Diagnostic accuracy of chest radiograph interpretation by graduate radiographers in Uganda

A G Mubuuke, PhD; **F Businge,** MSc; **E Kiguli-Malwadde,** MMed (Radiology)

Department of Radiology, School of Medicine, College of Health Sciences, Makerere University, Kampala, Uganda

Corresponding author: A G Mubuuke (gmubuuke@gmail.com)

Background. Radiographers are increasingly being called on to take on new roles, such as X-ray film interpretation in imaging departments. In Uganda, where this study was conducted, there are just >40 radiologists in a population of ~40 million. In many hospitals, especially in rural areas, clinicians often rely on radiographers to obtain an opinion to assist with proper patient management. Therefore, Ugandan radiographers are being trained in basic radiographic interpretation to address the shortage of radiologists.
Objective. To determine the diagnostic accuracy of graduate radiographers in interpreting chest radiographs.
Methods. This was a cross-sectional retrospective study involving 57 graduate radiographers who were provided with 53 randomly selected chest radiographs to interpret. The validation of a radiographer's interpretation of a radiograph was aided by the opinion of two senior radiologists. SPSS version 25 software (IBM Corp, USA) was used to analyse the findings and the radiographer's performance was assessed using the receiver operating characteristic (ROC). The mean abnormality location sensitivity, overall radiographer sensitivity, specificity and false-positive rates were calculated.
Results. The radiographers' diagnostic accuracy was high. The abnormality location sensitivity was 88.7%, overall sensitivity 76.6%, specificity 79.7% and false-positive rate 20.1%.
Conclusion. The study demonstrated that radiographers, if trained, can accurately report on chest radiographs to an acceptable standard.

A chest radiograph is the most common investigation in many Ugandan hospitals. This could be attributed to the many tropical infections, high prevalence of HIV infection and HIV/AIDS, as well as associated comorbidities such as tuberculosis (TB), malignancy and pneumonia. A chest radiograph has also been reported to be one of the most common radiological investigations in other parts of the world.[1,2] Furthermore, chest radiographs constitute >20% of all radiological investigations in imaging departments.[2-5]

The interpretation of chest X-ray images has long been the domain of radiologists, although radiographers are now increasingly taking on this role.[6] While radiologists are medical doctors with postgraduate training in radiology, radiographers are not trained in clinical medicine, and had traditionally been trained to operate equipment to produce images. Therefore, equipped with adequate medical knowledge, radiologists – not radiographers – usually have been the ones to interpret chest radiographs. However, it has also been reported that, globally, there are few radiologists compared with the number of patients who require radiological reports.[2] This is exacerbated in low-income countries, where radiologists are concentrated in tertiary hospitals in urban areas.[2] Therefore, most of the rural and remote areas have only radiographers.[7] For example, in 2014 there were 220 radiologists in Nigeria to serve a population of >150 million.[1]

In Uganda, a sub-Saharan African country where this study was conducted, there are just >40 radiologists to serve a population of ~40 million.[8] This has left many hospitals, especially in rural areas, with only radiographers, who therefore become very crucial regarding the provision of expert opinions on some of the X-ray images.[9] Against this background, the training of radiographers at degree level in Uganda currently involves the basic interpretation of radiographs. The curriculum for radiography training in Uganda has some components of X-ray film interpretation of the chest, abdomen, limbs, head and neck. The expected outcome is that graduate radiographers should be able to offer an informed opinion on radiographs in the absence of a radiologist. Despite these efforts, however, no study has been conducted in Uganda to assess the diagnostic accuracy of radiographers in interpreting radiographs. In our study, the chest radiograph was specifically chosen to determine the diagnostic accuracy of graduate radiographers, as it is the most common radiographic investigation requested in the radiology department for ~100 patients daily.

Methods
Study design and setting
This was a retrospective cross-sectional study conducted in Uganda, a low-income country in sub-Saharan Africa. The study involved reviewing chest radiographs by radiographers who had a degree qualification. They had to analyse a set of given chest radiographs and write a probable final diagnosis. The radiographs used in the study were obtained from Mulago Hospital, Uganda's national referral hospital and teaching hospital for Makerere University's College of Health Sciences in Kampala.

Sample size
Purposive sampling was used to select participants. A targeted group, i.e. graduate radiographers, was invited to participate in the study. All eligible radiographers who had a degree qualification were invited by e-mail and/or telephone. Their contact details were obtained from records of the Allied Health Professions Council, a body that regulates radiography practice

in Uganda. The degree-level radiographers are trained in plain X-ray image interpretation. The diploma-level radiographers were excluded because they are not trained in such interpretation. The invitation was sent to 70 targeted radiographers, of whom 57 who agreed to participate had a degree in diagnostic radiography and had received training in X-ray pattern recognition. Sociodemographic data on gender and years of practice since their degree training were also obtained.

