Title

Adult chest radiograph reporting by radiographers: preliminary data from an in-house audit programme.

Shortened Title

Auditing of radiographer chest reporting

Key words

Radiographer Reporting; Clinical Competence; Advanced Practice; Radiography, thoracic; Audit

Abstract

Aim. To examine the adult chest radiograph (CXR) reporting performance of a reporting radiographer in clinical practice using different audit systems; single radiologist and two radiologists, with clinical review of discordant cases.

Materials and Methods. 100 chest radiographs (CXRs) were drawn randomly from a consecutive series of 4,800 CXRs which had been reported during a nine month period at a district general hospital by a radiographer after two years of training. Diagnostic outcomes were normal or abnormal, and agreement with the reporting radiographer or not. There was 50% duplication of CXRs reported between three radiologists. Concordance rates were determined for the radiographer-radiologist and inter-radiologist interpretations. Independent clinical review of discordant cases was performed to establish the final diagnosis.

Results. Ninety-nine cases were reviewed, with 40 cases deemed abnormal by at least one radiologist. Consensus was found with the radiographers report in 59 normal and 33 abnormal CXRs reviewed by two radiologists (96.7% and 86.8% respectively). Seven CXR reports were discrepant with clinical review: mediastinal lymphadenopathy was missed by both radiologist and radiographer; linear atelectasis was reported by two radiologists but not the radiographer. Three cases were over-interpreted and on two occasions at least one radiologist agreed with the radiographer. There was very high concordance between the radiographer and each radiologist, 96%, 96% and 92% respectively.

Conclusions. This study suggested that regular audit, which incorporates case note review and discrepant reporting within a multidisciplinary setting, should contribute to safe practice. [239 words]

Introduction

Radiographers who report imaging examinations must demonstrate ongoing competence, with performance comparable to consultant radiologists (1). Audit has been advocated as a key component of ensuring safe practice but no definitive structure has been established (2-5). Proposed audit frameworks for radiographer reporting have been developed; musculoskeletal (minimum 95% accuracy, single reporting radiographer reviewer)(6) and ultrasound (95% compliance with scope of practice)(7). However, no published work has yet examined the audit of chest radiograph interpretation by trained radiographers.

The research evidence which supports the reporting of musculoskeletal images by radiographers is definitive(8) and there is a growing body of evidence for other modalities, but not for chest radiograph interpretation (9-14) . Recent work has established high levels of sensitivity and specificity of reporting radiographers at the end of an accredited training programme (15) and other historical studies have examined the accuracy of radiographers as part of a lung cancer screening programme(16, 17). Sonnex et al. evaluated the preliminary clinical evaluation of chest radiographs within a specialist cardiothoracic hospital with promising results (18). However, no study has been identified which examines the agreement between reporting radiographers and consultant radiologists producing definitive chest radiograph reports in clinical practice.

Review of the literature demonstrates considerable observer variation when interpreting chest radiographs. The reading of radiographs in emergency departments (19, 20) and of standard banks of films (21) by experienced radiologists show similar error rates approaching 20%. Inexperience and excessive workload

contribute to errors in reporting, whilst clinical details, double reading, discrepancy meetings and multidisciplinary conferences improve accuracy (21-23). Radiologists in training and other physicians are poorer at reading radiographs than consultant radiologists with >4 years' experience, although significant variation is still reported between experienced observers (24). An audit of radiographer performance should, therefore, include several consultant radiologist reviewers to take into account this variability.

Radiographer adult chest radiograph (CXR) reports were therefore audited by three experienced consultant radiologists. The definitive clinical diagnosis was obtained for all discordant cases and compared to the radiographer and radiologist reports.

Materials and Methods

Design, setting and ethical approval

Mirrored on a case controlled design (25), this audit was conducted in an acute district general hospital (DGH) which performs approximately 20,000 hospital based adult CXRs per year. The hospital functions as a DGH, but has medical students and some academic departments which permit the use of "University" in its name. The local Research and Development department indicated that NHS ethical approval was not required for this audit of practice.

Radiograph selection

A sample of cases (n=100, 1.5% of workload) was randomly selected (Microsoft Excel 2007 algorithm) from a retrospective consecutive series of 4,800 digital radiography (DR) adult CXRs interpreted by a trained reporting radiographer in

routine clinical practice from April 2011 to January 2012. Exclusions were CXRs from patients under 16 years of age and those referred from general practice which reflected the scope of practice of the reporting radiographer. One hundred cases is significantly more than the 30 cases suggested by the Royal College of Radiologists for peer review (3) and is in line with the maximum of 100 cases proposed by Stephenson et al for radiographer skeletal reporting (6).

