was selected to represent the current radiograph. Then, a second patient was randomly selected from the remaining 29, and a randomly selected radiograph from this second patient served as the comparison radiograph. It was ensured that the comparison radiograph was temporally earlier than the current radiograph.

Figure 1 shows a representative wrong-patient error that was randomly generated during the study from the 166 composite radiograph-photograph combinations. Fig. 1(A) shows a 64 year-old white woman with history of aortic stenosis and aortic valve replacement; Fig. 1(B), a radiograph obtained two months earlier, shows a 73 year-old man also with a history of aortic stenosis and aortic valve replacement. The radiographic differences are subtle and mainly related to body habitus.

Figure 5 shows a representative wrong-patient error without photographs. Fig. 5(A) shows an 89 year-old white man with a history of aortic stenosis, status post surgical aortic valve replacement; the surgical median sternotomy wires are clearly sign with proper window-level settings. Fig. 5(B), the comparison radiograph from three weeks earlier shows a 63 year-old female also with a history of aortic stenosis, status post percutaneous aortic valve replacement.

Observer Characteristics

A total of 90 observers were recruited into the study. However, due to a software error with initialization on day four of the study, three of the observers interpreted the same set of radiographic pairs as three other observers. The data from these three observers was excluded to maintain that each observer interpreted an independent set of 10 radiographic pairs. Thus, there were a total of 87 observers representing both genders, a wide range of subspecialty training and subspecialty experience, and overall years of experience (Table 2).

Quantitative Results

Over the four day period, 44 observers viewed 10-pairs of radiographs without photos and 43 observers viewed 10-pairs of radiographs with photos (Fig. 6). A total of 28 errors were shown to readers who interpreted without photographs, and 8 (8/28 = 29%) of these errors were correctly identified as wrong-patient errors (Table 3). A total of 28 errors were shown to readers who interpreted with photographs, and 23 (23/28 = 82%) of these were correctly identified as wrong-patient errors. The likelihood of detecting a wrong-patient error by radiologist characteristics was also examined (Table 4, Fig. 7). All subgroups of observers performed better in terms of identifying wrong-patient errors with photographs than without photographs. Significance was achieved in many of these subgroups. Other observer characteristics perhaps did not achieve statistical significance because of the small numbers.

The univariate logistic regression comparing the odds of finding a wrong-patient error with and without photographs (Table 5) shows that a radiologist is 11.5 times more likely to find a wrong patient error with photographs (95% confidence interval [3.46, 44.89]). The two-tailed χ^2 test P-value < 0.001. Table 5 shows that the presence of a photograph was the only predictor for which the odds ratio of detecting a wrong-patient error is significant; in contrast all other observer characteristics do not affect the odds of detecting a wrong patient error.

For logistic regression on the outcome of finding a wrong-patient error, three models were considered. The first model (Model 1) considered the interaction between current subspecialty in cardiothoracic radiology and photograph on the outcome of detecting a wrong-patient error. The second model (Model 2) considered the interaction between experience level and photograph on the outcome of detecting a wrong-patient error. The third model (Model 3) considered the interaction between competency in reading portable chest radiographs and photograph on the outcome of detecting a wrong-patient error. There was no evidence of effect modification on the detection of a wrong-patient error with photographs by subspecialty in cardiothoracic radiology, experience level, or expected competency in interpreting portable chest radiographs (Table 6).

The median (range) interpretation time in seconds per radiograph pair without and with the presence of photographs was 52 (22-119) and 61 (17-140); Student t-test P-value = 0.85. The median (range) interpretation time in seconds per radiograph pair without and with the presence of photographs in the pairs *without* errors was 51 (29-119) and 56 (31-93); Student t-test P-value = 0.99.

Post-study Questionnaire

The post-study questionnaire completed by 40 of the 43 observers who interpreted the studies with photographs yielded the following results (Table 7).

- 80% of the observers felt that photographs were not a distraction.
- 42.5% of the observers subjectively felt that they spent more time because of the photographs.
- 42.5% of the observers reported that they found the photographs helped with the interpretation. Six of these observers specifically mentioned that the photographs helped with evaluating lines and tubes. Three specifically mentioned that it accelerated their discovery of the wrong-patient error. Fourteen of these observers stated that the photograph gave a sense of the patient's well being and alertness, although almost all of them cautioned that radiographic indicators can lag behind external appearances of patients.
- 100% of the observers who noticed a discrepancy between the current and prior photographs reported it prompted them to reexamine the radiographs for discrepancies.

DISCUSSION

The impact of including point-of-care photographs with portable chest radiographs in a large multi-reader study involving a diverse group of radiologists including those with different subspecialties and varying levels of experience was assessed. There was a significant improvement in their ability to detect wrong-patient chest radiographs when photographs were introduced, irrespective of whether they were chest radiologists or not. The introduction of photographs led to a small increase of <3 seconds to the average interpretation time of a radiograph (~5%).

