The Accuracy of Radiographers Preliminary Image Evaluations of Axial Radiographs: a Prospective Longitudinal Study at Al-Hussein Hospital, Iraq

Ali Riyad Saleim[1], Firas Abdullah Noori AlBaghdadi[2], Ibtissem Hasni[3]

[1]*Department of Radiology, Faculty of medicine Ibn Al-Jazzar Sousse, university of Sousse, Tunisia.*
[1]*Radiography Department, southern technical university , Basrah,Iraq Email: Alisaleim@stu.edu.iq*
[2]*surgery Department, college of medicine, ThiQar university, Ira. Email: dr.firas@utq.edu.iq*
[3]*Department of Radiology, Faculty of medicine Ibn Al-Jazzar Sousse, university of Sousse, Sousse, Tunisia. Email:* ibtissemhasni@yahoo.fr

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ABSTRACT

Introduction: Modern emergency departments are under increasing pressure that can only be alleviated by new approaches to meeting demand. One strategy could be the adoption of radiographer preliminary image evaluations (PIEs), which would significantly reduce the time it takes emergency teams to receive critical imagery results. The aim of this study was to examine the accuracy of radiographers' interpretations of axial radiographs and the impact a short training program had on their image interpretation skills. Methods: Forty-one radiographers volunteered to participate in the study. From 15 January to 15 April 2023 radiographers produced PIEs for 24 axial radiographs which were compared to the radiology reports for the same images. The accuracy each of the radiographers' PIEs were categorized as true positive, true negative, false positive and false negative, with numerical scores to enable mean accuracies to be calculated. The radiographers' accuracy was then reassessed on the same images after they had completed a two-week training program on axial skeletal radiograph interpretation. Results: The study reported that demonstrated that most (TP) radiographer PIEs (M = 5.66, SD = 1.24) were about facial bone fracture. Moreover, this study demonstrated that most (FN/TP) radiographer PIEs (M = 3.83, SD = 1.69) were that cases about inflammatory disease of the axial spine, such as ankylosing spondylitis. In contrast, the most common cases misinterpreted were about cervical spine disorders such as diffuse idiopathic skeletal hyperostosis (DISH) (M = 2.49, SD = 1.36). Years of experience in radiography showed a positive but not statistically significant influence on accuracy. Additionally, post training mean accuracy significantly improved. Conclusion: This study found radiographers provided quite accurate PIEs for facial bone fractures when compared to the full radiology reports of the same images. The findings also highlighted specific pathologies that were frequently misinterpreted. A two-week training program was found to be effective at improving radiographers' ability to correctly identify and describe abnormalities present in axial radiographs.

1. Introduction

Hospital radiography departments are under increasing pressure to supply emergency departments (EDs) with medical images and radiologist reports, as these provide doctors with crucial information with which to make treatment decisions. In many instances, however, radiography reports are not available in time (1), forcing the emergency referrers to make such decisions without them. Unfortunately, existing evidence suggests that emergency referrers often have insufficient experience to interpret x-ray images without the radiologist's report, which can result in poor clinical decision making with adverse effects on the quality of patient care, to such an extent that it is now becoming a concern for patient safety (3-5). As an example, in Alhussin hospital (in ThiQar, southern Iraq) most emergency radiographs have to be acted on without the definitive reports of radiologists.For the Iraqi health service to continue to provide high quality and up-to-date care, new approaches to managing high demand are essential. In emergency departments, keeping waiting times for treatment to a minimum and reducing diagnostic errors remain key priorities that can only be maintained with innovative strategies, one of which is for radiographers to provide a summary opinion of the medical images to alert the emergency team to any abnormalities (6-9). Such a strategy could be an effective first step in minimizing the problems associated with delayed radiologist reporting as this information would be passed on to the emergency department at the same time as the image itself.

A similar strategy has, in fact, been in operation in UK hospitals since the mid-1980s (10), where radiographers would place a marker – a salient red dot – on any images they perceived to indicate serious pathology. While an effective warning system, this scheme provided minimal information as it was restricted to the radiographer's binary normal/abnormal decision about the image. To provide emergency departments with more useful clinical information, the scheme was later extended to include a brief Preliminary Image Evaluation (PIE) from the radiographer, with some evidence suggesting this has helped to reduce diagnostic misinterpretations (11). Such a system is also employed in Australian hospitals. While such preliminary evaluations are not a substitute for the full radiology reports, they can provide critical information at times when it is needed most by emergency departments (6). Any decision to implement such a strategy, however, must only be made after a comprehensive assessment of radiographers' abilities to accurately detect serious abnormalities in the images they process – a consideration that motivated the research presented here.This study, therefore, examined radiographers' ability to accurately interpret axial radiographs. Their performance was initially assessed over a three-month period, after which they underwent a training program in axial skeletal radiograph interpretation and were reassessed. Demographic and experiential factors were also examined.

