Journal of HOSPITAL MEDICINE www.journalofhospitalmedicine.com

ORIGINAL RESEARCH

Clinical Utility of Abnormal Opacity Overlying the Vertebral Column on Lateral Chest Radiography

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Disclosure: Nothing to report.

BACKGROUND: Chest radiography is an important component of the evaluation of patients with complaints referable to the chest. We sought to investigate the clinical utility of one particular finding on the lateral chest radiograph (CXR), namely, radioopacity obscuring the normal superior to inferior progression of vertebral radiolucency. A review of the literature yielded little published evidence to characterize the clinical utility of this finding to date.

METHODS: We retrospectively identified 370 patients from a hospital database who underwent both computed tomography (CT) imaging of the chest and lateral chest radiography within 24 hours. We calculated the sensitivity, specificity, and likelihood ratios (LRs) associated with the presence or absence of an abnormal opacity overlying the vertebral column on lateral chest radiography using CT imaging of the chest as the reference standard. We also estimated interobserver and intraobserver reliability of this finding.

RESULTS: Abnormal opacity overlying the vertebral column had a sensitivity of 86.9% (95% confidence interval [CI], 82.5%-90.3%) and specificity of 70.4% (95% CI, 59.7%-79.2%) for relevant CT-documented lower lobe and associated structural pathology. The associated summary positive LR (LR+) was 2.9 (95% CI, 2.1-4.1) and summary negative LR (LR−) was 0.19 (95% CI, 0.13-0.26). Kappa statistics were indicative of moderate intraobserver and interobserver agreement.

CONCLUSIONS: The presence of abnormal opacity overlying the vertebral column on lateral chest radiography increases the probability of lower lobe and associated structural pathology somewhat. The absence of this finding decreased the probability of such pathology to a greater degree. Thus, this finding is useful in differentiating those patients with pathology from those without. ***Journal of Hospital Medicine*** **2009;4:E15–E19**. © *2009 Society of Hospital Medicine.*

KEYWORDS: diagnostic decision-making, chest pain, pulmonary risk assessment.

In the evaluation of patients presenting with complaints referable to the chest, the chest radiograph (CXR) is an important and almost universal component of the initial assessment.

Chest radiography is normally performed with both posterior-anterior (PA) and lateral projections.[1] The lateral projection is generally accepted as an indispensable component because it allows better visualization of certain structures including the lower lobes, areas of which are partially obscured by the heart or hemidiaphragms on the PA projection. As such, some radiographic findings are only apparent on the lateral projection. As well, when an abnormality is discovered on the PA projection, the orthogonal orientation of the lateral projection often allows lesion localization.

Together with information gleaned from a thorough history and physical examination, the results of chest radiography often inform initial management when a diagnosis has been established, and the need for additional investigations when the diagnosis remains in question. In the hospital setting, the CXR is often reviewed first by physicians who are not radiologists (eg, internists, emergency physicians, and trainees at various stages of training) when evaluating a patient.

We undertook the current study to investigate the test characteristics (sensitivity, specificity, and likelihood ratio [LR]), and precision of 1 particular finding on lateral chest radiography as interpreted by nonradiologist physicians in the hospital setting. On a normal lateral CXR, one should observe progressive superior-inferior vertebral radiolucency (Figure 1A). Observed opacity overlying the vertebral column obscuring this progression is usually abnormal and suggestive of pathology in the lower lobes of the lungs or associated structures (Figure 1B). A review of the literature yielded only 1 study of this finding,[2] which used a case-control design and lacked a true "gold standard" investigation necessary for calculation of meaningful test characteristics. In fact, few studies have compared findings on chest radiography with more definitive investigations,[3,4] and none have examined the predictive value of this finding by nonradiologist observers using a reference standard investigation such as computed tomography (CT) of the chest.

2009 Society of Hospital Medicine DOI 10.1002/jhm.500
Published online in wiley InterScience (www.interscience.wiley.com).

Methods

The radiology Picture Archiving and Communication System (PACS) used at our institution allows us to search for exams by date and study type. We retrospectively identified all patients seen at 1 of 3 university-affiliated tertiary care adult teaching hospitals (Toronto General, Toronto Western, and Mount Sinai Hospitals) within an 8-month period (January 1, 2006 to August 31, 2006) who underwent a 2-view CXR (PA and lateral views). (Note that in this study, the terms "radiograph," "x-ray," and "plain film" are used synonymously.) We then determined which of these patients had a subsequent CT within 24 hours of the x-ray, resulting in a sample of 370 patients for this study. These patients primarily included patients presenting to the emergency department, and inpatients, with a very small number of outpatients. The majority of the index CXRs were performed for chief complaints of dyspnea, chest pain, cough, or for follow-up of a previous CXR. However, many were simply performed routinely for admission. Patients with prosthetic devices or appliances obscuring the vertebral column were excluded.