Since wrong-patient error rates in radiology around the country are likely <1%, an argument could be made that techniques such as photography to detect these errors may not be cost-effective. At Emory University Hospital (EUH), an error rate of approximately 0.01% is reported, although this is likely a lower bound on the true error rate. Given approximately 1 million examinations annually at EUH and affiliated hospitals are performed, the absolute number of errors is still too high, since it probably results in over 100 errors annually just in one hospital system. Given that it has been shown that the cost of adding a photograph to a radiograph is perhaps a few pennies per examination (10), such a system may be beneficial in preventing patient harm while remaining cost-effective. Furthermore, such a system would likely pay for itself if it could avoid even a single lawsuit resulting from a wrong-patient error.

Relationship to Prior Studies

The idea of including photographs with medical imaging examinations was explored earlier by Turner and Hadas-Halpern (12), where they showed that the addition of photographs to CT scans increased both the word-length of radiologists' interpretation and the number of incidental findings that were reported. This study, however, did not evaluate the possibility of improved sensitivity for detection of wrong-patient errors.

Weiss and Safdar (13) conducted a single-institution survey of 21 radiologists to assess their perception of including photographs with medical imaging studies: 67% of the respondents said that photographs should not be included with medical imaging studies, although the respondents appear to have been answering the question without having experienced the effect of adding photographs to radiographs. This study asked a slightly different question of the observers who experienced the study with photographs, and only 20% of them thought that the photographs were distracting.

In the feasibility study at EUH, a significant increase in the error-detection capabilities of 10 recently trained radiologists from a single institution, none of whom were trained or served as subspecialty cardiothoracic radiologists, was demonstrated (11). That study design was slightly different in that the same radiologists interpreted sets of radiograph pairs both with and without photographs. The current study was conducted to evaluate if these results could be generalized to a larger set of radiologists with varying levels of experience and subspecialty training that included cardiothoracic imaging. Indeed, experience may matter in that several of the readers (8/28) were able to detect errors even without the presence of photographs. However, significant improvement in error detection capability was still obtained with the introduction of photographs.

Consideration of Interpretation Time

In contrast to the findings in the EUH feasibility study, which demonstrated a decrease in interpretation time with the introduction of photographs, this study found that there was a slight increase in interpretation time per radiograph for observers who were provided photographs although the difference in interpretation was not significant in either of the studies. In the feasibility study, we hypothesized that the decrease in interpretation could be attributed to two possible etiologies:

1) observers, who first interpreted without photographs and then with photographs, became accustomed to the mechanics of the study and were thus faster in phase 2 of the study, or

2) observers were faster with photographs because of the visual clues that the photographs provided regarding the presence, or lack, of lines and tubes. The interpretation of portable chest radiographs requires that a substantial portion of the time be spent on evaluating whether lines and tubes are external or internal to the patient and that the internal ones are appropriately positioned. It was conjectured that a photograph that showed no tubes entering the nose or mouth would speed up the reader since s/he would not have to spend time examining the radiograph for misplaced tubes, i.e., any tubes seen on the radiograph would be correctly and quickly surmised to be external (11). The current study suggests that such a benefit may not exist.

One potential explanation for our current finding of a minimal increase in interpretation time after the introduction of photographs may be the age and experience differences in the population of observers between the two studies. In the current study, the radiologists had significantly more experience (the prior study reported in (11) only enrolled either radiologists currently in fellowship training or radiologists who were first year faculty members). It is known that more experienced clinicians lag behind younger physicians in adopting new technology (14). It is possible that more experienced radiologists resist incorporating new technologies into their search pattern quickly.

In summary, the presence of photographs may be efficient, since the time that radiologists spend in making phone calls to ascertain whether a patient has a certain line of tube is not factored into this study. A clinical trial to study the effects of photographs in a real-world setting is warranted.

Strengths and Limitations

A major strength of the study is its magnitude. This is the first large-scale observers study with a diverse population of radiologists. Moreover, the computer-based user interface provided to the observers was well received suggesting that, while the study was simulated, the study environment approached the contemporary work environment of radiologists.

The results demonstrate that the inclusion of point-of-care facial photographs with portable radiographs significantly improves radiologists' sensitivity for detection of wrong-patient errors. This was not restricted to subspecialty, indicating that this technique could be widely applicable; hence the results may be generalizable.

