Received:
5 May 2016

Revised:
14 August 2016

Accepted:
5 September 2016

<http://dx.doi.org/10.1259/bjr.20160394>

Cite this article as:

Kluthke RA, Kickuth R, Bansmann PM, Tüshaus C, Adams S, Liermann D, et al. The additional value of the lateral chest radiograph for the detection of small pulmonary nodules—a ROC analysis. *Br J Radiol* 2016; **89**: 20160394.

FULL PAPER

The additional value of the lateral chest radiograph for the detection of small pulmonary nodules—a ROC analysis

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Objective: For the past 30 years, many authors have described different advantages of the use of the additional lateral chest radiograph. However, some radiologic departments gave up performing the lateral view recently. A potential reason for this might be a lack of evidence for any diagnostic benefit of the additional lateral view of the thorax in recent studies. The objective of this study was to evaluate the diagnostic benefit of the additional lateral view for the detection of small pulmonary nodules compared with CT examinations as a gold standard.

Method: The patient population consisted of 45 patients with SPN and 45 patients without SPN. Four radiologists with varying experience in the assessment of thoracic imaging first examined the sole posteroanterior (PA) projection. After a few days, they were instructed to examine the PA and the additional lateral view. A receiver-operating characteristic analysis was accomplished to compare the documented results.

Results: The mean Az value of the sole PA view was 0.75 and 0.77 by the combination of PA and additional lateral view. So, there was no significant difference between the detectable Az values ($\Delta = 0.02$; $p = 0.384$). With a cut-off value of >3 , the additional view even reduced the sensitivity by averaging to 5.6%. The decrease of sensitivity by using the additional view was most detectable within the group of more experienced radiologists.

Conclusion: The additional lateral view of the chest provides no diagnostic benefit in the detection of small pulmonary nodules in comparison with the sole PA projection. Nevertheless, the results of the present study must not be understood as a general evaluation of the benefits of the lateral radiograph *per se*, because we did not examine other relevant issues (*i.e.* cardiac failure, lung parenchyma diseases or abnormalities in hilar anatomy).

Advances in knowledge: Our study demonstrates a lack of evidence for any diagnostic benefit of the additional lateral view of the thorax in detecting SPN.

INTRODUCTION

The plain chest X-ray (CXR) is the most performed imaging method in radiology. Nevertheless, uniform recommendations about the optimal planes of projection are rare and can be found only for a small number of syndromes. From a historical point of view, the combination of posteroanterior (PA) radiograph and lateral radiograph has evolved into the usual method for thoracic imaging. Since a short time ago, a deviation from this procedure can be observed and a lateral CXR is no longer part of the UK Royal College of Radiologists recommendations. Despite past and current criticism, several studies of the recent years show an additional benefit of the lateral radiograph in occasional cases (Figure 1). These include improved assessment of the hilar anatomy,¹ spatial mapping of

suspected intrapulmonary nodules (spondylophytes, pleural processes, opacities by the nipples, etc.), improved insight into the posterior phrenicocostal sinus (approximately 15% of the lung)² and the possibility to assess the lower lobe infiltrates (criterion of poorer delineation or the obscuring effect of the lower vertebral body). Although there are a few studies that describe the benefit of the lateral view for the diagnosis of different pathologies, there has been no study that has examined the additional value of the lateral radiograph in the detection of small pulmonary nodules (SPN). Owing to the high prevalence of nodules,³ this investigation seems urgently needed. Against this background, the aim of this study was to provide the (additional) benefit of examination with two views (PA and lateral views) in the detection of pulmonary nodules compared with the examination by the sole PA view.

Figure 1. Additional benefit of chest X-ray with radiographs in two projections: a 64-year-old patient suffering from breast cancer. Posteroanterior view (a) is showing SPN of 21mm in the right lower field. Three readers classified this finding as “presumably present” and one reader as “indistinguishable”. As no mass was observed in the lateral view (b), the situation was classified as follows: one reader: “SPN definitely not present”, two readers: “presumably not present” and one reader: “indistinguishable”. CT examination (c) is clearly demonstrating exulceration of breast cancer as the cause of the potential false-positive finding of SPN.

METHODS AND MATERIALS

The study includes patients who were examined in the period from 1 March 2008 to 31 December 2013 at the Center for Diagnostic and Interventional Radiology at the general hospital in Hagen. Patients were selected by an inquiry on the clinic's internal radiology information system (Gap IT®; ISOFT Corp., Mannheim, Germany) among all CT thorax examinations during this period. Following search keywords were used: “SPN”, “nodule”, “lung” and “lesion” with the full-text search. Two independent radiologists tested each examination for the actual presence of a nodule. All patients who fulfilled the following criteria were included into the experimental group. For the control group, randomly selected patients without lung nodules in CT at the same recruitment period were chosen. Two independent radiologists ensured and documented the absence of pulmonary nodules for these patients.