2. Method

This research was a longitudinal prospective study examining the accuracy of radiographer PIEs in Al-Hussein Hospital, southern Iraq, from 15 January 2023 to 15 April 2023. Approval was granted by the Institutional Review Board (IRB) of The Southern Technical University and all procedures adhered to the current ethical guidelines of the Helsinki declaration.Forty-one radiographers from the medical imaging department of Al-Hussein Hospital, Dhi Qar Health Department, were selected by purposive sampling and volunteered to participate. A condition for selection was that the radiographers demonstrated an interest in image interpretation and would be available to complete the image interpretation training program.

Procedure

Radiographers of the ED of the hospital were instructed to complete an immediate and concise written opinion about any possible traumatic injuries or acute abnormalities indicated by their radiographical examinations. The Iraqi radiography regulatory guidelines (2021) were used to define what pathologies were to be considered by the radiographers (shown in Table 1). These were listed on the radiography request form and the radiographers were explicitly instructed to examine the images for these specific pathologies. The images had to assigned to one of 4 categories: 'alert' (abnormality present), 'no alert' (no abnormality present), 'unsure' or 'outside scope'. This classification was stamped on the request form. If the 'alert' category was chosen they were requested to give a brief written description of their concerns on the same form (see Appendix A). Any referrals not about the listed pathologies were simply marked with the 'outside scope' category.

To provide an independent and objective measure of the radiographers' accuracy, the PIEs were reviewed once every week by one auditor according to marking criteria created by the researchers and shown in Figure 1 (see also Appendix B). The accuracy of the PIEs was categorized as:

- True Positive (TP)
- True Negative (TN)
- False Positive (FP)
- False Negative (FN)
- Combined True Positive/False Negative (TP/FN)
- Unsure
- No PIE provided (non-participation)

The detailed descriptions of the above categories were as follows:

True Positive: The PIE concurred with the radiology report on the presence of an acute abnormality, including the type of injury, its location, and side (any mistakes resulted in the PIE being considered for the TP/FN category). In the case of multiple injuries TP was only assigned if all had been correctly identified.True Negative: The PIE and radiology report agreed on the absence of any abnormalities or on the presence of a normal variant.

False Positive: The PIE identified an abnormality that was not considered such in the radiology report.

False Negative: The PIE categorized the image as normal, but the radiology report considered an abnormality to be present.

TP/FN: Half marks were given when the PIE was only partially correct. This could occur if they had identified the presence of an abnormality but made errors in some of the details (type of injury, site, side). Similarly, when the PIE only indicated a single abnormality when the radiologist identified several. In these cases the PIEs were awarded 1/2 TP + 1/2 FN.

Unsure: This category was used if the PIE had been marked as unsure irrespective of the contents of the radiology report.

Non-Participation: This was assigned if the image request was for a condition within the scope of the study but no PIE was produced.

Marking Criteria

True Positive (TP) scores are only assigned if the PIE is in agreement with the radiology report in all of the following three criteria:

1. Injury type(Fracture, dislocation, etc.)
2. Bone/body part affected
3. Side of injury (where both sides are present in the image, the correct one must be

identified) Figure 1: Marking Criteria for True Positives

After the three-month study period the radiographers took part in a 2-week training program on the interpretation of axial radiographs. The content of the program was reviewed by one of the authors (F.A) who specializes in radiology, and included all conditions within the scope of the PIEs defined for the study (Table 1). Common pathologies of the axial spine were also covered. The program was delivered through a combination of lectures and practical training sessions, with the lecture notes and additional pathological imagery made available electronically. The radiographers took part in a posttest five days after completing the training program, during which they had to interpret the same images used for the pretest. The procedure and scoring scheme employed for the posttest were identical to those used for the pretest. The time from pretest to posttest was approximately two weeks and the participants work commitments meant that the study period could not be extended.