After several training sessions by an experienced internist (A.S.D.), 2 authors (D.R.M., M.E.D.) independently reviewed each lateral CXR using standard 17-inch displays and documented the presence or absence of abnormal radioopacity obscuring the superior to inferior progression of vertebral radiolucency. These 2 authors were fourth-year medical students at the time the study began and first-year trainees in internal medicine when it ended. The presence of abnormal opacity overlying the vertebral column was recorded as a positive test while the absence of this finding was recorded as a negative test.

Observed opacity overlying the vertebral column on lateral CXRs was considered abnormal when it did not represent manifestations of normal anatomical structures. However, the finding of opacity overlying the vertebral column of little diagnostic significance, such as prominent pulmonary vessels, degenerative bony changes, or the finding of a tortuous aorta, were considered normal in this study. Corresponding PA CXRs were also available for viewing. In most cases, the authors viewed both the lateral and PA CXRs, reflecting their use in clinical practice. However, in cases of obvious abnormality on the lateral CXR, only that projection was viewed. No clinical information was made available to the observers of the lateral CXR and they were blinded to the results of CT imaging of the chest. All 370 cases were reviewed by both observers (D.R.M. and M.E.D.). For the purpose of calculating test characteristics and LRs, cases of disagreement between the 3 lateral CXR observers were resolved by independent review by a third author (A.S.D.), a general internist with over 20 years of experience interpreting the lateral CXR.

A fourth author (M.O.B) reviewed the chest CT reports for each patient and recorded the mention of the presence or absence of various pathologies in the lower lobes of the lungs and associated structures in those reports. No clinical information was made available to this author and he was blinded to the results of lateral CXR. All CT investigations were originally interpreted by a university-affiliated chest radiology faculty member at the time of the investigation. Table 1 lists all relevant chest CT findings in our sample that were recorded as "disease-positive" for the purpose of dichotomizing the results of the reference standard, and enabling calculation of test characteristics (Table 2). Notable chest CT findings that were not recorded as disease-positive for this purpose included mediastinal lymphadenopathy, subpleural density, lytic vertebral lesions, cystic or emphysematous changes, and pneumothorax. Dependent atelectasis was included within the disease-positive category, though some cases may not have been pathological. It should be pointed out that there may be some variation in terminology used between staff radiologists (eg, "reticulation" by one radiologist may be called "minor densities" by another radiologist).

Using the chest CT report as the reference standard for abnormal opacity overlying the vertebral column on lateral chest radiography, we calculated the sensitivity, specificity, and positive and negative LRs (LR+ and LR−, respectively) with 95% confidence intervals (CIs) for individual and summary CT-documented pathologies.[5] For this purpose, we constructed a 2×2 table (Table 2) for summary CT-documented abnormal findings, in which patients with any abnormal CT finding were considered disease-positive and compared with patients whose CTs were interpreted as normal, considered disease-negative. We also constructed 2×2 tables for each of the individual CT-documented pathologies using data from Table 1, in which only the patients with the abnormal CT finding of interest (eg, consolidation) were considered disease-positive and compared with patients whose CTs were interpreted as normal, considered disease-negative. In this case, patients with abnormal CT findings (eg, atelectasis, effusion) other than the finding of interest were excluded from the analysis. This secondary analysis is an attempt to estimate the variability of the accuracy of the finding in question across different diagnoses, and not to derive precise estimates of LRs given the small sample sizes for some individual findings.

Of the 370 original patients, we selected a sample of 100 patients by random number assignment whose lateral CXRs were reviewed a second time by the same observers to quantify intraobserver variability. Interobserver variability was quantified by comparing the data of the 2 independent lateral CXR observers on all 370 patients. In both cases, we calculated simple agreement and kappa statistics as measures of precision.[6] Our chest CT observer also identified a sample of 10 CT investigations by random number assignment and reviewed the images in a blinded fashion to quantify interobserver variability in CT findings (ie, a comparison of the original CT report with our chest CT observer's interpretation).

We obtained approval from the relevant research ethics boards for the hospitals in which our study population was identified and have endeavored to comply with the

2009 Society of Hospital Medicine DOI 10.1002/jhm.500
Published online in wiley InterScience (www.interscience.wiley.com).

