A pilot study to assess radiographer preliminary clinical evaluation (PCE) introduced for emergency department adult appendicular X-ray examinations: Comparison of trained and untrained radiographers.

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Manuscript

Introduction

In the 1980s, Radiographers began to use "Red Dot" annotations to indicate when they could see an abnormality on trauma X-ray images.[1] The aim was to prevent referrers from missing abnormalities that the radiographers had already identified and to maximise diagnostic accuracy through a collaborative approach. This was necessary because the definitive radiological clinical report would often be issued after the referrer had treated or discharged the patient based on their own evaluation of the X-ray images. Such difficulties with timely radiological reporting have persisted despite aspirations for hot reporting of suspected fracture cases before emergency department discharge.[2, 3, 4] Whilst radiographer red dot systems were useful, their communication was limited to binary flagging of abnormal images and non-mandatory systems made it unclear whether a lack of a red dot annotation meant that no abnormality was detected or was due to non-participation. In 2013, the Society and College of Radiographers (SCOR) issued guidance to standardise practice, which instead advised radiographers to provide written preliminary clinical evaluation (PCE) diagnostic comments to accurately communicate and specifically describe their findings from reviewing X-ray images after each examination, to assist referrers with patient management whilst awaiting radiological reporting.[5] However, unfortunately, radiographer PCE scheme adoption has been slow and workforce surveys have identified objections to mandatory commenting with fears of errors leading to litigation, concerns about lack of time for commenting without affecting patient workflows and lower confidence in PCE performance compared to red dot.[6, 7]

A systematic review of three red dot studies and five radiographer triage commenting studies, from 2006 by Brealey et al. [8], actually identified higher skeletal X-ray radiographer triage comment accuracy (pre-training 92%, post-training 94%) compared to red dot (pre-training 90%, post-training 92%). However, it is unclear how specific the triage comments were required to be and simply describing whether cases were normal or abnormal could have been sufficient to gain marks without identifying the type or sites of injury. From 2007 to 2018, radiographer abnormality commenting was assessed by numerous non-clinical practice image test bank assessment studies but most were small in scale, consisting of 20 to 58 cases, and these may have been unreflective of real-life practice.[9-14] There was a paucity of research into specific radiographer PCE commenting accuracy in the clinical practice setting but recently, in 2022, a study by Verrier et al.[15] analysed radiographer PCE in clinical practice at an English public hospital. Accuracy, sensitivity and specificity of 92%, 84% and 97% respectively was identified for appendicular X-ray, which suggested encouragingly similar standards for PCE as for red dot and triage commenting. However, potential for case selection bias was described as participants only had to provide PCE for X-ray images that they felt confident to interpret.

The aims of the current study were to further assess radiographer PCE participation rates and accuracy compared to radiological clinical reports during a trial period. The performance of a group who had completed local PCE training would also be compared with those who had yet to complete it to identify whether training course preparation was useful. The results would determine the feasibility of transitioning from a red dot system to radiographer PCE moving forwards.

Methods

Study Design

This was a small scale pilot study conducted in the Emergency Department of an English public hospital. During a feasibility trial period the participants had been instructed to enter their own "Radiographer PCE Trial" comments onto the radiology information system for adult (>18 years) trauma appendicular X-ray examinations (shoulder – finger; hips – toes) without collaborating. The images were assessed by the participants on the Samsung X-ray acquisition console (using an EIZO RadiForce MS236WT 23inch Medical LCD monitor) immediately after each examination. The researchers retrospectively collected these PCE comments for examinations performed between the hours of 8.30-17.00 Monday-Friday over five months between September 2021 and January 2022. The participant's identities were pseudonymised and the PCE comments were scored for accuracy compared to the standard radiology report issued by a reporting radiographer.

Ethics

The Health Research Authority (HRA) evaluation tool deemed the project to be a service evaluation.[16] Ethical approval was granted by Canterbury Christ Church University and the project was permitted by the hospital Trust Research and Development Department. The radiographer participants were recruited by email invitation without offer of incentive for participation or performance levels. Each participant was issued with a participant information sheet and signed a consent form prior to data collection. The red dot system continued to operate during the PCE trial period and the PCE trial comments were not available to the referring clinicians to ensure that normal practice was unaffected.