Inclusion criteria were the presence of a nodule with a diameter between 5 and 25 mm in CT, retrospectively visible in conventional radiograph and a maximum period of 5 days between the conventional radiograph and the thoracic CT examination.

A total of four independent radiologists participated in the study as “readers” (judges) of conventional recordings. Two readers were chest radiologists with very high experience in conventional imaging; two readers were interventional radiologists involved in general radiology. The two chest radiologists were defined as experienced readers and the general radiologists as less experienced readers.

Table 1. Localization of the nodules in our study (absolute number of patients)

	Left lung	Right lung	Total
Upper third	13% (6)	7% (3)	20% (9)
Middle third	18% (8)	16% (7)	33% (15)
Lower third	16% (7)	31% (14)	47% (21)
Total	47% (21)	53% (24)	100% (45)

For the evaluation of the CXR, each radiologist had to analyze nine patient groups. Each group consisted of 10 cases. They included five cases of the experimental group (with SPN) and five cases of the control group (without SPN). The radiologists were not informed about the distribution of positive and negative cases in the nine groups. The assessment proceeded as follows: first, the radiologists assessed the sole PA examination. In order to avoid a bias, radiologists had to satisfy an interval of 2 weeks before evaluating the CXR with two radiographs. The next 10 cases were evaluated in reverse order (first two radiographs, interval of 2 weeks, sole PA radiograph). The radiologists documented their findings on a standardized evaluation questionnaire. A separate questionnaire was applied for each examination method. Each questionnaire contained information about the patient age and gender as well as information in order to identify the patient without doubt but anonymously. For SPN detection, five characteristic values were available (definitely present, presumably present, indistinguishable, presumably not present and definitely not present). Radiologists marked their (medical) opinion with a cross. In addition, they were asked to locate (left/right lung and upper third, middle third, lower third) and measure the detected nodule.

Figure 2. Receiver-operating characteristic curve comparison (all radiologists) of sole posteroanterior (PA) view vs both PA and lateral (lat.) views.

By using the documented results of the radiologists, a receiver-operating characteristic (ROC) analysis was performed to compare the examination methods. This analysis provides information about the values of diagnostic accuracy [area under the curve (AUC) value or Az value], sensitivity, specificity and positive- and negative-predictive values for different cut-off values.^{4,5} We chose a cut-off value of >3 for comparison. Student's *t*-Test was used to calculate *p*-values for differences between the compared AUC values. *p*-values of <0.05 were considered significant, and 95% confidence interval (CI) for sensitivity and specificity were calculated with the probabilities of the binomial distribution.

To verify the agreement between the individual radiologists, we calculated interrater agreement and intrarater agreement values of Landis and Koch⁶ (κ).

RESULTS

A total of 90 patients were registered in this study. 45 patients were assigned to the control group (without nodule). The share of male patients in the total collective accounted for 53.3% (corresponding to 48 patients), whereas the proportion of female patients was 46.7% (corresponding to 42 patients). The average age was 66.4 years (CI 95%: 63.8–69.0). The median was 67.5 years (CI 95%: 64.0–70.0), with a variance of 155.86 and a corresponding standard deviation (σ) of 12.4845.

In the study group, the gender distribution was 53.3% male and 46.7% female patients. The average age in this group was 68.9 years (median: 70.0 years). For comparison, the average age of the control group was 63.9 years (median: 65.0 years). Accordingly, the control group was not significantly younger ($p = 0.059$). The share of male and female patients was similar to the study group.

Nodules

The average diameter of nodules in this study amounted to 10.2 mm (median: 10 mm). The nodule size was not normally distributed ($\chi^2 = 11.601$, $p = 0.041$). Moreover, 47% of the nodules were located in the left lung, while 53% of the nodules were located in the right lung lobe (Table 1).

Comparison of sole posteroanterior view vs both posteroanterior and lateral view

ROC analysis of all radiologists showed no differences between the AUC values of the various investigation modalities.

The findings were almost identical, which is demonstrated by the curve shape in Figure 2. The ROC analysis of the examination of the chest with sole PA view showed an AUC value of 0.749 (± 0.026). By comparison, the AUC value was 0.768 (± 0.025) for the examination of the thorax with two views (PA and lateral). Hence, no significant difference ($p = 0.38$) of diagnostic accuracy could be shown. In addition, the inclusion of the additional lateral radiograph led to a decrease in sensitivity of 5.6% and an increase in specificity of 1.6%. These results and the values for positive- and negative-predictive values are contrasted in Table 2.