There are several limitations of this study to consider. First, color photographs were shown in this study. It is possible that color could be more helpful in distinguishing facial features than gray-scale photographs, but this may not be possible in all settings since many radiology departments only have gray-scale monitors. However, many departments are migrating to color monitors in order to visualize color Doppler and power Doppler images from ultrasound studies, so this problem may diminish with time. Second, the observers who participated in this study were mostly academic radiologists, the majority of whom were engaged in subspecialty practice, and the performance of private practice general radiologists could be different. However, we included both cardiothoracic radiologists and non-cardiothoracic radiologists both with a wide range of experience levels that may mitigate against this potential bias. For example, many of the recruited observers had training in a different subspecialty, but did read portable chest radiographs while they were on call: this could approximate the competence level of a private practice generalist with respect to interpreting portable chest radiographs. While none of the observer characteristics such as age, number of years of experience, subspecialty training or practice, or practice location were found to be significant predictors in the ability to detect wrong-patient errors, this may have been due to our relatively small sample size and reduced power for these secondary outcomes.

CONCLUSIONS

In summary, the results demonstrate that the inclusion of point-of-care facial photographs with portable radiographs significantly improves radiologists' sensitivity for detection of wrong-patient errors. The inclusion of such photographs could impact patient care and safety in medical imaging. Understanding the interpretation time overhead is an important next step.

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Table 1. Patient Characteristics		
Characteristics		**Value**
Age*		61 ± 15 (range: 22 to 89)
Gender**		
	Male	15 (50)
	Female	15 (50)
Four most common diagnoses**		
	Aortic stenosis	10 (33.33)
	Congestive heart failure	12 (40)
	Mitral valve regurgitation	4 (13.3)
	Coronary artery disease	3 (10)
	Other	1 (3.3)
Four most common surgeries**		
	Aortic valve replacement	9 (30)
	Left ventricular assist device	6 (20)
	Mitral valve replacement	3 (10)
	Coronary artery bypass graft	3 (10)
	Other	9 (30)

*Data presented as mean ± standard deviation
**Data presented as number and % in parentheses

Table 2. Observer Characteristics			
Characteristic	Value **without** photos (n = 44)	Value **with** photos (n = 43)	**Total**
Age* (years)	53 ± 10 (35, 83)	53 ± 9 (37, 82)	53 ± 10 (35, 83)
Gender**			
Male	26	27	53 (61)
Female	18	16	34 (39)
Years post-residency training	22 ± 18 (4, 52)	21 ± 10 (6, 50)	21 ± 10 (4, 52)
Fellowship training			
Yes	37	36	73 (84)
No	7	7	14 (16)
Fellowship subspecialty			
Abdominal	10	5	15 (17)
Breast	2	4	6 (7)
Cardiothoracic	7	9	16 (18)
Interventional	5	5	10 (11)
Musculoskeletal	2	4	6 (7)
Neuroradiology	2	2	4 (5)
Nuclear medicine	2	3	5 (6)
Pediatric	4	4	8 (9)
Other	3	1	4 (5)
Not applicable	7	6	13 (15)
Current subspecialty practice			
Abdominal	10	6	16 (18)
Breast	8	7	15 (17)
Cardiothoracic	9	9	18 (21)
Interventional	4	5	9 (10)
Musculoskeletal	3	6	9 (10)
Neuroradiology	2	2	4 (5)
Nuclear Medicine	2	2	4 (5)
Pediatric	3	5	8 (9)
General radiology	3	1	4 (5)

*Data presented as mean ± standard deviation
**Data presented as number and % in parentheses

Table 3. Likelihood of Detecting A Wrong-Patient Error: All Radiologists

	Without photos	**With** photos
Radiologists ***unexposed*** to wrong-patient error (n = 31)	0 / 15* (0**)	0 / 16* (0)
Radiologists ***exposed*** to wrong-patient error (n = 56)	8 / 28* (29)	23 / 28* (82)

* Ratio of (errors detected) / (number of observers in each category)
**Data presented as % in parentheses

Table 4. Likelihood of Detecting A Wrong-Patient Error By Radiologist Characteristics

Characteristics	**Without** photos % errors detected	**With** photos % errors detected	***P*-value***
Total readers (n = 56)**	29	82	< 0.001
Gender			
Female (n = 23)	23	100	0.004
Male (n = 33)	33	72	0.038
Age			
> 45 years (n = 39)	26	85	0.001
≤45 years (n = 17)	33	75	0.081
Fellowship trained			
Yes (n = 48)	29	88	< 0.001
No (n = 8)	25	50	0.465
Fellowship subspecialty			
Cardiothoracic (n = 10)	33	86	0.103
Non-cardio. (n = 46)	28	81	0.002
Current subspecialty			
Cardiothoracic (n = 12)	20	86	0.103
Non-cardio. (n = 44)	30	81	0.002
Portable chest radiograph competency			
Specialties expected to be competent in interpreting portables (n = 33)	25	82	0.002
Specialties not expected to be competent in interpreting portables (n = 23)	33	82	0.004
Experience level			
> 10 yr post res. (n = 47)	29	87	< 0.001
≤ 10 yr post res. (n = 9)	25	60	0.523