Report audit

The radiographer had twelve years post registration experience and had been reporting CXRs for one year in clinical practice after completion of two years of accredited postgraduate education and personal mentoring from the consultant radiologists within the department. Three consultant radiologists (CR1, CR2 and CR3), with 13, 18 and 18 years' experience, were each given 50 cases and asked to determine if, in their opinion, the CXR was normal or abnormal and if they agreed or disagreed with the report produced by the radiographer. The radiographer's reports included both non-significant comments (old fractures, apical fibrosis, small calcific foci, previous surgery and hiatus hernia) as well as clinically important details (pleural fluid, pneumothorax, collapse or consolidation) (19). The clinical request and previous chest radiographs and reports were available as is the case in routine clinical practice. A 50% case duplication (25 radiographs) between consultant observers was used to assess variability in radiologist agreement with the radiographer report (Figure 1). The consultants performed their evaluation of report concordance independently, blinded to the proportion and identity of cases receiving multiple radiologist opinions. Radiologists were not blinded to the radiographer report, and this pragmatic approach is in line with Royal College of Radiologist

guidance on double reporting (3) and consistent with other reporting radiographer audit systems (6).

Final Diagnosis

A consultant respiratory physician assessed the final clinical diagnosis 18-24 months after the CXR for all discordant cases. No further clinical evaluation was performed for cases which had concordant radiographer and radiologist interpretations. Discrepancy grade was determined by the consultant physician; a major discrepancy would produce a change in patient management.

Statistical analysis

2x2 contingency tables were constructed. Concordance rates between the radiographer report and radiologist interpretation were determined. To assess for agreement greater than chance for radiographer-radiologist concordance, the kappa statistic was calculated (26). Fisher's exact test was used to determine any relationship between access to previous investigations and agreement.

Results

One radiologist observer failed to review one case, resulting in 99 cases which produced 149 interpretations for analysis. One case was reviewed by all three radiologist observers. Fifty-five cases had previous chest radiographs (27 normal, 28 abnormal) available to the reporting practitioner. Of the seven discordant radiographs three (43%) had previous images available. The availability of previous imaging did not influence agreement between observers (Fisher's exact test $p>0.1$). Emergency department referrals accounted for the majority of the cases (52 of 99);

in-patient (24) and out-patient (23) provided similar contributions. The range and frequency of pathologies included in the study are described in Table 1.

Concordance

Table 2 shows very high concordance between the radiographer reports and radiologist interpretation (92-96%). Disagreements were minor (Table 2). Overall, there were 8 differing interpretations on 7 radiographs, but in 6 (86%) of the reports reviewed by two radiologists, the radiographer report agreed with one of the radiologists (2 normal, 1 abnormal). Kappa statistic demonstrated very high agreement ($\kappa > 0.8$) between the radiographer report and radiologist interpretation (Figure 2).

Radiographer report concordance assessed by two or more radiologists

Concordance with the radiographer reports by two radiologists was very similar to the concordance with the radiographer report by a single radiologist. If CR2 is selected as the arbiter one case would have produced an over-interpretation (false-positive consolidation) and two true positive diagnosis made (lower zone atelectasis, mediastinal lymphadenopathy). The mediastinal lymphadenopathy would have been missed if CR3 was the sole reviewer (RR and CR3 normal, CR2 abnormal). The use of CR1 as an arbiter would not have resulted in any clinically significant improvement in performance. There was disagreement in two instances between CR2 and CR3 and one case for CR1-CR2, with concordant opinions in 24 (of 25 cases, 96%) for CR1-2 and 22 (of 24 cases, 92%) for CR2-3.

Radiographer and Definitive Clinical Diagnosis

Clinical details of discordant reports are described in Table 3. There was a single case where both radiologists disagreed with the reporting radiographer (Figure 3). This was a posterior-anterior (PA) CXR with suboptimal inspiration with no previous chest imaging. Case note review revealed that the patient developed a raised white blood cell count and C-reactive protein on subsequent blood tests and a diagnosis of post-operative pneumonia was made. In another instance the radiographer made a diagnosis of congestive cardiac failure where the single reviewing radiologist thought the features were consistent with chronic obstructive pulmonary disease (Figure 4). Cardiomegaly and pleural plaques were reported by both radiographer and radiologist for this case, and were stable compared to previous CXRs. No respiratory function tests were performed on this 79 year old male patient and the clinical data was consistent with the radiographer diagnosis of heart failure.

There was only one major discrepancy between observers in the study which required clinical intervention. One radiologist diagnosed lymphadenopathy at the left hilum and aortopulmonary window, in contrast to the reporting radiographer and another radiologist (Figure 5) in a patient with a history of localised breast cancer treated by mastectomy and tamoxifen. Although the clinical information did not provide the history of cancer, the patient had previous mammograms performed at the hospital. CT confirmed mediastinal lymphadenopathy (range 8 – 18 mm; Figures 6 & 7) but subsequent endobronchial ultrasound biopsy diagnosed tuberculosis.

Clinically Insignificant Disagreements

The radiographer diagnosed consolidation which the radiologist felt to be normal, and this was confirmed at clinical follow up. The radiographer and one radiologist diagnosed lower zone consolidation but the other radiologist felt that this was due to

rotation and composite shadowing; clinical follow up was not consistent with infection (normal white blood cell count and antibiotics were not prescribed). One radiologist added co-existing cardiomegaly to their report in a patient with a large left pleural effusion. The radiographer diagnosed left lower zone bronchial wall thickening which was not commented upon by the radiologists in a known asthmatic patient.

Discussion

Very high concordance rates were found in this audit when radiologists examined a random selection of 99 chest radiograph reports performed by a reporting radiographer in clinical practice. Only one CXR showed a discrepancy that was clinically significant and this case was reported as normal by one of the two radiologists.

