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FULL PAPER

Radiographers' performance in chest X-ray interpretation: the Nigerian experience

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Objective: To assess the performance of Nigerian radiographers in interpretation of plain chest radiographs and to assess whether age, years since qualification and sector of practice are associated with performance.

Methods: A test set of 50 radiographs containing 23 cases with no pathology (normal) and 27 abnormal cases (cardiopulmonary conditions) independently confirmed by 3 radiologists were presented to 51 radiographers in a random order. Readers independently evaluated radiographs for absence or presence of disease and stated the location, radiographic features and diagnosis. Readers self-reported their age, years since qualification and sector of practice. Receiver operating characteristic was used to assess the performance. Mann-Whitney *U* test was used to assess whether age, years since qualification and sector of practice were associated with performance.

Results: Mean location sensitivity was 88.9 [95% confidence interval (CI), 0.787–0.980]. Mean sensitivity and specificity were 76.9 (95% CI, 0.658–0.864) and 79.8 (95% CI, 0.658–0.864), respectively. Age was not associated with performance ($p = 0.07$). Number of years qualified as radiographer ($p = 0.005$) and private practice ($p = 0.004$) were positively associated with performance.

Conclusion: Nigerian radiographers can correctly report chest radiographs to a reasonable standard, and performance is associated with number of years since qualification and the sector of practice.

Advances in knowledge: There are less than 300 radiologists serving a Nigerian population of about 170 million; therefore, X-ray interpretation by radiographers deserves consideration. Nigerian radiographers have potential to interpret chest X-ray in the clinical setting, and this may significantly improve radiology service delivery in this region.

Plain chest radiography is the most common of all radiological investigations owing to its usefulness in the detection and characterization of pulmonary and cardiothoracic disorders. It is also a screening tool for pre-employment and preoperative purposes.^{1–4} In some countries, chest X-ray constitutes about 20% of all radiological examinations.⁴ It is a non-invasive and quick examination; however, it is considered one of the most challenging radiological examinations to interpret.⁵ Reasons for this challenge include but are not limited to anatomical noise caused by superimposition of thoracic structures, similarity in radiographic appearances of some chest diseases, and subtlety of some chest pathologies.^{1,6,7} Results of the radiological examinations are often not readily available especially in developing low-resource countries, partly due to shortage of qualified personnel to interpret the acquired images and the ever-increasing population.^{2,4}

In 2011, the International Skeletal Society outreach in Sub-Saharan West Africa estimated that there were 220 certified radiologists in Nigeria with a population of 152.21 million,

and a radiologist to population ratio of 1 : 692,000.⁸ With the population increasing to over 170 million and the bottomless demand for radiological examinations, radiologists are faced with a high work volume, making throughput of radiological services quite slow. At the same time, the population of radiographers in this region according to the Radiographers Registration Board of Nigeria has risen from 729 in 2008 to about 2000 in 2014.⁹ Additionally, most radiologists work in public metropolitan tertiary hospitals and private diagnostic centres, while hospitals with X-ray and ultrasound facilities serving the vast suburban and rural regions are bereft of radiologists to carry out radiological procedures and interpretation. These together with the absence of functional picture archiving and communication system or teleradiology facilities in the country have resulted in delays in X-ray interpretation and have consequently negatively impacted patient management.⁸ The consequences of delayed interpretation of X-ray examinations emphasize the need for practical measures to improve radiological service delivery so that patients' needs are met and at the appropriate time.

In the developed world, the high workload on radiologists has been lessened by employing the services of radiographers or radiology assistants trained in plain axial and appendicular X-ray as well as ultrasound interpretation.⁴ While this approach has been used for over 40 years in the UK and other industrialized countries, and has been shown to be effective,^{2,4,10} X-ray interpretation by radiographers is still a subject of contention in Nigeria and Africa at large. Against this background, and with the increasing pressure from patients and their relatives for radiographers to provide their X-ray result, there have been agitations for relaxation of regulations on radiographers to interpret radiographs. Additionally, efforts to increase throughput and provide radiodiagnostic results early have led to proliferation of private radiodiagnostic centres operated mostly by radiographers. Although majority of these radiographers focus on ultrasound reporting, a few have extended to interpretation of X-ray examinations such as plain chest and skeletal X-rays without formal training.