Participants

Ten radiographers were recruited as a convenience sample from the available workforce who were rostered in the emergency X-ray service regularly enough to obtain adequate PCE case quantities during the trial period. There were two radiographers rostered in emergency X-ray for each of the five weekdays and, therefore, the radiographer sample size (n = 10) was considered to be representative of the typical weekly workforce. The trained radiographers (n = 5) were senior Band 6 grade with more than five years' experience and had attended a local PCE and image interpretation course provided by the hospital's reporting radiographer practitioners as part of a test bank trial study in February and March 2020.[17] This study assessed the radiographers performance before and six weeks after intervention training, when providing PCE comments for a bank of 30 selected trauma examinations; with 15 abnormal and 15 normal cases. The course provided two, three hour, small group teaching sessions, including Microsoft PowerPoint presentations with targeted teaching about the clinical presentations, X-ray appearances and subsequent treatments of a wide variety of appendicular skeletal injuries encountered in emergency X-ray (Table 1). This was followed by reviewing interesting cases with interactive questions and answers to develop the participants' PCE commenting skills. The training was provided 18 months prior to the current study but top-up training was not possible because studies that involved randomisation or intervention required HRA Ethics Committee review, which was suspended for non COVID-19 related student research projects when approval was sought.[18] For the current study, another control group of "untrained" radiographer participants were also recruited from the remaining emergency X-ray workforce. The untrained radiographers (n = 5) were all junior Band 5 grade radiographers who had been qualified for less than five years at the onset of the PCE trial. They had received standard undergraduate PCE training as part

of their BSc (Hons) Diagnostic Radiography degrees but had not attended the targeted local training course that was provided for the senior radiographers.

Sample Size

Sample size estimate calculations were performed based on a formula described by Scally and Brealey's confidence interval and sample size calculation article.[19] The aim was to obtain sufficient data quantities to compare the performance of the locally trained and untrained groups. At the onset of the study, there was no available literature that described radiographer PCE commenting accuracy in clinical practice as a basis for the calculation. Most recent local audit data suggested that untrained radiographer red dot accuracy of 85% could be expected from the workforce, which was assumed as the lowest expected accuracy. A maximum expected accuracy of 95% for trained radiographer commenting was adopted based on the available previous research that assessed radiographer triage commenting in clinical practice.[8] Assuming interest in a 10% difference in PCE accuracy between trained and untrained radiographers the researchers adopted a two-tailed test methodology and calculated that a total of 454 X-ray examinations would be sufficient, with 227 examinations per radiographer group.

Data Scoring

The radiographers' PCE comments were extracted and pseudonymised by the audit lead reporting radiographer prior to scoring to prevent any scoring bias. The lead researcher then scored the PCE comments compared to the clinical reports with true positive/negative (TP/TN) and false positive/negative (FP/FN) fractions. Each case score totalled at 1 but incremental fractions were applied where there were cases of partial correctness or error. For example, if a PCE comment correctly described the main diagnosis such as a distal radius fracture but omitted an associated small ulna styloid process fracture then this would score 0.75 TP and 0.25 FN. Similar scoring methods have been employed by comparable previous research on this topic.[9, 15] Radiographers were required to include the correct site of each fracture to gain a full mark. Simply stating that a fracture was present was not sufficient to gain any marks and injuries incorrectly described at the wrong site were scored as false positives. This would prevent false over scoring where PCE comments were inaccurate or incorrectly described a fracture at a different site to the clinical report. A randomised subsample of 60 cases (11%; six per participant) were independently scored by a moderator reporting radiographer for consistency, which found complete agreement. After scoring was completed, the lead researcher was un-blinded so that the results of the trained and untrained groups could be determined.