Selection of chest radiographs

The radiographs were randomly selected – 53 postero-anterior (PA) chest radiographs were used in the study. These were of patients 10 - 72 years of age, with a mean age of 35.1 years. Of these radiographs, 24 were of female and 29 of male patients.

Interpretation of chest radiographs by radiologists

Two independent radiologists initially interpreted the chest radiographs and thus validated the cases selected. These interpretations were also used to compare the radiographers' findings. The final diagnosis of each chest radiograph was required from the radiologists. They interpreted the radiographs independently at different times before the radiographers interpreted them. Using two radiologists was meant to increase the validity of the interpretation, which was used as a reference standard when assessing the radiographers' performance. Of the 53 PA chest radiographs that the radiologists interpreted, 50 reflected the same final opinion, which produced a reference standard that was later used to assess the performance of radiographers. Of the 50 cases, 22 were reported as normal by the radiologists, while 28 were reported as abnormal. The latter cases were compiled, and assisted in assessing the performance of the radiographers (Table 1). Only 3 chest radiograph interpretations by the radiologists differed. These were not included in the final list to be given to the radiographers for interpretation.

Interpretation of chest radiographs by radiographers

After interpretation by the two radiologists, the 50 chest radiographs that reflected a common interpretation (reference standard) were given to the radiographers to interpret. To standardise the interpretation environment for all 57 radiographers, the same viewer and room were used by the radiologists and radiographers in the radiology department. It was impossible to have all 57 radiographers in one room at the same time. Therefore, interpretation of the chest radiographs was done at different times until all 57 radiographers

Table 1. Abnormal pathological conditions on radiographs, as reported by radiologists

Abnormality	n
Tuberculosis	5
Pleural effusion	4
Pneumonia	4
Pulmonary oedema	3
Atelectasis	3
Chronic obstructive pulmonary disease	3
Primary lung cancer	2
Lung metastases	2
Pneumothorax	1
Cardiac failure	1

had seen the same radiographs. Only one radiographer would be in the room at any one time to prevent possible influencing of each other if there were more than one in the room.

The radiographers were requested to analyse the radiographs and write a final diagnostic opinion, as was the case with the radiologists. The radiographers were requested to write down the features seen on the chest X-ray images and provide the most likely diagnosis according to the features described. The researcher (AGM) considered this final diagnostic opinion (the conclusion) for analysis. The radiographers were not given any indication of how many radiographs were normal or abnormal or of the two radiologists' conclusions. They were blinded from the radiologists' findings. It was not possible to trace the clinical notes on the request forms from the records; therefore, the radiographers did not receive the request forms and clinical information. Each radiographer was given chest radiographs at random and no specific time frame was fixed for interpreting a radiograph. They first had to state whether the radiograph was normal or abnormal; for those judged as abnormal, each radiographer was requested to provide an opinion of the final possible diagnosis. The reporting by each radiographer did not happen simultaneously for all 50 radiographs owing to time constraints, but was staggered over 1 year to suit the radiographers, as they were employed.

Data analysis

Findings were analysed using SPSS version 25 (IBM Corp, USA). The performance of each radiographer was assessed using the receiver operating characteristic (ROC) analysis. ROC analysis is a statistical tool used to relate sensitivity and specificity of the diagnostic ability of a tool or group of people – in this case, the radiographers compared with the radiologists to provide an accurate evaluation of the diagnostic accuracy. It has previously been used in a related study.[2] ROC analysis enabled us to assess parameters, such as correct location of an abnormality on the chest radiograph. Sensitivity and specificity of radiographers to diagnose an abnormality were also calculated. Sensitivity refers to true positive rates (i.e. presence of an abnormality correctly diagnosed by the radiographers). Specificity refers to true negative rates (i.e. absence of an abnormality correctly diagnosed by the radiographers). The performance of all the radiographers was represented by the mean.

Ethical approval

Permission to conduct the study, including review of chest X-ray films, was obtained from Mulago Hospital Research Ethics Committee (ref. no. REC 109-2019), as well as from the records officer to access the radiographs. The patients' names and the numbers on the selected chest radiographs were removed before interpretation by the radiographers. Consent was also obtained from the study participants.

Results

Demographic information of the radiographers

Of the 57 radiographers who attempted to interpret the 50 chest radiographs, 6 did not complete the work and opted out. The remaining 51 completed the task. The 6 radiographers who opted out were eliminated from the final analysis of findings. Therefore, there was a total of 2 550 independent reports by radiographers. The age range of the radiographers was between 22 and 40 years. The years since the radiographers' qualification ranged

from 1 to 5. All radiographers involved in this study were employed and have been actively reporting chest radiographs (30 were males and 27 were females).