Table 1 Pathologies within the scope of the preliminary image evaluation

1- Bony Fractures (e.g., of the skull, vertebrae, or pelvis)
2- Joint Dislocations or Subluxations
3- Birth defects in the vertebral column (such as spina bifida)
4- Spine disorders such as diffuse idiopathic skeletal hyperostosis (DISH)

Statistical analyses

Prior to analyses, Cronbach's alpha was used to confirm the internal consistency reliability of the rating scales used by respondents to rate their confidence.The consistency of the scale used to measure participants' confidence in their PIEs was checked for internal consistency by computing Chronbach's alpha. Descriptive statistics of participant scores across groups were used to examine the data. A chi-square test of independence found no evidence for any relationships between the categorical variables.One-way ANOVA was used to ensure the significant value among three groups (>10, 6-9, 1-5) of the participants and overall scores. A one-way ANOVA was used to examine differences in the overall scores of participants grouped by educational level, and a one-sample t-test was used to compare the scores of male and female participants.

3. Results and Disscusion

Forty-one radiographers (34 male, 7 female) participated in the study, with experience ranging from 1 to 29 years. The scale used by the radiographers to rate their confidence in the accuracy of their PIEs had high reliability, with a Cronbach's alpha of 0.88. Participant demographics are presented in Table 2. For the analyses, participants were categorized into three groups according to their years of experience in radiography (1-5, 6-9, > 10), and also according to their ages (≤ 24, 25-30 and ≥ 31).

Table 2 Participant demographics

Variables	Category	Frequency	Percent
Gender	Male	34	83%
	Female	7	17%
Age	< 24	2	5 %
	25-30	7	17%
	> 31	32	78%
Year of experience	> 10	27	66%
	6-9	6	15%
	1-5	8	19%
Highest Qualification	BSc	20	49%
	Masters	14	34%
	PhD	7	17%
	Total	41	100.0%

The pathology most frequently identified correctly was facial bone fracture ($M = 5.66$, $SD = 1.24$). Most radiographer PIEs assigned to the (FN/TP) category were cases with inflammatory disease of the axial spine such as ankylosing spondylitis ($M = 3.83$, $SD = 1.69$). In contrast, the most commonly misinterpreted cases were images of cervical spine disorders such as diffuse idiopathic skeletal hyperostosis (DISH) ($M = 2.49$, $SD = 1.36$). The highest PIE scores ($M = 5.31$, $SD = .383$) were attained by participants aged 24 years or less, while the lowest those 31 years or more ($M = 3.90$, $SD = .780$). However, the differences in PIE scores across the age groups was not significant ($p = .56$).

Participants with 1-5 years of experience had the highest PIE scores ($M = 4.83$, $SD = .54$) while participants with 6-9 years of experience had the lowest ($M = 3.15$, $SD = .872$), and this difference was significant ($p < .001$).The male radiographers obtained higher PIE scores ($M = 4.04$, $SD = .80$) than females ($M = 3.96$, $SD = 1.18$), but this difference was not significant.

Differences in PIE scores across the years of experience groups were examined with a one–way ANOVA. Radiographers educated to PhD level obtained the highest PIE score ($M = 4.31$, $SD = .63$), with a range of 2 to 6, and those educated to master's level the lowest ($M = 3.92$, $SD =.796$), but the observed differences were not significantly different ($p = .62$, $p < .05$).Pearson's correlation coefficients were calculated to examine the relationships between age, gender, year of experience, and educational level. Interpretation accuracy was negatively correlated with age, while years of experience showed a positive but not statistically significant correlation. Gender and educational level were not correlated with diagnostic accuracy. No significant correlations were found between gender and any of the other variables. As would be expected, there was a strong positive correlation between years of experience and age ($r = .794$, $p < .001$) indicating that the radiographers with more experience tended to be older. Similarly, there was a moderate positive correlation between years of experience and educational level (r = .794, p < .001) suggesting that higher educational levels are associated with more years of experience.

The ages of the radiographers were moderately and negatively correlated with their educational levels (r = .45, p = .003), suggesting that older radiographers may have lower levels of education.

Table 3 Linear regression of pie accuracy with years of experience

Coefficients[a]						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.584	.282		12.700	.000
	Years of Experience	.290	.163	.274	1.781	.003

Table 3 shows the statistics for the simple linear regression of PIE accuracy with years of experience as the predictor. As is evident, there was a significant linear relationship (p = .003), with the adjusted R-squared of .075 indicating that 75% of the variation in PIE accuracy can be explained by years of experience.