Audit Systems

There is no defined benchmark for acceptable performance for radiograph interpretation (22). The established consensus is the performance of the average competent practitioner (19, 22, 27, 28).

Single Reviewer

In this study, the use of a single radiologist reviewer would have produced a range of results, with concordance found in 48 (96%) cases for CR1 and CR2 and only 46 (92%) of cases for CR3. Analysis of the discordant cases revealed only one case where both reviewing radiologists disagreed with the radiographer report. Three cases produced discordant radiologist interpretations, including the only significant discrepancy in the study. The use of CR3 as the sole reviewer would produce a

clinically significant false-negative result and incorrectly diagnosed COPD instead of heart failure. Relative to CR1, there were two discrepancies, neither of which was clinically significant. These high concordance rates are comparable to the performance of radiographers in an objective structured examination (OSE) at the end of an accredited postgraduate programme (15).

The audit system proposed by Stephenson et al (6) for musculoskeletal examinations utilized a single radiographer reviewer, appropriate for investigations with high levels of agreement between experienced observers (8, 19). The variation found in chest radiograph interpretation could render this approach unsuitable for single reviewer audit.

Clinical Review of Discordant Cases from Multiple Reviewers

The use of single and double reviewer systems failed to identify all clinically significant discrepancies when compared to the definitive clinical diagnosis. Inherent observer variation in chest radiograph interpretation requires a more robust method to determine accuracy. It is not feasible in routine practice to perform case note review for all cases; resources are best allocated to those which produced discordant interpretations. This allows the discrepancies of the practitioner to be graded according to clinical impact; the one important discrepancy which required intervention in this study was reported by only one radiologist and required confirmation by CT scan. This audit framework, multiple radiologist opinions on chest radiograph reports produced by a reporting radiographer with clinical review of discordant cases, provides a pragmatic measure of performance.

<u>Limitations</u>

There are several methodological limitations which need to be considered when interpreting the results from this audit. Disease prevalence (29, 30), selection and spectrum bias (only hospital patients) (31), may have inflated concordance rates. The inclusion of hospital patients reflects the case load of the radiographer, but the proportion of diseased in this study reflects that found in inpatients across the UK (32). These biases have been minimised by the random selection of cases. Verification bias could have been avoided if all radiologists reviewed all cases, but time constraints precluded this and this study has not shown a significant difference between radiologists. The definitive clinical review was performed independently to the radiological diagnoses.

A major limitation was the sample size, representing only 1.5% of the radiographer's workload of 4,800 cases for the audit period. In order to have significant power to detect a number of differences (at least 5 in each square of the 2x2 table), the sample would need to have been at least 500. An audit of 5% of the radiographer's adult CXR annual caseload (6,500 CXRs) would require 325 cases to be reviewed. It is important when auditing practice that the task is not so onerous that it may impact on routine clinical care (3, 6). The number of cases reviewed in this study is greater than the 60 suggested when auditing sonographer reporting(7), more than three times the 30 cases suggested as part of radiologist re-validation (3), and comparable to a sample size recommended for musculoskeletal reporting (6). Audits are sufficient to indicate the maintenance of competence by the reporting radiographer, but would not be satisfactory as a determinant of competence.

Another limitation in this study was that the radiologists performed their interpretations with knowledge of the clinical report produced by the radiographer. This introduced reference standard review bias (31) which would have inflated

observer concordance. The systems used in this audit are, however, in line with the Royal College of Radiologists guidance on double reporting for revalidation, where one pragmatic method is that the reviewing consultant grades the initial report for agreement (3). The practical framework proposed by Stephenson et al (6) also requires the reviewing practitioner to assess concurrence between their interpretation and the clinical report. The chest radiographs could have been reviewed again as though a new radiograph to avoid knowing the radiographer's report and compared by a neural arbiter to reduce this type of bias.

The presence of reference standard bias (31) and the sample size used (33) in this audit mean that the kappa statistics should be interpreted with caution, and are not comparable to other observer performance studies. The overall concordance rates reported by Stephenson et al (6) do not differentiate between concordance in normal and abnormal cases. It is important to identify agreement and disagreement in both normal and abnormal cases as this may have implications for practice (34). Concordance rates also fail to account for agreement between the reporting and reviewing practitioner due to chance. The kappa statistic is useful as an additional measure of radiographer performance as it measures the agreement due to chance (33).

Variation in reporting

Significant variation is reported in chest radiograph interpretation in clinical practice by experienced radiologist observers (35, 36), (19, 20, 24, 37). Pneumothorax and lung cancer are critical yet commonly overlooked diagnoses (20, 35-39), but were recognized by the trained radiographer and the radiologists in this study. After training in lung cancer detection, radiographers produced similar numbers of false

negative reports (8 and 4 from 100 CXRs, 52 abnormal) compared to the radiology registrars and the consultant radiologists, eight and six respectively in a structured test environment (17). In another lung cancer screening evaluation, a trained radiographer gave 3/1387 false negatives but 72/123 false positives in a study of pre-screening, although the study design favoured identification of false-positives (16). A more recent study of the preliminary interpretation of CXRs by radiographers in a specialist cardiothoracic unit again confirmed 100/464 (22%) false-positives compared to fewer (38/8150; 0.5%) false-negatives (18). In this study, the radiographer had four (9.8%) false-positives compared to the radiologists [1 (6.3%), 1(6.3%) and 1(5.3%)]. A recent study of the performance of trained reporting radiographers in a structured clinical examination reported a high sensitivity and specificity (95.4% and 95.9% respectively), with the common false negative and false positive errors comparable to those made by radiologists(15).