The range of pathological conditions as interpreted by the two radiologists is summarised in Table 1.

Accuracy of radiographers' interpretation of chest radiographs

The radiographers' sensitivity of correctly locating an abnormality on the chest radiographs ranged from 80.2% (95% confidence interval (CI) 0.654 - 0.866) to 100% (95% CI 0.886 - 1.000) (mean 88.7%; 95% CI 0.785 - 0.978). The sensitivity of locating abnormalities (i.e. location sensitivity) was done to ensure that the final diagnosis was based on the radiographic features observed. Overall, from this study it can be inferred that the radiographers' final diagnoses were based on observed radiographic patterns rather than on assumptions.

The ROC for radiographer diagnostic performance demonstrated that overall sensitivity ranged from 62.8% (95% CI 0.520 - 0.792) to 100% (95% CI 0.920 - 1.000) (mean 76.6%). The overall specificity of radiographer performance ranged from 63.8% (95% CI 0.479 - 0.800) to 95.5% (95% CI 0.927 - 1.000) (mean 79.7%). The overall mean false-positive rate for radiographer reporting was 20.1%.

The abnormalities on the chest radiographs that appeared to have been reliably and correctly pointed out by the radiographers included tuberculosis, pneumonia, lung metastases and pleural effusion. The abnormalities that were commonly missed or misinterpreted included pulmonary oedema, atelectasis and cardiac failure.

Discussion

This study suggests that the radiographers made a final diagnosis based on observed chest radiographic patterns rather than on assumptions. Therefore, with the necessary training in radiographic interpretation during undergraduate studies, radiographers are capable of an expert opinion on some chest radiographs, which can aid prompt patient management. The radiographers involved in this study had been trained in basic radiographic interpretation, which probably explains why they were able to interpret the chest X-rays films provided. With few radiologists against the ever-increasing patient load, role extension for radiographers to interpret and report on chest radiographs is becoming urgent.[9,10] Analysing findings from this study, it can be concluded that trained radiographers can correctly and consistently locate some abnormal disease patterns on chest radiographs, especially those included in this study, and can also reliably report or offer an expert opinion on some of the chest X-ray images to a satisfactory extent.

The radiographers' sensitivity of locating the abnormality (i.e. location sensitivity) was high (88.7%). The overall sensitivity regarding the number of chest radiographs with a correctly identified condition was high (76.6%), while overall radiographer specificity regarding the number of chest radiographs without pathology correctly identified was also high (79.7%). Furthermore, this study recorded a fairly low final false-positive rate (20.1%) (i.e. number of normal chest radiographs reported as indicating pathology). Therefore, the diagnostic accuracy of radiographers correctly reporting on chest films was remarkably high.

The false-positive rate could possibly have been lower, but some key factors might explain the 20.1%. For example, the quality of radiographs interpreted was a factor. The chest radiographs given to the radiographers were retrieved from storage, where conditions might not have been optimal, thus affecting the overall diagnostic quality of the films. For example, the image might have faded or mixed with dust or even become scratched. The radiographers also possibly had limited experience, as they had been been practising for relatively fewer years than the two radiologists. It can be argued that with time and experience, the false-positive rate could be reduced considerably, which might also apply to the radiologists. Moreover, the radiographers might have felt as if they were being tested in an examination-like context and thus felt pressurised to identify some form of pathology, even when it was not present on the radiographs.

The radiographers were not provided with clinical information relating to the radiographs. Although there is no guarantee that availability of clinical information would have significantly improved their performance, it is highly likely that it would have reduced the false-positive rate observed. Some of the abnormalities that were misinterpreted, such as pulmonary oedema and cardiac failure, have also been reported in the literature as potentially difficult.[10] A chest radiograph is very challenging to interpret, even for experienced radiologists. For example, variability of interpretation by qualified radiologists has also been observed elsewhere.[11]

Overall, findings from this study showing a relatively high diagnostic accuracy for radiographer interpretation of X-ray images are comparable with those of a study done in Nigeria that reported a sensitivity of 76.9%, specificity of 79.8% and false-positive rate of 20.2%.[2] The findings are also comparable with those of a study in South Africa (80% sensitivity),[12] and with studies done in the developed world.[13] This therefore indicates that with training, radiographers can correctly report on X-ray images with a diagnostic accuracy comparable with that of radiologists.[13] The study thus provides evidence that radiographers can accurately interpret some chest radiographs, which can be very useful, especially in areas where there are no radiologists.