Although there are legal restrictions on radiographers to perform X-ray interpretation, these restrictions are only effective in Nigerian public hospitals. While it is the common practice to have radiologists report in conjunction with radiographers in some private settings, others rely on radiographers and a further review by radiologists in cases of uncertainty or on request by a physician. The absence of efficient regulation and monitoring of practice has led to an all-comers situation where radiographers perform X-ray interpretation in the private setting. Increasingly, more radiographers are interpreting X-rays in the private setting, and the accuracy of these reports is unclear. Also, factors such as age, academic qualification or training, and number of years since qualification have been shown to influence accuracy of image interpretation.^{11,12} While radiographers in the developed world acquire formal training in image interpretation,⁴ there is no postgraduate training program in X-ray interpretation in Nigeria as yet. However, radiographers attain informal knowledge of image interpretation during practice through personal study, from radiologists, and other radiographers knowledgeable in X-ray interpretation. The foregoing underscores the need to assess the performance of Nigerian radiographers in X-ray interpretation and the parameters that drive performance. This has the potential to improve radiology service delivery in the area. Therefore, the aim of this study is to assess the performance of Nigerian radiographers in interpretation of plain chest radiographs. The study also aims to assess whether age, years since qualification and sector of practice (public or private) are associated with performance.

METHODS AND MATERIALS

Radiographs used for this study were obtained from a private health institution. The institutional board approved the study and waived the need for patient consent, as the study was a retrospective review of already acquired radiographs. All selected radiographs were de-identified, with patients' names and X-ray number excluded from details provided to readers.

Reader population and image test set

A total of 58 diagnostic radiographers participated in the study. All participants self-reported their demographic information: age, gender, academic qualification, number of years since qualification, sector of practice (public or private) and employment status

(full-time or part-time). They also stated whether or not they have had previous training (formal or informal) in X-ray interpretation.

The initial test set contained 54 posteroanterior radiographs of patients aged 12–74 years (mean = 35.3 years), with 25 and 29 of these cases being females and males, respectively. Cases were randomly selected, and radiographs included in the final test set were based on a consensus of three radiologists. Radiographs were previously reported by a consultant radiologist. To further validate the content or cases in the test set, two other consultant radiologists independently interpreted the radiographs. 50 cases had the same opinion at all readings; this produced a truth table that was used as a reference standard to assess the performance of radiographers. These cases contained 23 radiographs with no pathology (normal) and 27 radiographs with features of chest diseases (abnormal). The abnormal case mix was a combination of pulmonary and cardiac pathologies (Table 1).

Images were read in two different locations; 76% of participants read the images in a conference venue (Association of Radiographers of Nigeria conference, 2014) and the remaining 24% reviewed images in a private diagnostic facility. To standardize the reporting environment in both reading locations, room's ambient lighting was measured using a calibrated illuminance meter [Model Konica Minolta T-10A (A58U-213); Konica Minolta, Ramsey, NJ], and varied between 10 and 18 lux. Images were displayed on two 3 mega-pixel monitors (Sony, Tokyo, Japan). Monitors were calibrated to the digital imaging and communications grayscale standard display function. The monitors demonstrated a calibrated maximum luminance within 5% of 500 cd m⁻², minimum luminance of 0.99 cd m⁻² and a contrast ratio of 505 : 1.

Study design

Participants were recruited by one of the authors through the Radiography Nigeria Facebook page. They were asked to e-mail one of the authors if they were interested in participating in the study. Prior to the study, radiographers who indicated interest were informed through e-mail about the task required of them.