The value of clinical review

Multidisciplinary meetings (MDM) where radiographs are reviewed by radiologists with the clinicians have become increasingly common (1, 40). They also provide a learning environment for radiologist, reporting radiographer and clinician alike. Discrepant reporting can be identified and practice corrected (3, 36). Even so, there remain radiographs which can be misinterpreted. Attendance by reporting radiographers at the relevant MDM should be mandated to assist in maintaining competence and developing practice and is aligned with recent guidance (41). A test bank, composed of cases known to be difficult such as those with mediastinal lymphadenopathy, subtle pneumothoraces and early malignancies for example, could be used to confirm the competence of a reporting radiographer. This method is

used when assessing practitioners at the end of an accredited postgraduate education programme (15).

Conclusion

Audits of chest radiograph reporting can be used to monitor the continuing competence of the reporting radiographer. Each radiographer should have a minimum of 100 examinations audited, ideally blinded to the clinical report. This audit could form part of the radiographer's annual appraisal. This study suggests that single is as good as multiple radiologist review for this exercise however multiple radiologist review enables inter-observer concordance to be evaluated. Some chest radiographs remain difficult to interpret and often only retrospective review by either clinical data or further imaging is sufficient to establish the diagnosis. Multidisciplinary review is a good learning environment for the reporting radiographer.

[2,844 words]

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Conflicts of interest

The authors declare no conflicts of interest.

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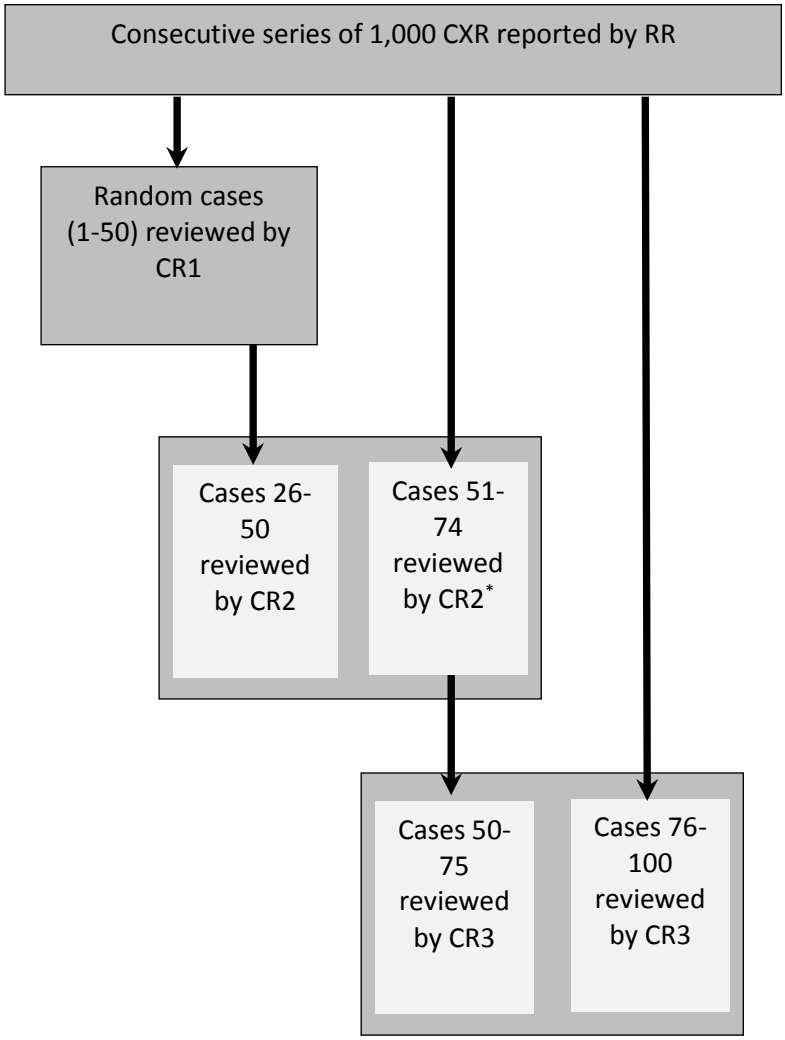

Figure 1. Methodology flow diagram
RR = reporting radiologist, CR = consultant radiologist

* One case not interpreted by CR2

	Cardiac	Infection	Malignant	COPD	PTX	Other	Normal	Total
Number of Cases	10	12	6	2	2	8*	59	99

Table 1. Cases by pathology.

* Other pathology includes 4 stable post-surgical cases, 2 cases of atelectasis, 1 case of asbestos related pleural disease and 1 case with granulomata and old rib fractures.