* P-value for hypothesis that likelihood of detection is not affected by inclusion of photographs (5% significance level), **Data presented as number and % in parentheses
Two-tailed χ^2 test was used to compare likelihood of detection of wrong-patient errors without and with photographs

Table 5. Univariate Association of Predictor with the Likelihood of Detecting a Wrong-patient Error

Predictor	OR*	P-value for Effect of the Predictor
Photograph	11.5 [3.46, 44.89]	< 0.001
Current practice subspecialty in cardiothoracic radiology	1.17 [0.32, 4.48]	0.815
Expected to be competent in portable chest radiographs	0.92 [0.32, 2.69]	0.884
Experience level > 10 years post-residency	1.69 [0.40, 7.10]	0.474
Gender (Male vs. Female)	0.92 [0.32, 2.70]	0.884
Older than 45 years	1.15 [0.36, 3.64]	0.810
Fellowship specialty cardiothoracic radiology	2.14 [0.52, 10.88]	0.297

*OR = Odds Ratio, 95% confidence intervals in brackets

Table 6. Logistic Regression on Outcome of Detecting A Wrong-Patient Error with Photograph-Predictor Pairs with an Interaction Term (Effect Modification)

	Photograph and predictor	P-value for the effect of the parameter estimate	OR*
Model 1	Photograph	0.0015	11.69 [3.34, 111.03]
	Current practice in cardio. radiology	0.9002	0.77 [0.14, 5.58]
	Photograph modified by practice	0.5973	
Model 2	Photograph	0.0097	8.53 [1.82, 54.28]
	Years of experience > 10 yrs post-res	0.3046	2.34 [0.48, 14.58]
	Photograph modified by experience	0.4402	
Model 3	Photograph	0.0002	11.22 [3.31, 45.04]
	Competency in portable radiographs	0.7786	0.77 [0.22, 3.01]
	Photograph modified by competency	0.7365	

*OR = Odds Ratio, 95% confidence intervals in brackets

Table 7. Results of Questionnaire that Observers Who Interpreted Studies with Photographs Completed at the End of Their Interpretation Session

Question	Response Yes	Response No
1) Were the photographs a distraction?	8 (20)	32 (80)
2) Did you feel you spent more time because of the photographs?	17 (42.5)	23 (57.5)
3) Did the photographs help with the interpretation?	17 (42.5)	23 (57.5)
4) If you noted mismatched photographs, did you go back and check the radiographs?	20 (100)	0 (0)