Table 1. Case mix of pathologies in the abnormal test set

Abnormal cases	Frequency
Chronic obstructive pulmonary disease	3
Pneumonia	4
Atelectasis	3
Pleural effusion	3
Tuberculosis	3
Congestive cardiac failure	2
Pulmonary hypertension	2
Lung cancer	1
Lung metastasis	1
Pneumothorax	3
Pulmonary oedema	1
Subphrenic abscess	1

However, no information about the number of normal and abnormal cases, and the types of abnormalities in the test sample was divulged. Readers were provided with patients' information extracted from request forms (clinical history, gender and age), and no time limitation was placed on them to report the radiographs. Images were presented to each reader in a random order, and readers were asked to assess the radiographs and state whether or not an abnormality was present. They were also asked to describe the location and radiographic features of any observed abnormality and provide the final diagnosis for each case. Each reader independently interpreted the radiographs included in the test set.

Statistical analysis

The statistical package for social sciences v. 21 (SPSS Inc., Chicago, IL) was used for data analysis. Receiver operating characteristic (ROC) analysis was used to assess the performance of each radiographer. This enabled assessment of location sensitivity (correct identification of area or location of abnormality) and the sensitivity or true-positive rate and specificity (SPC) of diagnosis. False-positive rates (FPRs) were also calculated ($FPR = 1 - SPC$). The mean of all readers was used to represent overall performance of radiographers. Participants were grouped according to sector of practice (public vs private), age (≤ 32 vs > 32 years), gender, years qualified (≤ 5 vs > 5 years), employment status (full-time vs part-time), educational level (graduate vs postgraduate) and previous training in X-ray reporting. The distribution of the data was assessed using Shapiro–Wilk test and confirmed to be non-parametric, and Mann–Whitney U test was used to compare reader groupings. Statistical significance was assessed based on a two-sided p -value of 0.05. Because 5.9% ($n = 3$) of readers were female, 9.8% ($n = 5$) had postgraduate qualification, none had formal training in X-ray reporting and all were working full-time, these groupings were excluded in the final analysis.

RESULTS

Of the 58 participants, 7 readers did not complete the assessment and were excluded in the final analysis. 51 readers reported all images included in the test set, and a total of 2550 readings were made. The ages of the participants ranged from 26 to 60 years (mean = 34.7 years). 46% of participants were 32 years or younger. Years since qualification ranged from 3 to 20 years (mean = 9.4 years), and 22 readers were employed in public hospitals and 29 in private medical diagnostic facilities.

Location sensitivity ranged from 80.4 [95% confidence interval (CI), 0.656–0.868] to 100 (95% CI, 0.888–1.000) (mean = 88.9; 95% CI, 0.787–0.980) (Table 2). ROC analyses for diagnostic performance shows sensitivity ranging from 63.6 (95% CI, 0.522–0.828) to 100 (95% CI, 0.929–1.000), with SPC ranging from 64.3 (95% CI, 0.483–0.796) to 95.7 (95% CI, 0.929–1.000). The mean FPR was 20.2%. The mean sensitivity, SPC and FPR of reader groupings are presented in Table 3. Disease conditions that were consistently correctly interpreted included subphrenic abscess, lung cancer, tuberculosis, pneumonia, and pulmonary metastasis (Table 4). Disease conditions that were commonly missed and those that were infrequently misinterpreted are also presented in Table 4.

Location sensitivity was statistically significantly different between the groups compared ($p \leq 0.005$). Statistically significant differences in diagnostic accuracy were noted for years since qualification ($p = 0.005$) and sector of practice ($p = 0.004$), but not for age ($p = 0.07$). The mean FPRs of reader groupings are presented in Table 3.

DISCUSSION

With the increasing population and dearth of radiologists in Nigeria,⁸ it is likely that radiological services will get worse if palliative measures are not put in place. It is also increasingly likely that if inroads are to be made, skill mix and role extension for radiographers would be necessary and therefore requires consideration. The result of this study demonstrates that Nigerian radiographers can correctly identify the location of abnormality on plain chest X-ray and can correctly report cardiopulmonary diseases on plain chest X-ray to a reasonable extent. Location sensitivity was particularly high for almost all readers (Table 2). Sensitivity, defined as the number of cases with abnormality correctly classified, was about 77%. Similarly, SPC (number of cases without pathology correctly identified) was also appreciably high, with a mean FPR (the percentage of normal cases reported as having pathology) of 20.2% (Table 3).