		RR		CR1		CR2	
		Normal	*Abnormal*	*Normal*	*Abnormal*	*Normal*	*Abnormal*
CR1	*Normal*	33	1[+]				
	Abnormal	1[+]	15				
CR2	*Normal*	32	0	18	1		
	Abnormal	2[+]	15	0	6		
CR3	*Normal*	28	3[+]			14	1
	Abnormal	1[+]	18			1	8
CR (any)	*Normal*	28	2[+]				
	Abnormal	1[+]	19				
CRs*	*Normal*	31	0				
	Abnormal	1	15				

Table 2. Agreement in chest radiograph interpretation.
CR = consultant radiologist, RR = reporting radiographer, CRs = ≥ 2 consultant radiologists.

[+] Discordant cases were subject to clinical review

Disagreements between RR and CRs were: over-call of bronchial wall thickening, consolidation (2: due to rotation and composite shadowing); under-call of not adding cardiomegaly to a report of bilateral pleural effusions, lower zone atelectasis (CR2 and CR3) and hilar/mediastinal lymphadenopathy. Disagreements between CRs were the addition of cardiomegaly, lower zone consolidation and hilar lymphadenopathy.

* Does not include 3 CR discrepancies

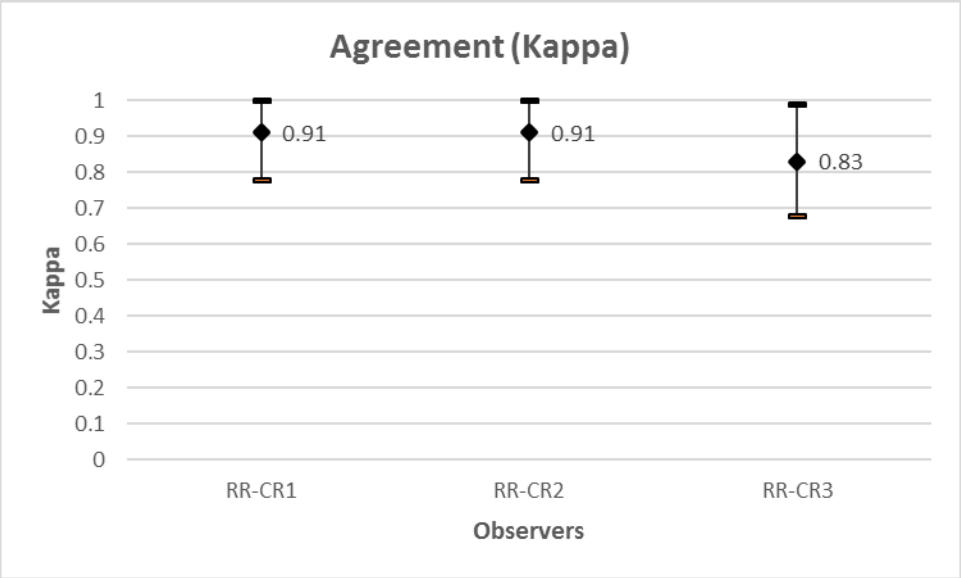

Figure 2. Inter-observer agreement (Kappa) with 95% confidence intervals.
CR = consultant radiologist, RR = reporting radiographer
All inter-observer agreement was statistically significant $p<0.001$

Discrepancy Grade	Clinical History	Radiographer	Radiologist	Radiologist	Final Clinical Diagnosis
Single Consultant Review					
Minor	?infection, cough & DIB	Basal bronchial wall thickening	Normal [CR1]		Asthma (normal x-ray)
	eos. pneumonia, on treatment	Consolidation	Normal (rotation) [CR3]		Normal
Major					
Figure 4	chronic renal failure, increasing oedema and left basal crackles ?pulm oedema	Congestive Cardiac Failure	Chronic Obstructive Pulmonary Disease [CR3]		Congestive Cardiac Failure
Double Consultant Review					
Minor					
Figure 3	erect chest for ?perf 1/52 BNO post section, distended ++	Normal	Left lower zone linear atelectasis [CR2]	Left lower zone linear atelectasis [CR3]	Post-operative pneumonia
	new confusion ?LRTI	Left lower zone consolidation	Left lower zone consolidation [CR2]	Normal (rotation) [CR3]	No infection
	? Hospital acquired pneumonia Admitted with CCF, known to have left pleural effusion, currently treated with diuretic, developed cough, o/e new right base crackles	Left pleural effusion and right lower zone consolidation	Left pleural effusion and right lower zone consolidation [CR2]	Also cardiomegaly [CR1]	Atrial Fibrillation, Congestive Cardiac Failure, Chronic Renal Failure
Major	cough 2 weeks ?TB on histology	Normal	Normal [CR3]	Mediastinal lymphadenopathy [CR2]	Tuberculosis
Figures 5 – 7					

Table 3. Cases which produced discordant interpretations. DIB = difficulty in breathing, eos. = eosinophilic, Perf = perforation, BNO = bowels not opened, LRTI = lower respiratory tract infection, CCF = congestive cardiac failure, TB = tuberculosis