As expected, the individual radiologists did not always document identical findings. This was evidenced in the calculation of the kappa values (κ). For the sole PA view, a maximum value of $\kappa_{\max} = 0.446$ was observed for the chest examination with additional lateral radiograph $\kappa_{\max} = 0.429$, respectively. This result is equivalent to a “moderate” match rate by Landis and Koch.⁷ The match rate is almost identical in both examination modalities.

According to varying levels of experience, the differentiation of the participating radiologists revealed a diagnostic superiority of the more experienced radiologists. They reached a significantly higher AUC value than the radiologists with less experience ($P_{\text{PA}} = 0.003$, $p_{2\text{views}} = 0.006$) in both examination procedures (sole PA view and combination frontal and lateral views). The ROC analysis provided an AUC value of 0.829 for experienced radiologists (sole PA) and AUC = 0.84 for the examination by two views, respectively (Table 3). The inclusion of the lateral radiograph did not show an additional benefit for all experience levels (Figures 3 and 4). As noted before, the AUC values changed only marginally. On the contrary, the values for sensitivity revealed explicit changes. A subanalysis showed that sensitivity of all radiologists decreased (Table 2) (sensitivity loss of 5.6%).

A distinct decrease in sensitivity was observed in the group with a higher level of experience. Owing to the inclusion of the lateral radiograph, sensitivity decreased by 7.8% (Table 3). We also noticed a decrease of sensitivity in the group with less experienced radiologists. However, in this group, the reduction of sensitivity was not so clear. Sensitivity diminished only by 3.4% for less experienced radiologists. This decrease in sensitivity was caused by a higher proportion of false-negative results (Figure 5).

Table 2. Comparison of the results of ROC-analysis (all radiologists)

	AUC	Sensitivity (%)	Specificity (%)	Positive-predictive value (%)	Negative-predictive value (%)
Sole PA-view	0.749	48.9	95.6	91.7	65.2
PA + lat.view	0.768	43.3	97.2	94.0	63.2
Δ	0.019	−5.6	1.6	2.3	−2

AUC, area under the curve; PA, posteroanterior.

Table 3. Comparison of the examination modalities [(sole posteroanterior (PA) view vs two views)—experienced radiologists

	Sole PA view	PA and lateral views
	Experienced radiologists (inexperienced radiologists)	Experienced radiologists (inexperienced radiologists)
AUC	0.829 (0.703)	0.84 (0.721)
Sensitivity	61.1% (36.7%)	53.3% (33.3%)
Specificity	96.7% (94.4%)	97.8 (96.7%)

AUC, area under the curve.

In addition, our analysis showed a higher number of false-negative results for the examination with two views than for the examination with sole PA view.

In addition to the other results, our collected data show that especially the less experienced radiologists documented similar results on both evaluation sheets. This was clearly shown by the interrater agreement ($\kappa = 0.823$).

DISCUSSION

A growing number of radiologists are relinquishing the lateral view in CXR.^{8,9} Today, primarily the sole frontal view is taken and analyzed. If uncertainties arise during this evaluation, CT is often subsequently performed.¹⁰ This approach is justified by a higher specificity of CT. Undeniably, CT is currently the gold standard in the detection of pulmonary nodules. However, the additional CT examinations result in an increase of radiation exposure for the patient and cost intensification for the health care system. This holds for the so-called low-dose CT also (on an average >1.5 mSv).¹¹

The value of the additional lateral CXR was the predominant object of research in the context of detection of pneumonia in children.^{12,13} Nevertheless, there are contradictory recommendations on the additional lateral view. There are studies verifying a benefit of the lateral CXR,¹³ whereas others indicate the lateral view as unnecessary.¹² While there are varying results in the context of detection of pneumonia, there are more homogeneous results in the context of SPN detection. Manninen *et al*⁷ investigated the influence of different imaging systems on nodule detection. They analyzed CXR (2 views) of 150 patients for the presence of nodules and observed a sensitivity of 54% for the detection of nodules for the CXR with 2 views, although they were dependent on analogue imaging technology.⁷ In our study, we found a comparatively low sensitivity of 44.4% and a specificity of 98.5%. In our view, different inclusion criteria are a potential cause of the varying results. In the study of Manninen *et al*,⁷ the nodule size was larger than that in our study. Manninen *et al*⁷ included several nodules with a diameter of 30 mm. In comparison, the average diameter in our study was 10.2 mm and we included no nodule of >23 mm diameter. In addition, Manninen *et al*⁷ integrated several patients with multiple nodules (up to five nodules). Both circumstances are responsible for a comparatively higher sensitivity in the study of Manninen *et al*.⁷

On the other hand, the results of our study are underlined by the findings of Lee *et al*.¹ They describe almost identical values for the sensitivity of the examination with two radiographs, identifying a sensitivity of 45%.