Location sensitivity was assessed to be sure that readers' final diagnoses were based on features present in the radiographs. Location sensitivity is particularly important in radiology, as it provides information about the location and characteristics of a disease, and is useful in guiding treatment such as surgical interventions.¹³ Overall, it was observed that readers' final

Table 2. Location sensitivity of reader groupings and all readers

Readers	Location sensitivity (%)	Standard error	95% confidence interval
Public practitioners	84.1	0.011	0.732–0.963
Private practitioners	93.6	0.007	0.751–0.984
≤ 5 years since qualification	83.1	0.009	0.711–0.941
> 5 years since qualification	94.6	0.008	0.887–1.000
Age ≤ 32 years	85.4	0.010	0.856–0.918
Age > 32 years	90.8	0.007	0.898–1.000
All readers	88.9	0.009	0.787–0.980

Table 3. Mean diagnostic performance of reader groupings and all readers

Readers	Mean area under curve (accuracy)	Standard error	95% confidence interval	Mean sensitivity (%)	Mean specificity (%)	Mean false-positive rate (%)
Public practitioners	0.725	0.018	0.585–0.871	71.0	74.0	26.0
Private practitioners	0.842	0.015	0.722–0.962	82.7	85.6	14.4
≤5 years since qualification	0.758	0.019	0.608–0.887	74.8	76.8	23.1
>5 years since qualification	0.808	0.018	0.745–0.924	78.9	82.7	17.3
Age ≤32 years	0.735	0.019	0.590–0.866	75.8	78.2	21.8
Age >32 years	0.825	0.013	0.722–0.962	77.9	81.4	18.6
All readers	0.784	0.016	0.658–0.864	76.9	79.8	20.2

diagnoses were based on radiographic features rather than guesswork. Location sensitivity and diagnostic accuracy were lower for readers working in public hospitals, those who have worked for fewer years, and younger readers (Table 2). Lower performance for radiographers in public hospitals may be attributed to effective legal restriction that prevents them from undertaking image interpretation, high radiographic workload and limited radiographer–radiologists interaction due to separation of image acquisition and reporting workstations. Conversely, the higher performance of private practitioners may be attributed to mentorship from senior colleagues and radiologists in the private setting. Also, lower work volume and practice-based knowledge acquired through regular image interpretation, as well as feedback on performance from referring clinicians may have a significant impact on readers in private practice. Cumulative exposure to radiographic features of disease may be the reason for the impact of duration of practice or years after qualification on performance. It is possible that performance may also be influenced by individual's interest in radiographic interpretation as demonstrated by the varying

levels of performance among readers of the same age, years qualified and sector of practice.

The considerable number of false positives may be due to the laboratory effect as readers were assessed in an experimental setting. In such an environment, readers are cognizant of the fact that they are being tested, and as a result anticipate higher number of cases with pathology.^{14,15} Therefore, their anticipation is not satisfied until a suspicious feature(s) is reported as disease condition.¹³ Additionally, external variables such as artificiality of test environment and extent of scrutiny of one's assessment influence performance in a laboratory setting.¹⁶ These variables cause discrepancy between laboratory findings and results obtained in real clinical situations and are often cited as limitations to generalizing laboratory findings to prospective clinical situations.^{14,16} However, the discrepancy between laboratory and clinical findings has been shown to be insignificant.¹⁴

The findings show that mild pleural effusions, mild right lower lobe collapse and pneumothoraces with subtle features constituted

Table 4. Percentage distribution of disease conditions correctly interpreted, missed or misinterpreted; values represent number of times correctly identified, missed or misinterpreted relative to the total number of readings for that disease condition (%)

Correctly interpreted	Number of times correctly identified	Missed or misinterpreted	Number of times missed or misinterpreted
Congestive cardiac failure	89.2	Pleural effusion	8.3 ^a
Hypertensive heart disease	86.1	Pneumothoraces	13.5 ^a
Lung cancer	91.2	Atelectasis	12.2 ^a
Pulmonary metastasis	89.2	Pulmonary oedema	33.3 ^b
Tuberculosis	91.3	Atelectasis	15.7 ^b
Pneumonia	90.6	Pneumothorax	18.5 ^b
Chronic obstructive pulmonary disease	87.2	Pleural effusion	18.7 ^b
Subphrenic abscess	91.4		

^aMissed.