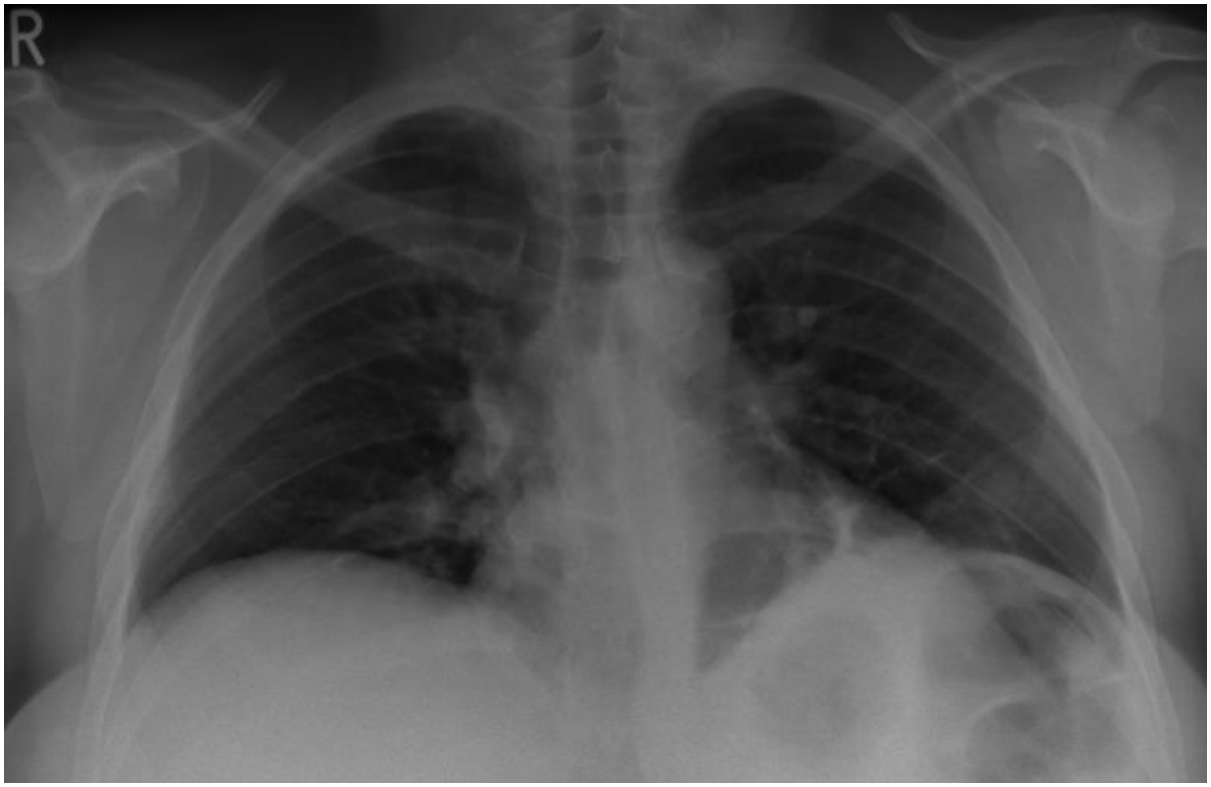

Figure 3. A PA CXR with suboptimal inspiration and no previous chest imaging available. Left lower zone linear atelectasis, interpreted as normal by the reporting radiographer, but diagnosed by both reviewing consultant radiologists.