Table 4 Descriptive statistics for pretest and posttest PIE accuracy

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
Pre-test scores	41	3.70	.999	.156
Post-test scores	41	3.99	.910	.142

Table 5 One-sample t-test for the pretest and posttest accuracy scores

One-Sample Test					
	Test Value = 0.05				
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference
					Lower
Pre-test scores	23.35	40	.000	3.64	3.33
Post-test	27.72	40	.000	3.94	3.65

As stated in Table 4 and Table 5, an analysis of PIE score mean differences between the pretest and posttest means and the hypothesized population mean was examined using a one-sample t-test. Pretest-and posttest accuracy scores (M=3.70, SD=.999) and (M=3.99, SD=.910), were both significantly different from the hypothesized value of 0.05 (pre-test: $t = 23.35$, $p = .001$; posttest: $t < 27.72$, $p <.001$, $p <0.05$) with the test value established at 0.05.

Discussion

This study was carried out to examine the accuracy with which Iraqi radiographers could identify abnormalities in radiographs, when compared to radiologists. As shown in Table 2, the accuracy of their diagnoses was not as high as the radiologists. The pathology that was most accurately diagnosed was skull fractures, which is in agreement with previous studies, where accuracies of 81% have been reported (13). In a large (7179 cases), multi-centre study of radiographers' reports concerning skeletal trauma in four sites in the United Kingdom, the accuracy of the reports was very high at 99.1%, and their sensitivity 97.6%, and specificity 99.3% (14).In this study, the pathologies that were found to be identified but with less accuracy or completeness in the reporting (the FN/TP cases) were inflammatory diseases such as ankylosing spondylitis. Similar results have been reported in a South African study on abnormality detection in X-ray images (15). Encouragingly, it was also found that the accuracy could be improved with postgraduate training (16, 17), which highlights the importance of providing such training for radiographers.Cervical spine disorders, such as DISH, were the pathologies that the radiographers had the most difficulty with. These were frequently misinterpreted by the radiographers in the study. These pathologies have also been previously reported as challenging for radiographers, 86.7% of whom indicated that their training was insufficient to become reporting radiographers, and that there needed to be improvements in areas such as radio-pathology and the proper format for reporting (18).

This finding is important, as it is a specific pathology that could be focused on during training to improve the skills of radiographers and ensure they detect these types of abnormality. It also highlights that more emphasis needs to be placed on classes of conditions that are commonly misdiagnosed by radiographers.There was no evidence in our data, to suggest that there were any systematic differences in the accuracy of PIEs produced by male and female radiographers or of any relationship between their ages or educational level with accuracy. However, the linear regression of PIE accuracy with years of experience showed that was influenced by the radiographers' experience, as found in previous studies (19). This finding is in many ways encouraging (and, perhaps, to be expected), as it implies that radiographers continue to refine their image interpretation skills through experience despite most not having any formal training in this skill. Moreover, the development of these skills may well involve complex pattern recognition processes that depend on subtle perceptual cues that are likely to be detected in the image only implicitly. That is, experienced radiographers may not have conscious access to the multiple image features and their spatial arrangements, that they use to make image interpretations and that are probably responsible for the significant effect on accuracy found in this study (20).

Some studies have indicated that the training radiographers receive on medical school curricula is insufficient (21, 22). While experience does appear to improve image interpretation accuracy, it needs to be combined with regular training and practice to develop these skills further.The training intervention that formed part of the current study showed that two weeks of image interpretation education and practice had a positive effect on radiographers' PIE accuracy, as can be seen in Table 10. These types of improvements have been found in previous studies of such training carried out in the UK (23, 24).The current study has both strengths and limitations. One strength is the relatively large sample of radiographers who participated. One limitation, however, was that all the participants came from the ThiQar province, and so may not be representative of the entire country's radiographers and their image interpretation skills. This is also true of the site used for the study, as this was only one public health facility and the results might not generalize to all such facilities.Similarly, the number of images used in the study was quite limited. However, this was thought necessary to ensure both a high response rate and response quality. To address these limitations, future studies could adopt a multi-centre design with a greater sample of images for evaluation.

Conclusion

This study showed that radiographers were able to evaluate radiographs with a reasonable level of diagnostic accuracy when compared to radiologists. More experienced radiographers tended to produce more accurate PIEs and a short (two weeks) training program was effective at improving the radiographers interpretational skills. Of the pathologies present in the images, facial bone fractures were most consistently identified. Importantly, the results also were informative about those pathologies that were the least well diagnosed. This information could be used to target areas of the current curricula for improvement, as well as to inform additional education and training programs. The findings provide valuable information for healthcare providers, and in particular for the emergency and medical imaging departments of hospitals, and could be used to enhance radiographers' and other health professionals' skills in interpreting radiographs.

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