*Data presented as number and % in parentheses

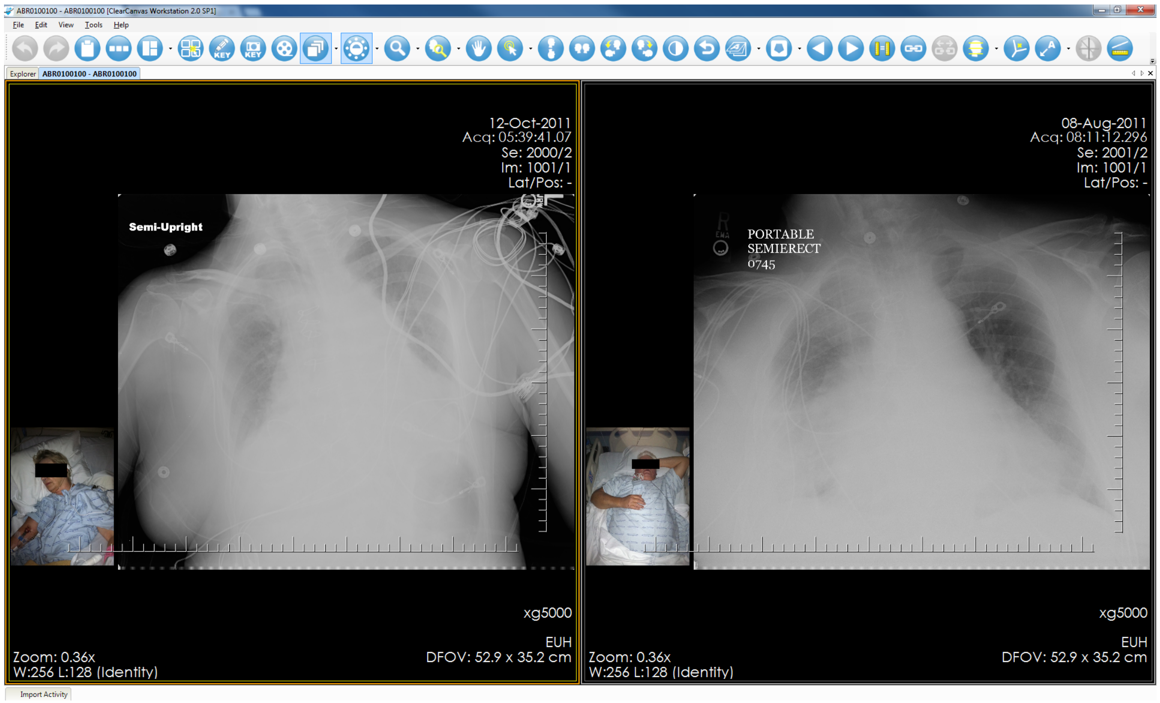

Figure 1. Hanging protocol displaying of a study as seen by some of the observers. (A) The radiograph-photograph combination on the left refers to the *current* study, and shows a 64 year-old white woman with history of aortic stenosis and aortic valve replacement; (B) the radiograph-photograph combination on the right refers to the *prior* study, which shows a radiograph obtained two months earlier, of a 73 year-old man also with a history of aortic stenosis and aortic valve replacement. The presence of the photographs, which show more obvious differences in hair color and body habitus, possibly led the observer, who was asked to interpret this case, to correctly identify the wrong-patient error.

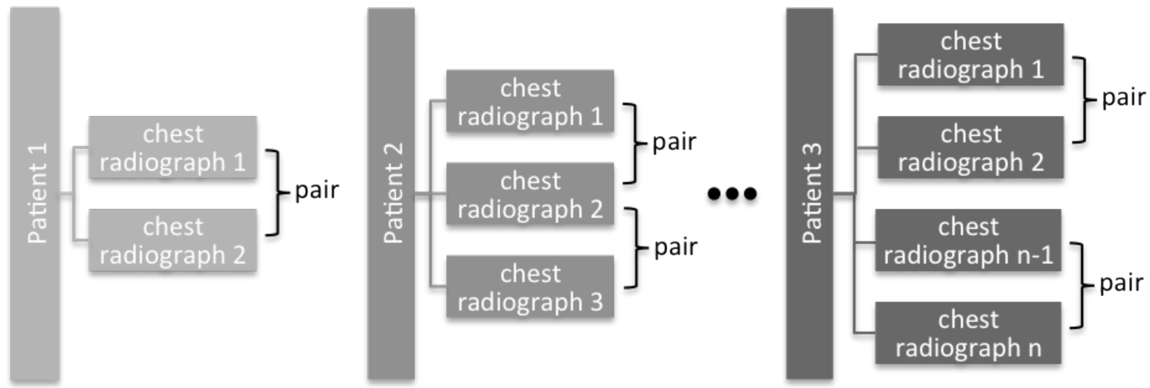

Figure 2. Radiographic pair creation. Anonymized study pairs were generated by combining two sequential radiographs from the same patient. When more than two radiographs existed for the same patient, every two consecutive images were paired.