The radiographers were graduates and had received training in basic chest radiographic interpretation. This possibly explains their ability to interpret some of the radiographs. It is therefore suggested that radiographers should be trained in X-ray film interpretation during their undergraduate studies so that they are able to contribute to the role extension. This should subsequently ease the workload of the radiologists and ensure that patients, especially in rural areas, receive the much-needed service immediately, until an advanced opinion from a radiologist is sought. To ensure quality, the trained radiographers should be encouraged to always consult when in doubt. Standardisation of their reporting can be explored by professional regulatory bodies.

Study limitations

Only chest radiographs were used to assess the diagnostic accuracy of radiographers. This does not imply that findings would be the same for other body systems outside a chest cavity, a potential limitation of the study.

Further research

As this study focused on the interpretation of chest radiographs and not any other body systems, many more empirical studies are needed to look at the accuracy of radiographer reporting of such systems.

Conclusions

Findings from this study have demonstrated that the majority of graduate radiographers with the required training in chest X-ray film interpretation can accurately interpret and report on some specific chest radiographs, such as those included in this study – almost to the same level as radiologists. With the scarcity of radiologists, especially in low-income countries, there is a need to focus the training of radiographers at degree level and beyond in radiographic interpretation skills involving some body systems. It is, however, important to define the necessary competencies, required standards and scope of reporting for trained radiographers in this role extension.

1. Neep MJ, Steffens T, Owen R, McPhail SM. A survey of radiographers' confidence and self-perceived accuracy in frontline image interpretation and their continuing educational preferences. J Med Rad Sci 2014;61(2):69-77. https://doi.org/10.1002/jmrs.48
2. Ekpo EU, Egbe NO, Akpan BE. Radiographers' performance in chest X-ray interpretation: The Nigerian experience. Br J Radiol 2015;88(1051):20150023. https://doi.org/10.1259/bjr.20150023
3. Ekpo EU, Hoban AC, McEntee MF. Optimisation of direct digital chest radiography using Cu filtration. Radiography 2014;20(4):346-350. https://doi.org/10.1016/j.radi.2014.07.001
4. Piper K, Cox S, Paterson A, et al. Chest reporting by radiographers: Findings of an accredited postgraduate programme. Radiography 2014;20(2):94-99. https://doi.org/10.1016/j.radi.2014.01.003
5. Hayashi H, Ashizawa K, Uetani M, et al. Detectability of peripheral lung cancer on chest radiographs: Effect of the size, location and extent of ground-glass opacity. Br J Radiol 2009;82(976):272-278. https://doi.org/10.1259/bjr/22411514
6. Brealey S, Scally A, Hahn S, Thomas N, Godfrey C, Crane S. Accuracy of radiographers red dot or triage of accident and emergency radiographs in clinical practice: A systematic review. Clin Radiol 2006;61(7):604-615. https://doi.org/10.1016/j.crad.2006.01.015
7. Soh BP, Lee W, Kench PL, et al. Assessing reader performance in radiology, an imperfect science: Lessons from breast screening. Clin Radiol 2012;67(7):623-628. https://doi.org/10.1016/j.crad.2012.02.007
8. Kiguli-Malwadde E, Mubuuke AG, Businge F, Nakatudde R, Bule S. Evaluation of ultrasound training in the problem-based learning radiography curriculum at Makerere University, Uganda. Radiography 2010;16(4):314-320. https://doi.org/10.1016/j.radi.2010.05.003
9. Lee CS, Nagy PG, Weaver SJ, Newman-Toker DE. Cognitive and system factors contributing to diagnostic errors in radiology. AJR Am J Roentgenol 2013;201(3):611-617. https://doi.org/10.2214/AJR.12.10375
10. Monu JU, Hewlett V, Ostlere S. International Skeletal Society outreach in sub-Saharan West Africa. Skeletal Radiol 2011;40(3):251-254. https://doi.org/10.1007/s00256-010-1084-0
11. Samei E, Flynn MJ, EylerWR. Detection of subtle lung nodules: Relative influence of quantum and anatomic noise on chest radiographs. Radiology 1999;213(3):727-734. https://doi.org/10.1148/radiology.213.3.r99dc19727
12. Williams I. Reporting trauma and emergency plain film radiographs: Radiologists' support for role extension of South African radiographers. S Afr Radiographer 2009;47(1):15-18.
13. Brealey S, Scally A, Hahn S, Thomas N, Godfrey C, Coomarasamy A. Accuracy of radiographer plain radiograph reporting in clinical practice: A meta-analysis. Clin Radiol 2005;60(2):232-241. https://doi.org/10.1016/j.crad.2004.07.012