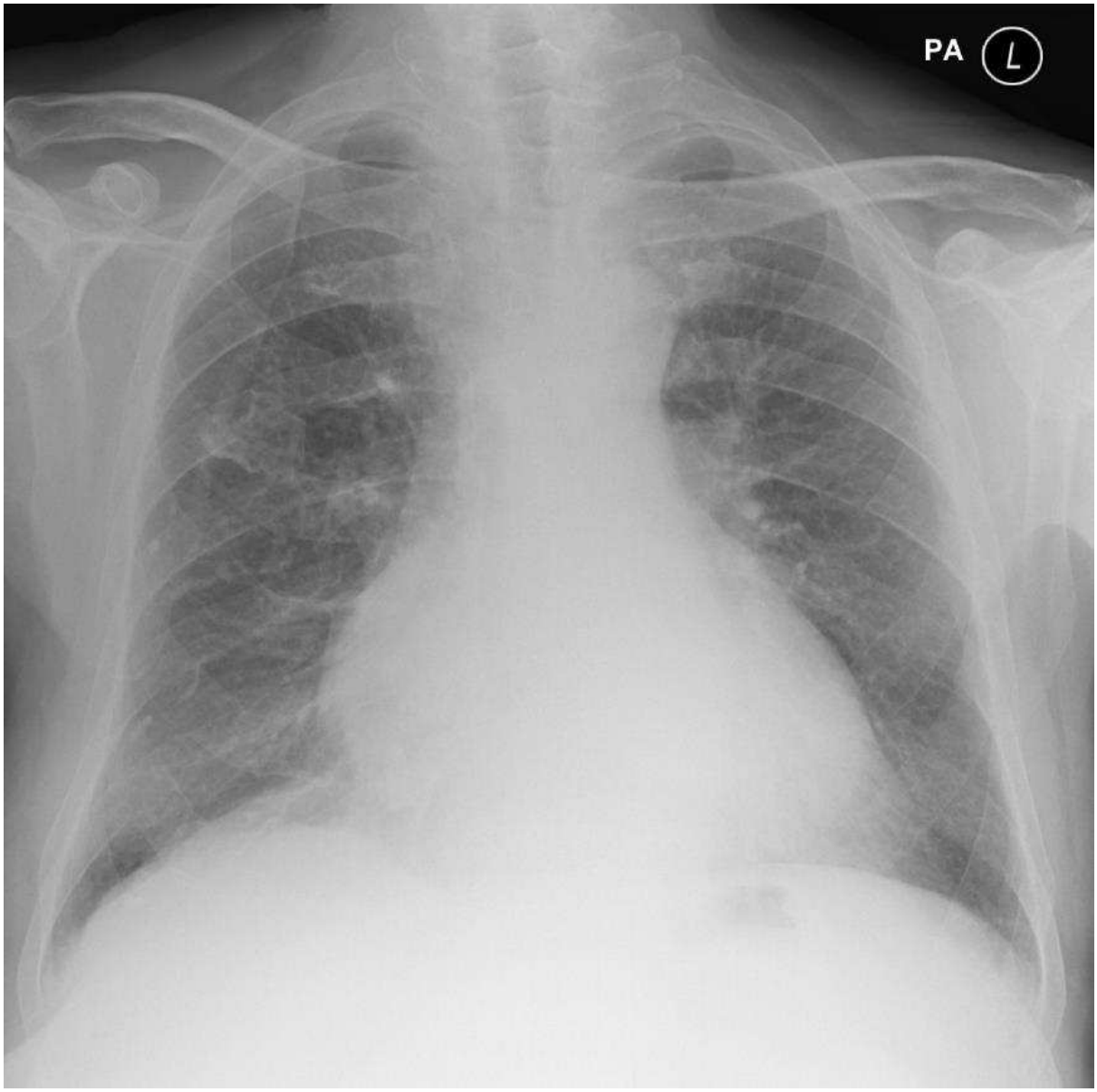

Figure 4. Congestive cardiac failure not chronic obstructive pulmonary disease after clinical review in this 79 year old patient with cardiomegaly and pleural plaques.