According to the mentioned studies, Morton *et al*¹⁴ described a sensitivity of 48% for the examination of the CXR with two radiographs. Morton *et al*¹⁴ investigated the diagnostic value of the CXR (with two views) for follow-ups in patients with known malignant melanoma. The low sensitivity is assumed to be caused, *inter alia*, by a high number of false-negative test results. Morton *et al*¹⁴ observed that in several of these false-negative findings, there was no lateral recording available.

In contrast to this finding, the results of our study do not indicate avoiding false-negative results by using the additional lateral view. We even observed a higher proportion of false-negative results by using the CXR with two views (in comparison with sole PA radiograph). Our study showed these results for both the experienced and the less experienced radiologists. The radiologists with a lower level of experience documented 1.5% more false-negative findings by integrating the lateral view, whereas this proportion was 3.5% in the experienced group. We consider these findings to be the main causal factor for the decreased sensitivity in case of using the additional image information of the lateral radiograph (PA: 48.8% vs two views: 43.3%). Our study showed even clearer results for experienced radiologists. The inclusion of the

Figure 3. Comparison of examination modalities [sole posteroanterior (PA) view vs combination of PA and lateral (lat.) views]—experienced radiologists.

Figure 4. Comparison of examination modalities [sole posteroanterior (PA) view vs combination of PA and lateral (lat.) views]—less experienced radiologists.

lateral CXR resulted in sensitivity reduction of 7.8% (sensitivity in experienced radiologists—PA: 61.1% vs two views: 53.3%).

The results of less experienced radiologists with sole PA examination were similar to the results of the examination with two views of the thorax. A low level of knowledge about the interpretation of the lateral view can be an explanation for these results. The interpretation of the PA CXR is routine work for less experienced radiologists. Therefore, they link a higher diagnostic value to the result of the PA CXR.¹⁵ Hypothetically, less experienced radiologists base their final judgment on the results of PA radiograph. Radiologists who are well educated in the interpretation of the lateral view and are able to recognize and interpret variation in normal anatomy would probably doubt an intrapulmonary presence of a nodule if the nodule is not depicted in the lateral radiograph.

Nevertheless, the additional lateral CXR can have a clarifying or confirming character.¹⁶ A nodule was rarely detected only by the examination with two radiographs after being missed in the

PA projection. The frequency in our study for this case was 4.2% ($n = 15$) and is thus comparable with the data of Forrest et al.¹⁷

Our study has several limitations. First, the number of reviewed CXR is rather small, which prevents a generalization of our results. In order to define guidelines for clinical practice for SPN detection, prospective studies with larger patient numbers are needed.

Another limitation is that our study was focused on single small pulmonary nodules to assure a correct statistical evaluation. It would be interesting whether a lateral view helped in the case of several small nodules.

Our study did not answer whether advanced radiography techniques like dual-energy subtraction will influence recommendations about the optimal planes. While not widely used, there is evidence that dual-energy subtraction improves the diagnosis of SPN.¹⁸

CONCLUSION

Our study shows that the additional lateral CXR offers only a marginal benefit for SPN detection. The calculated AUC values for the two CXR modalities of this study (sole PA CXR vs combination of PA and lateral CXR) were almost identical. Above this, the additional lateral view appeared to increase the false-negative rate for the presence of SPN in experienced CXR reporters.

Based on our results, the additional lateral CXR seems to be dispensable for SPN detection. However, our study did not reliably answer other relevant issues (*i.e.* cardiac stasis, lung parenchyma diseases or abnormalities in hilar anatomy). As a consequence, the results of the present study must not be understood as a general evaluation of the benefits of the lateral radiograph *per se*.

Figure 5. Posteroanterior (PA) projection (a) and lateral view (b) of the chest X-ray in a 70-year-old patient suffering from acute coronary syndrome: by means of the sole PA radiograph, two readers described a 9-mm SPN in the right lower field as “presumably present” and one reader as “definitely present”. Evaluation of both projections has resulted in a decrease of sensitivity; thus, one reader classified the finding as SPN “definitely present”, one reader as “indistinguishable”, one reader as “presumably not present” and one reader as “definitely not present”. CT (c) confirmed the presence of SPN in lung segment 9 of the right lung (S9R).

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