Results

PCE Participation

Picture archiving and communication system search parameters identified 796 eligible adult appendicular skeletal emergency X-ray examinations performed by the radiographer participants during the PCE trial period, out of which 528 (66%) had trial PCE comments recorded (Table 2). Participation was significantly higher (23%; Z = 6.65, $p < 0.001$; 95% CI: 16.52, 29.02) for the trained radiographer group (80%; n = 253/316) compared to the untrained radiographer group (57%; n = 275/480). The median number of cases with PCE recorded was 50 per radiographer (range 8 – 103).

Radiographer Groups' PCE Accuracy

Of the examinations with PCE comments, 37% (195/528) were abnormal on the clinical report. There were 29% (*n* = 154) with single abnormalities and 8% (*n* = 41) with multiple abnormalities present. Similar PCE accuracy (90% vs. 89%) was achieved by both the trained and untrained groups respectively (Z = 0.26, *p* = 0.80; 95% CI: -4.58, 6.00). Sensitivity performance was higher for the trained group (86%) compared to the untrained group (82%) but the difference was not statistically significant (Z = 0.79, *p* = 0.43; 95% CI: -6.18, 14.60). No significant difference was found for specificity between the trained (91%) and untrained (93%) radiographers (Z = 0.42, *p* = 0.67; 95% CI: -4.58, 7.06). A two-tailed Chi square test also did not find statistically significant variance between the groups' TP, TN, FP and FN scores (X^2 = 0.800, *p* = 0.85).

Inter-Radiographer Performance

Two trained radiographers (4 and 5) completed fewer PCE entries than expected due to job changes (*n* = 12 and *n* = 8 respectively). As a result, their individual performances were included within cohort (trained vs. untrained) analysis but not for inter-radiographer analysis. The eight remaining participants who provided more than 40 PCE comments were included in inter-radiographer analysis. The PCE accuracy for these radiographers ranged from 85% to 92% (Table 3). Sensitivity ranged from 71% for untrained Radiographer 10 to 94% for trained Radiographer 3. Specificity was higher than sensitivity for most radiographers (6/8) and ranged from 86% to 96%.

Body Region

Examination body regions were grouped for sub-analysis (Table 4) and accuracy breakdown is included in Figure 1. Similar quantities of upper limb (*n* = 121 vs. 137) and lower limb (*n* = 132 vs. 138) examinations were included for both the trained and untrained groups respectively. The study was not powered to detect the significance of differences between body part accuracy or individual inter-radiographer performance, which would require a vast number of cases.

Error Types

A broad spectrum of skeletal injuries were identified by the radiographers (TP, *n* = 158). False negative errors (*n* = 29.75) were typically for subtle injuries such as non-displaced fractures, subtle avulsion fractures or acromioclavicular joint disruptions (Table 5). False positive errors (*n* = 27.5) occurred when radiographers over-called fracture lines or when they misinterpreted normal variants of skeletal anatomy. There were few "satisfaction of search" type errors where one abnormality was correctly described but other injuries were not.[20] These included distal radius fractures where associated ulna fractures were not mentioned and distal fibula fractures where associated tibial posterior malleolus fractures or lateral talar shift were not described (Table 6).

Discussion

Over the five month evaluation of radiographer PCE for adult appendicular trauma skeletal X-ray examinations at an English public hospital, PCE participation rates were significantly higher for the group of locally trained radiographers (80%) compared to the untrained radiographers (57%) but no statistically significant difference was found between the groups' PCE sensitivity, specificity and accuracy levels. The results suggest that PCE training courses may improve radiographer confidence,

resulting in higher levels of PCE participation. If more recent top-up training had been available before the trial commenced, it is possible that the participation rates of the trained group could have been improved even further. An approach of local PCE training provided by reporting radiographers could be a low cost solution to improve the willingness of radiographers to engage with mandatory PCE schemes, which have previously raised concerns.[6]