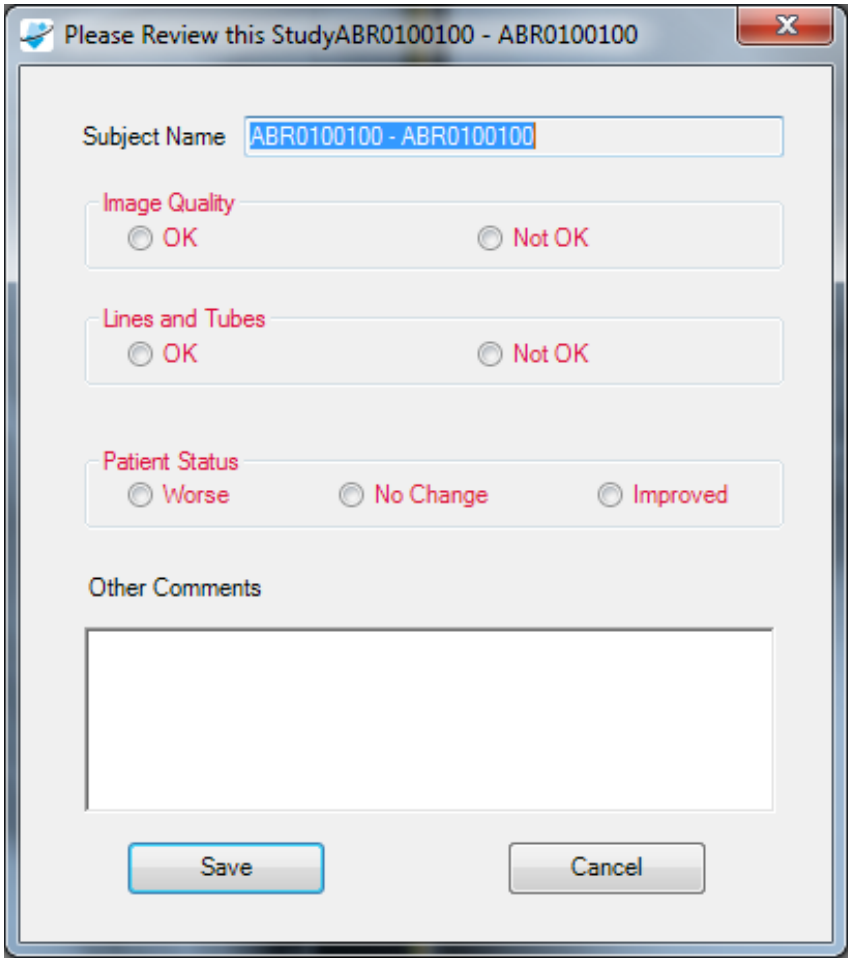

Figure 3. Review Study Component—image of pop-up window used by the observers to evaluate the image pairs

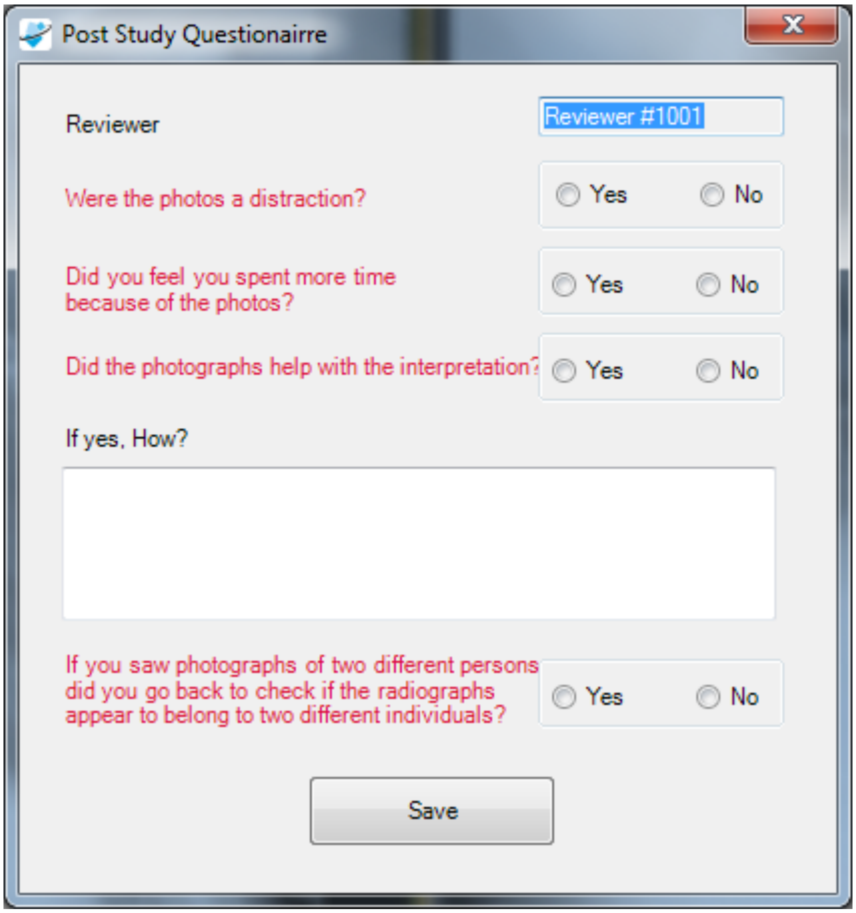

Figure 4. Post-Study Questionnaire—image of pop-up window with questionnaire for observers who interpreted studies with photographs. This was completed at the end of the interpretation session.

