Differentiation of Pleural Effusions From Parenchymal Opacities: Accuracy of Bedside Chest Radiography

OBJECTIVE. The purpose of this study was to determine, with CT as the reference standard, the ability of radiologists to detect pleural effusions on bedside chest radiographs.

MATERIALS AND METHODS. Images of 200 hemithoraces in 100 ICU patients undergoing chest radiography and CT within 24 hours were reviewed. Four readers with varying levels of experience reviewed the chest radiographs and predicted the likelihood of the presence of an effusion or parenchymal opacity on independent 5-point scales. The results were compared with the CT findings.

RESULTS. All readers regardless of experience had similar accuracy in detecting pleural effusions. Among 117 pleural effusions, 66% were detected on chest radiographs (53%, 71%, and 92% of small, moderate, and large effusions) with 89% specificity. Similarly, 65% of all parenchymal opacities were detected on chest radiographs, also with 89% specificity. Most (93%) of the misdiagnosed pulmonary opacities were simply not seen. Meniscus, apical cap, lateral band, and subpulmonic opacity were highly specific findings but had low individual sensitivity for effusions. The finding of homogeneous opacity, including both layering and gradient opacities, was the most sensitive sign of effusion. Atelectasis can occasionally mimic the pleural sign of effusion, accounting for most false-positive findings.

CONCLUSION. Radiologists interpreting bedside chest radiographs of ICU patients detect large pleural effusions 92% of the time and can exclude large effusions with high confidence. However, small and medium effusions often are misdiagnosed as parenchymal opacities (45%) or are not seen (55%). Pulmonary opacities often are missed (34%) but are rarely misdiagnosed as pleural effusions (7%).

Keywords: bedside, pleural effusion, semierect, supine

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Materials and Methods

After institutional review board approval and in accordance with HIPAA regulations, the cases of 100 patients in the surgical ICU who consecutively underwent CT of the chest less than 24 hours after undergoing chest radiography were retrospectively selected for review. Informed consent was not required. The exclusion criteria included complete omission of the lung bases, interval thoracentesis, and chest tube placement or a related procedure.

Chest Radiography

The chest radiographs were reviewed by four readers: a thoracic imaging attending radiologist with more than 18 years of experience, a thoracic imaging fellow, a fourth-year radiology resident, and a second-year radiology resident. No special training was given before interpretation.

Each hemithorax was separately evaluated for the presence of basilar opacities. If an opacity was present, the characteristics were recorded (Table 1, Figs. 1–3). The imaging features of pleural effusions were 1, definitely present; 2, probably not present; 3, possibly present; 2, probably not present; 1, definitely not present. The finding of a meniscus, apical cap, lateral band, and subpulmonic opacity. The second category is homogeneous densities overlying the hemithorax; these signs include layering and gradient opacities.

The readers independently determined the likelihood of the presence of pleural effusion and parenchymal opacity on a 5-point scale (5, definitely present; 4, probably present; 3, possibly present; 2, probably not present; 1, definitely not present). The finding of a meniscus, apical cap, or lateral band was interpreted as certain evidence of the presence of an effusion (typical score, 5). The finding of a gradient opacity, layering opacity, or subpulmonic opacity was interpreted as high likelihood of the presence of an effusion (typical score, 4).

Air bronchograms were interpreted as certain evidence of parenchymal opacities (typical score, 5), and heterogeneity was interpreted as high likelihood of a parenchymal opacity (typical score, 4 or 5). If imaging findings were indicative of moderate or large pleural effusion, it was assumed that associated passive atelectasis was present. Therefore, the presence of a parenchymal opacity also was predicted (typical score, 4 or 5) even in the absence of any other signs of parenchymal opacification.

When an opaque hemithorax was encountered, the location of the mediastinum was the principle differentiating criterion: an ipsilateral mediastinal shift indicated a parenchymal opacity, a contralateral mediastinal shift indicated probable pleural effusion, and an unshifted mediastinum indicated both possible effusion and possible parenchymal opacity.

All chest radiographs were obtained in the anteroposterior projection with a mobile radiography unit (AMX-4+, GE Healthcare). According to the position indicators, no radiograph was obtained in the erect position, 28 were semierect, and eight were supine. The position of 64 radiographs was not indicated.

CT

All CT scans were reviewed by the same thoracic imaging attending radiologist during a separate session after all radiographs had been interpreted. Pleural effusion was diagnosed if low-attenuation (0–20 HU) material was visualized between the lung parenchyma and the chest wall. The effusion was considered loculated if it was clearly divided into more than one compartment. There were no cases of high-attenuation pleural effusion or hemothorax in our patient sample. The quantity of pleural fluid was semiquantitatively scored on CT scans as small, moderate, or large. The quantity depended on the maximum anteroposterior depth of pleural fluid (measured at the maximum effusion depth, which varied by patient): less than 15% (=75 mL), 15–30%, or greater than 30% (=350 mL) of the diameter of the hemothorax [8].

Although many patients had diffuse airspace disease, such as pulmonary edema, an opacity was...
Chest Radiography of Pleural Effusions

Fig. 2—57-year-old man with pleural effusions appearing as layering opacities. A, Supine chest radiograph shows homogeneously increased opacification of right hemithorax typical of layering opacity, typically scored 4 for probable pleural effusion. Right hemithorax also was typically scored 4 for pulmonary opacity because readers were predicting presence of atelectasis independent of effusion. Most readers scored left lung base 4 for opacity and 2 for effusion. B, CT scan confirms presence of moderate right pleural effusion and associated passive atelectasis in adjacent right lower lobe.