The PCE accuracy scores for this study's trained and untrained groups (90% vs. 89% respectively) were similar to those of previous systematic review research that assessed pooled radiographer red dot (trained 92%, untrained 90%) and triage comment (trained 94%, untrained 92%) accuracy from clinical practice studies.[8] Lack of statistically significant differences between the groups' PCE accuracy scores, correlates with red dotting or triage commenting accuracy, where differences in performance before and after training courses were also non-significant.[8] Lower radiographer commenting accuracy has been observed in non-clinical practice test bank study research (trained 73%, untrained 64%) but this could be due to increased proportions of difficult abnormal cases being selected in this approach.[12] The overall radiographer appendicular PCE accuracy (89%) for the current study was similar to that observed by Verrier et al.[15] at another English public hospital (92%), which also adds confidence that these results are not isolated. The comparable accuracy of the current study's locally trained intervention group and untrained control group suggests that prior university PCE training provided the junior and more recently qualified radiographers with equivalent knowledge to that which their more senior colleagues had developed from the local training, experience of red dotting and continuing professional development; confirming that both methods can lead to the similar levels of performance, as previously suggested by the SCOR's policy guidance.[5]

Radiographer PCE accuracy (89%) exceeded previous local red dot audit accuracy (85%), which means that PCE would be a credible service improvement for the hospital trial site. This standard of radiographer PCE is also satisfactory compared to ranges of expected clinical reporting accuracy for skeletal X-ray imaging (minimum 80%, ideal 95%).[21] Expected radiographer PCE standards to benchmark and audit against should become more established as more hospitals trial PCE schemes. If acceptable PCE audit scores become a mandatory requirement for emergency X-ray radiographers then the implications for workforce management will have to be considered. This may lead to PCE being regarded as enhanced practice in relation to the general X-ray radiographer role.[22] The requirement for PCE trained radiographers may be more challenging for on-call rostering where staff who spend less time in emergency X-ray, may find it more difficult to maintain their skills.

Limitations

Whilst the senior radiographers who received the local training had higher levels of PCE participation, this could have also been due to increased confidence from their greater experience, amongst other factors, rather than due to the training course alone. Furthermore, the junior radiographers who did not receive the local training had received PCE training as part of their undergraduate degree studies and, therefore, were not entirely untrained in providing PCE. To separate the variables of training course impact, prior experience and seniority further, future study designs could examine pre and post training intervention PCE participation rates for the same cohorts of junior and senior radiographers; this approach was not possible for this study due to research limitations imposed during the COVID-19 pandemic.[18]

In total, 44% of the eligible examinations in this study were not commented on by the radiographers, which suggests that case selection bias could have inflated the scores if the radiographer participants avoided commenting on difficult examinations, and this may have also influenced the results of similar previous research.[15] Larger scale studies could use a mixed methods approach to further explore the reasons behind why omitted examinations occur. Including all other X-ray examination types (axial skeleton, chest and abdomen) as well as paediatric patients would also yield a more comprehensive understanding of radiographer PCE. Future research into out of hours and on-call radiographer PCE is also particularly important because radiographer PCE is likely to have even greater value in such circumstances, where immediate radiological clinical reporting is less available.

Interpretation errors identified were typically for subtle injuries, which could have been less perceptible on the X-ray acquisition console monitor where the resolution is slightly lower than the reporting monitors that were used. Whilst this was not reported as an issue, this may have lowered the PCE accuracy scores and ideally equivalent monitors should be used for comparable diagnostic conditions. Radiographer participants did, however, describe barriers to PCE participation that included busy periods, equipment failures and sickness affecting staffing levels. These limitations have also been identified by previous survey research and are likely to continue to hamper the consistency of PCE scheme implementation moving forwards.[6] It would be unreasonable to expect radiographers to provide mandatory PCE comments when working conditions do not permit due care; however, taking steps to introduce radiographer PCE where possible should help the role to become more established and accounted for as normal practice.

Conclusion

The senior radiographers who received local training were significantly more likely to provide PCE than their junior colleagues who did not, which indicates that training courses may be useful to boost confidence for more consistent PCE scheme participation and implementation. Similar acceptable levels of PCE accuracy achieved by both groups of radiographers suggests that undergraduate university PCE training for newly qualified radiographers provides similar knowledge to that which senior radiographers develop from CPD training courses and experience. The results provide further evidence to support the view that radiographers are equipped with sufficient adult appendicular X-ray image interpretation skills to transition from red dot to PCE systems, in order to provide more useful diagnostic services for patients and clinicians in the emergency setting.

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