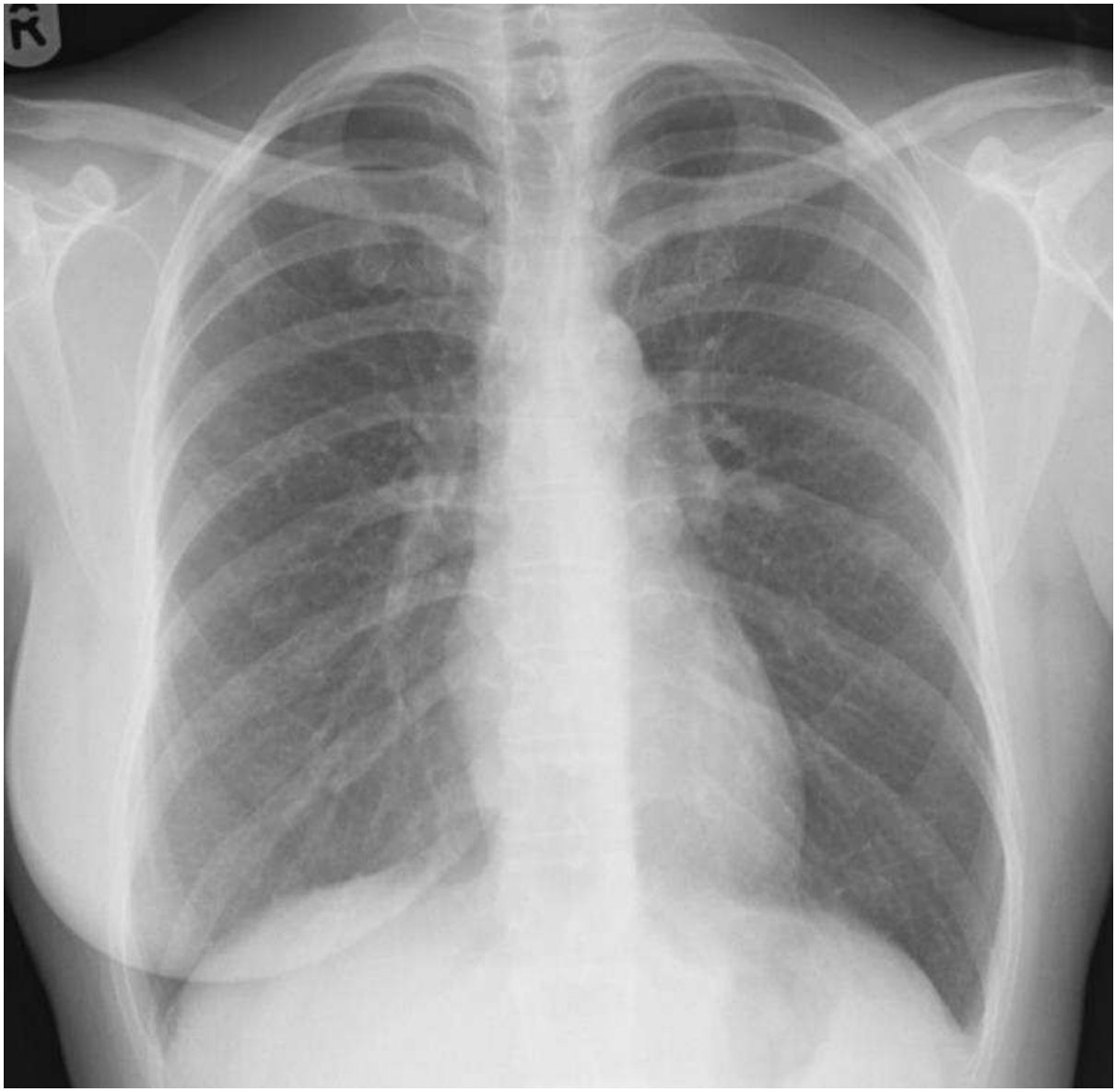

Figure 5. Chest radiograph which demonstrated mediastinal lymphadenopathy, missed by the reporting radiographer and a reviewing consultant radiologist but correctly diagnosed by another consultant radiologist in a patient with a history of breast cancer.

Figure 6. Post contrast CT of the chest (axial section) which demonstrates the mediastinal lymphadenopathy.

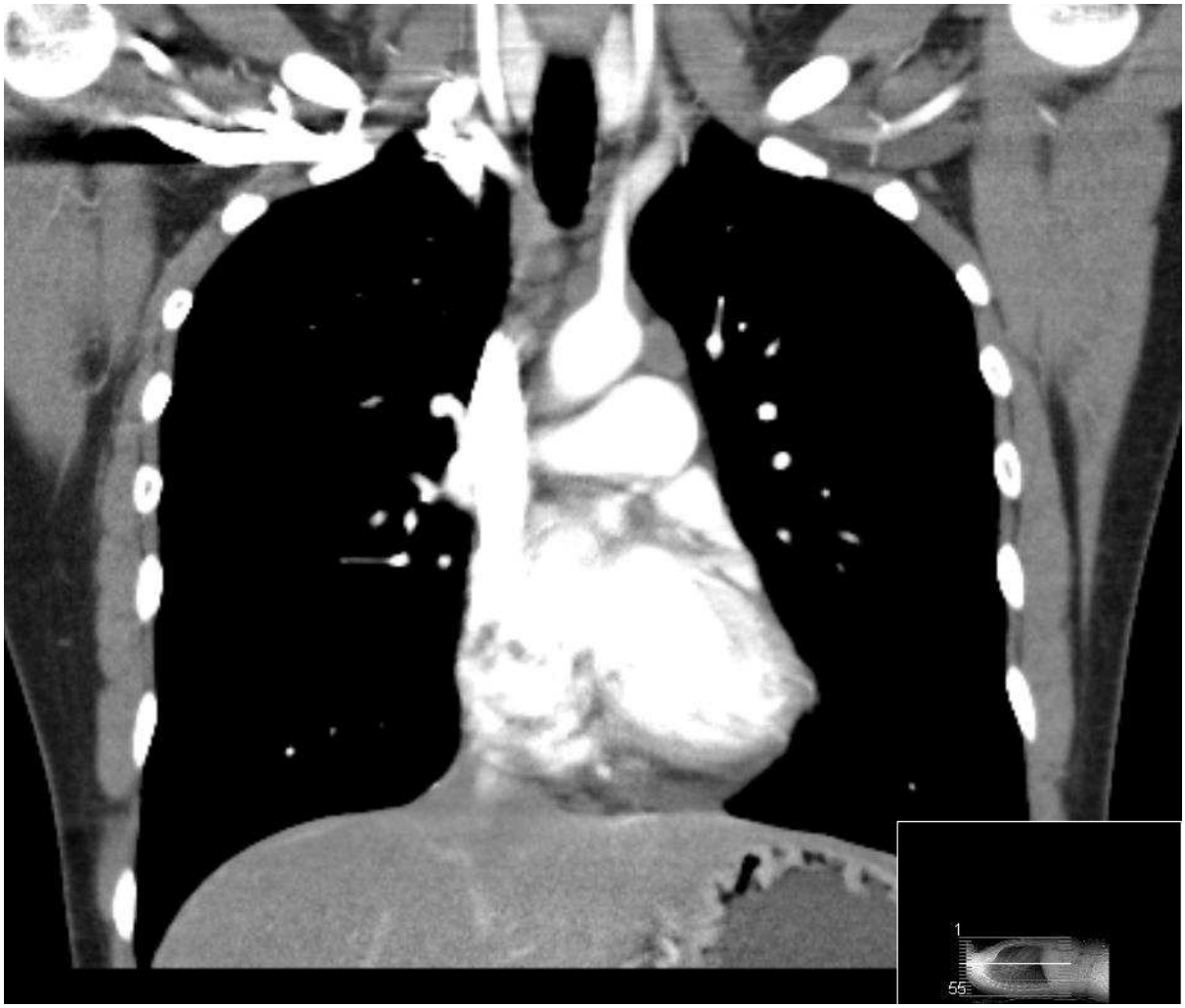

Figure 7. Post contrast CT of the chest (coronal section) which demonstrates the mediastinal lymphadenopathy.

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