TABLE 1. Relationship Between Lower Lobe Structural Pathologies on CT Imaging of the Chest and Opacity Overlying Vertebral Column on Lateral Chest Radiography

	Number of Cases	CXR (+)	CXR (−)	LR (+)*	LR (−)*
Disease-positive/abnormal findings					
Atelectasis or fibrosis including usual interstitial pneumonitis[†]	215	191	24	3.1	0.16
Effusion, loculated effusion, empyema or fluid collections in fissures	83	79	4	3.3	0.07
Consolidation, airspace disease, mucous plugging or postradiation opacities	57	54	3	3.3	0.07
Ground glass opacity	50	42	8	2.9	0.23
Nodule or mass >5 mm	48	44	4	3.1	0.12
Pulmonary embolus	22	18	4	2.8	0.26
Bronchiectasis or bronchial dilation	14	13	1	3.2	0.10
Reticulation	10	9	1	3.1	0.14
Sclerotic bone lesion	10	10	0	3.4	0
Pulmonary edema or septal thickening	8	8	0	3.4	0
Interlobular septal thickening	8	7	1	3.0	0.18
Pleural plaque or calcification	6	5	1	2.9	0.24
Abnormal hemidiaphragm	5	5	0	3.4	0
Hydrothorax	3	3	0	3.4	0
Cavitary lesion	2	2	0	3.4	0
Pleural thickening	1	1	0	3.4	0
Vertebral compression fracture(s)	1	1	0	3.4	0
Bronchial obstruction	1	1	0	3.4	0
Bronchial wall thickening	1	1	0	3.4	0
Any abnormal CT finding	289	251	38	2.9	0.19
Disease-negative/normal findings					
Normal	81	24	57		
Overall LR[‡]				2.9 (2.1–4.1)	0.19 (0.13–0.26)

Abbreviations: CI, confidence interval; CT, computed tomography; CXR, chest radiograph or x-ray; LR, likelihood ratio.

*The LRs for the individual findings incorporated only the Test (+) and Test (−) numbers for the pathology in that row and the Test (+) and Test (−) from the normal finding row.

[†]A minority of these cases involved "dependent" atelectasis, which is not a pathological finding.

[‡]Values are LR (95% CI).

TABLE 2. Summary 2 × 2 Table for Any Abnormal CT Finding

	Abnormal Chest CT	Normal Chest CT
Abnormal lateral CXR	251	24
Normal lateral CXR	38	57

NOTE: Sensitivity 86.9% (95% CI, 82.5%–90.3%); specificity 70.4% (95% CI, 59.7%–79.2%).

Abbreviations: CI, confidence interval; CT, computed tomography; CXR, chest radiograph or x-ray.

Standards for Reporting of Diagnostic Accuracy (STARD) initiative.[7] All statistical analyses were performed using R version 2.01[8] (Free Software Foundation, Boston, MA) and WinBUGS version 1.4. (MRC Biostatistics Unit, Cambridge, UK)[9]

Results

The identified study sample of 370 patients was 52% male and had an average age of 58 ± 17 years (range, 18 to 96 years). Of the 370 patients, 81 (21.9%) were found to have a normal chest CT, 118 (31.9%) had a single CT finding in the lower lobes designated as disease-positive, and 171 (46.2%) had 2 or more lower-lobe CT findings. Overall, 78.1% had 1 or more CT findings considered disease-positive.

Abnormal opacity overlying the vertebral column on lateral chest radiography had a sensitivity of 86.9% (95% CI, 82.5%-90.3%) and specificity of 70.4% (95% CI, 59.7%-79.2%) for CT-documented lower-lobe and associated structural pathology (Table 2). The summary LR+ for abnormal opacity overlying the vertebral column on lateral chest radiography was 2.9 (95% CI, 2.1-4.1) and the summary LR− for the absence of this finding was 0.19 (95% CI, 0.13-0.26). LRs for individual CT-documented pathologies were very similar to the summary LRs, with a range for LR+s between 2.8 and 3.4, and a range for LR−s between 0 and 0.26 (Table 1).

Intraobserver simple agreement and kappa statistics for each of the lateral CXR observers were 79% ($\kappa = 0.56$) and 81% ($\kappa = 0.58$), respectively. Interobserver simple agreement between the lateral CXR observers, as well as the associated kappa statistic, were similar at 77% ($\kappa = 0.52$). Compared with the original chest CT reports generated by university-affiliated radiology faculty members, the blinded review of 10 randomly-identified CT investigations by our chest CT observer (M.O.B.) yielded 100% agreement.

Discussion

This study fills a gap in the literature by providing evidence of the accuracy and precision of a particular finding on

2009 Society of Hospital Medicine DOI 10.1002/jhm.500
Published online in wiley InterScience (www.interscience.wiley.com).

lateral chest radiography: namely, observed radioopacity obscuring the normal succession of superior-inferior vertebral radiolucency.

Our investigation of this finding's test characteristics reveal that abnormal opacity overlying the vertebral column on lateral chest radiography is a more sensitive than specific finding, and thus in general more useful for ruling out the presence of disease than ruling it in. But it is our calculated LRs that allow application of this finding's predictive value to clinical scenarios in practice.