^bMisinterpreted.

the difficult abnormalities to detect. Also, pulmonary oedema was occasionally misinterpreted as congestive heart disease, and atelectasis and pleural effusions were infrequently misinterpreted as pneumonia (Table 4). Previous studies have also reported difficulty in differentiating some of these conditions on plain CXR.^{5,17} Errors and inter-reader variability in radiological image interpretation have been reported in the literature.^{18–20} Moderate to substantial variability in radiographic interpretation has been shown for radiologists.^{21,22} A 7.4% inter-radiologists' variability is also evident in the test set used as the truth table for assessing radiographers' performance in the current study.

The result of this pilot study is comparable to preliminary findings in South Africa (<80% sensitivity).^{23,24} Previous studies have reported mean sensitivity and SPC ranging from 81% to 98% and 95% to 100%, respectively, for radiographers in the developed world.^{2,4} Performance in many of these studies was adjusted for training and body part. A meta-analysis has shown insignificant variation in performance between trained (sensitivity = 92.9%; SPC = 97.8%) and untrained radiographers (sensitivity = 96.0%; SPC = 93.7%).² A review of the red dot system also shows no difference in performance between trained (sensitivity = 89.0%; SPC = 93.0%) and untrained (sensitivity = 91.0%; SPC = 95.0%) radiographers.¹⁰ The current study did not adjust for educational qualification and training as 90.2% of participants had no post-graduate qualification and none had formal training in image interpretation. Variables such as employment status (full-time and part-time) and gender were not assessed because all participants were full-time employees with 94.1% being male. An important observation in the study is that longer years of practice and private practice are significant determinants of radiographers' performance in Nigeria. Although mean sensitivity and SPC are considerably good, the heterogeneity of results among readers is appreciable; therefore, the result should be interpreted with caution.

The overall findings emphasize the need to explore other crucial experiential parameters that can maximize search, perception and decision-making skills of radiographers in this region. A recommended solution is the adequate theoretical and practical training in image perception and interpretation, and feedback mechanisms to assess performance. This may involve training of radiographers as radiology assistants as is the case in the USA and UK, where universities offer competency-based educational programs and certification examinations.⁴ Training may be carried out in collaboration with radiologists and oversea universities currently

undertaking X-ray interpretation training for radiographers. Certification may be based on performance, with constant continuous professional development and evaluation of practice. The recommendations by Williams²³ are also upheld in the current study. This will ensure that only radiographers with adequate skills and expertise report radiographs. Increased number of qualified personnel to interpret radiographs will enable timely availability of X-ray reports and improved radiological service delivery to suburban and rural Nigerian communities. It will also ease the workload on radiologists, pressure on radiographers to provide X-ray reports and anxiety for the patients and their relatives.

This study is not without limitations. First, the sample size was relatively small, as it was chosen in order to minimize the effect of fatigue on readers. Second, the proportion of pathologies in the test set was uneven. Conversely, the strength of the study includes that although the sample was small and randomly selected, the case mix was fairly representative of common chest diseases in the study environment²⁵ and the number of readers was considerably high. Also, since X-ray interpretation is currently being undertaken by some radiographers in the private setting, an evaluation of their performance is timely and pertinent; therefore, the result of this study is worthy of consideration. Further work is needed to assess how well Nigerian radiographers can interpret accident and emergency radiographs. This is because conditions such as abdominal obstruction and perforation, cardiovascular disorders and trauma are common causes of sudden deaths in Nigeria.^{26–28}

CONCLUSION

The findings demonstrate that Nigerian radiographers can correctly report plain chest radiographs to a standard equivalent to that reported in South Africa. Number of years qualified as radiographer and private practice are positively associated with performance. The major challenge, however, is how to attain the desired level of training and competency and to foster flexible working relationships between radiographers and radiologists to ensure that patients' needs are timely met.

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