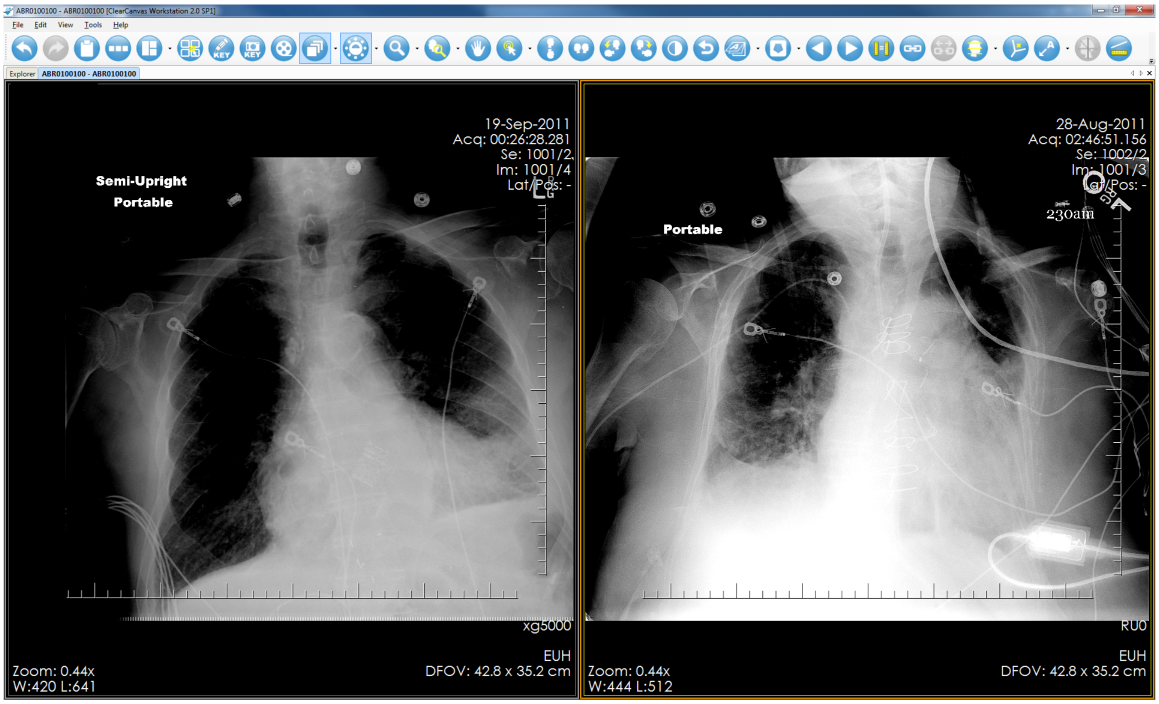

Figure 5. Representative wrong-patient error without photographs. Representative wrong-patient error without photographs. 5(A) An 89 year-old white man with a history of aortic stenosis, status post surgical aortic valve replacement; (B) comparison radiograph from three weeks earlier shows a 63 year-old female also with a history of aortic stenosis, status post percutaneous aortic valve replacement. There are differences in the prosthetic valves, sternotomy wires, and vascular and nodal calcifications.In addition to the differences in valves and median sternotomy, the patient on the left has aortic knob calcifications and calcified mediastinal lymph nodes, both not seen with the patient on the left. It is unlikely for a person who underwent surgical aortic valve replacement to subsequently undergo percutaneous aortic valve replacement (and have the medical sternotomy wires removed in the same period). Even more inconsistent is for the development of advanced calcified atherosclerotic disease and calcified mediastinal lymph nodes within three weeks. Despite these obvious differences, the observer who was shown this combination did not identify the wrong-patient error.