LRs are a powerful method of applying new information to the pretest probability of disease, to arrive at the posttest probability. If the summary point estimate LRs of our study are applied to a hypothetical pretest probability of 50% for any CT-documented pathology, abnormal opacity overlying the vertebral column (LR+ 2.9) gives a posttest probability of 75%, and the absence of this finding (LR− 0.19) gives a posttest probability of 16%. In some cases, these posttest probabilities may be high enough to stop investigating and start treating, or low enough to stop investigating.

We also calculated LRs for each subgroup of CT-documented pathology by comparing only patients with the CT finding of interest and patients with CTs interpreted as normal. While the validity of these calculations is compromised by ignoring the patients in the other subgroups of diagnoses in the calculation, the stability of these LR estimates suggests that the finding and summary LRs can be used for a variety of diagnoses. The individual LRs, however, should not be used in arriving at posttest probabilities of individual pathologies.

Our calculated kappa statistics, a measure of chance-corrected agreement, quantified the precision of abnormal opacity overlying the vertebral column noted by nonradiologist observers. The kappa statistics associated with intraobserver and interobserver variability for abnormal opacity overlying the vertebral column are indicative of moderate agreement, which is similar to the precision of many other investigational findings in common usage.

This study does have some limitations related to its design. First, CT was used as the gold standard in this study. Ideally, a combination of CT and more invasive measures such as lung biopsy would have been used; however, for ethical and logistical reasons this was obviously not possible. Second, when designing the study we had to decide whether or not to repeat the interpretation of CT images with observers we could ensure were blinded to the corresponding CXRs. We chose not to repeat the interpretation of CT images, and instead used the report of the staff chest radiologist who read the imaging study at the time it was performed. The person reviewing the report of the CT was blinded to the CXR. Our reasons for not rereading each of the CT images with a blinded "study radiologist" are as follows. First, the chest radiologists who reviewed the CT images at the time they were done were completely unaware of our hypothesis regarding the utility of the lateral CXR (our study took place after the CTs were interpreted). Second, the radiologists tell us that when they interpret CTs they rarely rely on findings in the CXR to help with those interpretations. For these 2 reasons, the original interpretation is very close to complete blinding. In addition, the individuals who interpret and write reports on chest CTs are all expert staff radiologists with considerable experience in this area. A "study radiologist" (likely a radiology resident) would not have been as proficient. Finally, in performing any study one must weigh the costs with the benefits of any methodological decision, reinterpretation of 370 chest CTs would have required an enormous amount of time. Finally, our small sample of 10 comparing official reports to the reinterpretation of the scans themselves supported the view that we did not need to review all 370 cases again.

Approximately three-quarters of our study population was found to have CT-documented disease. However, this is not surprising given our method of patient selection. Because the sample was collected from clinical practice, it is likely that only patients who exhibited a finding on the CXR that required delineation went on to have the reference standard investigation (CT). This study is therefore subject to workup bias. Workup bias in this scenario could work in 1 of 2 directions. In one situation, some patients would have a clear pathology or diagnosis based on the CXR, such that a CT was unnecessary and therefore not performed. In this case, our study would have underestimated the sensitivity of the sign being studied because a group of "true positives" would have been left out of the sample. In the second situation, patients with true pathology and a normal CXR (false negatives) fail to undergo CT. In this case, our study would have overestimated the sensitivity. We are not sure which effect of workup bias predominates in the study, but in either case an independent, prospective comparison of these imaging modalities in all patients who had CXRs was not feasible for ethical reasons. If we were to apply the reference standard investigation to all those patients, the potential for harm from excess radiation[10] would be too great. As such, our cohort of patients is the best possible sample that can be studied.

Another feature of this study is that it intentionally used nonradiologist (budding internist) interpreters of the lateral CXRs, thus defining its generalizability. We did so for 2 reasons. First, the sign studied is likely too basic to be of relevance to radiologists. Second, it is intended to be used by internists, emergency physicians, and nonradiology trainees at all levels, who are required to make initial treatment decisions based on their preliminary interpretation of x-rays, particularly in the hospital setting. Therefore, we decided our results would be more externally valid and applicable if the interpreters of the x-rays and use of the x-ray sign in this study was by trainees.

Abnormal opacity overlying the vertebral column on lateral chest radiography is a clinically useful finding that can help nonradiologist physicians determine initial management or the need for further investigation when diagnostic uncertainty remains. This study provides evidence that this finding is both reliable and useful for ruling the presence of lower-

2009 Society of Hospital Medicine DOI 10.1002/jhm.500
Published online in wiley InterScience (www.interscience.wiley.com).

lobe and associated structural pathology out, and somewhat useful for ruling the presence of such pathology in.

Acknowledgements

The authors thank Dr. Meyer Balter for his comments on an earlier version of this work.

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2009 Society of Hospital Medicine DOI 10.1002/jhm.500
Published online in wiley InterScience (www.interscience.wiley.com).