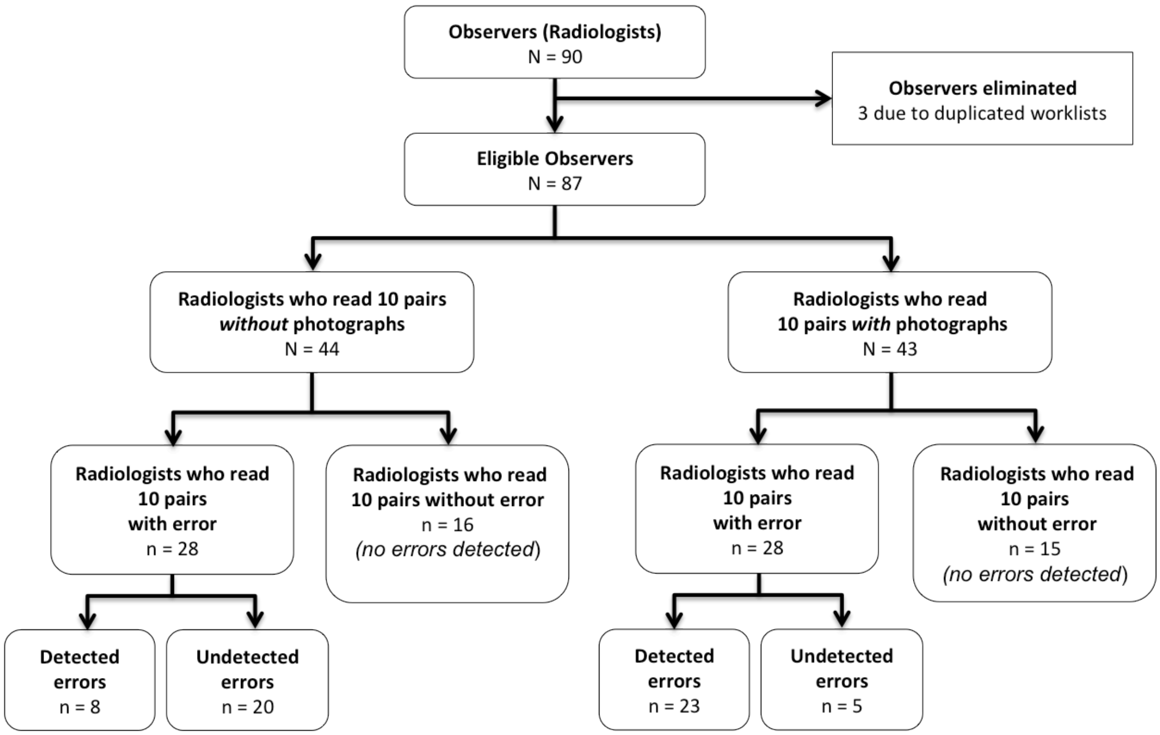

Figure 6. Radiologist outcome flowchart.

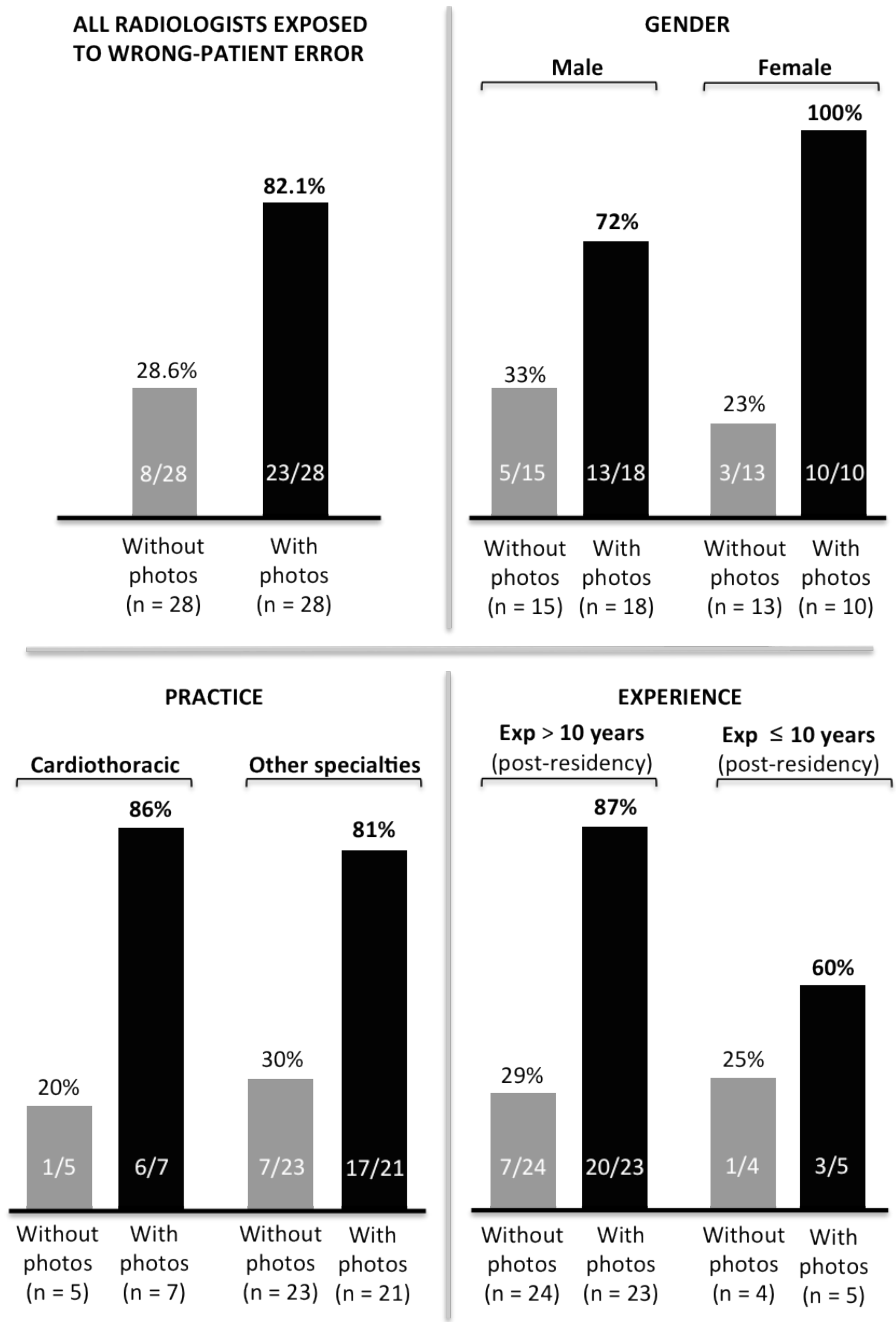

Figure 7. Bar graphs of likelihood of detecting a wrong-patient error by radiologist characteristics