Fig. 3—52-year-old man with pleural effusions appearing as gradient opacities. Semierect chest radiograph shows bilateral homogeneous opacities at lung bases interpreted as gradient opacities and scored 5 for pleural effusions by all readers. Probable associated bibasilar passive atelectasis was inferred from moderate size of pleural effusions. Pleural effusions and passive atelectasis were confirmed at CT (not shown).

Diagnosed only when a discrete region of alveolar opacification was found, either alone or superimposed on a diffuse alveolar process. For the purposes of this study, we made no distinction between opacification due to volume loss (atelectasis) and opacification due to alveolar filling (e.g., pneumonia, contusion, infarction). Various CT scanners were used, including a single-detector scanner (CTi, GE Healthcare), 4-MDCT scanners (Lightspeed QXI, GE Healthcare; Volume Zoom, Siemens Healthcare), a 16-MDCT scanner (Sensation 16, Siemens Healthcare), a 64-MDCT scanner (Sensation 64, Siemens Healthcare), and a dual-source 64-MDCT scanner (Somatom Definition, Siemens Healthcare). Several imaging techniques were used. Sixty-one examinations were performed with IV contrast enhancement: 47 with 100 mL of iohexol 300 mg I/mL (Omnipaque 300, GE Healthcare) and 14 with 100 mL of iohexol 350 mg I/mL (Omnipaque 350, GE Healthcare) at injection rates of 1.5–4.0 mL/s. Various collimations and pitches were used depending on the type of scanner and imaging protocol. Images were reviewed on a PACS workstation (RadWorks, GE Healthcare) at a slice thickness of 1, 3, or 5 mm.

Statistics

The sensitivity, specificity, and receiver operating characteristic (ROC) curves in the detection of pleural effusion on bedside chest radiographs were calculated with CT as the reference standard. Area under the ROC curve was calculated with a Web-based calculator [9]. Separate analyses were performed with IV contrast enhancement: 47 with 100 mL of iohexol 300 mg I/mL (Omnipaque 300, GE Healthcare) and 14 with 100 mL of iohexol 350 mg I/mL (Omnipaque 350, GE Healthcare) at injection rates of 1.5–4.0 mL/s. Various collimations and pitches were used depending on the type of scanner and imaging protocol. Images were reviewed on a PACS workstation (RadWorks, GE Healthcare) at a slice thickness of 1, 3, or 5 mm.

Results

CT of the chest was performed on 117 consecutively registered ICU patients within the 2-month period October and November 2007. Thirteen of the patients were excluded because they had not undergone chest radiography within 24 hours before CT. Two patients were excluded because overlying structures completely obscured the lung bases; one patient, because the lung bases were completely omitted; and one patient, because a chest tube was inserted between the imaging studies. The other 100 ICU patients (200 hemithoraces; 60 men and boys, 40 women and girls; mean age, 54.3 years; range, 14–91 years) formed the final study group. Diffuse airspace disease was present in 40 patients. Chest CT depicted 117 cases of pleural effusion: 16 large, 46 medium, and 55 small. Eight isolated right pleural effusions, 11 isolated left pleural effusions, and 49 bilateral pleural effusions were found. Fifteen cases of effusion were loculated.

Sensitivity and Specificity

All readers had similar accuracy in detecting effusions without a significant difference according to level of experience. The readers with the highest sensitivity had the lowest specificity, and thus all readers’ results were at different positions on similar ROC curves (Fig. 4). With the results for all readers averaged, the overall sensitivity in the diagnosis of pleural effusion on bedside chest radiographs was 66%. The specificity was 89% with a fitted area under the ROC curve of 0.852 (Table 2). Exclusion of the 15 loculated effusions did not change the diagnostic accuracy.

Because the four readers had similar diagnostic accuracy in diagnosing effusion, the composite results for all readers were used to determine overall accuracy in the detection of effusion on the basis of the size of the effusion and to analyze the accuracy of individual radiographic characteristics of effusion. Overall, 53% of the small pleural effusions, 71% of the moderate effusions, and almost all (92%) of the large pleural effusions were correctly diagnosed. The specificity was high, approximately 89%, for all pleural effusions (Table 3).

False-Negative Findings of Effusion

On average, 34% (161/468, the denominator being the total number of effusions multiplied by four readers) of the pleural effusions were missed on chest radiographs. Most (64%) of the missed effusions were small, 33% were moderate, and 3% were large. Forty-five percent (73/161) of the missed effusions were interpreted as parenchymal opacities rather than effusions, and the other 55% (88/161) were interpreted as not basilar opacities. In 59% (95/161) of the cases of false-negative findings of effusions interpreted as not basilar opacity, evidence of diffuse alveolar
lung disease was seen on chest radiographs, but the presence of an independent basilar opacity was not predicted.

**False-Positive Findings of Effusion**

Eleven percent (36/327) of the suspected effusions were false-positive findings, most of which (64%, 209/327) were homogeneous opacities on chest radiographs that proved to be atelectasis on CT scans. Approximately one of three (31%, 11/36) false-positive findings of effusion had a false meniscus sign, which was usually caused by pleural thickening or a large pericardial fat pad (Fig. 5). The attending radiologist made one false-positive finding of meniscus, and each of the other readers made three or four false-positive findings of meniscus.

**Characteristics of Pleural Effusion**

Meniscus, apical cap, lateral band, sub-pulmonic opacity, layering opacity, and gradient opacity all were highly specific but not sensitive signs of pleural effusion (Table 4). In total, 73% (342/468) of all patients with pleural effusions had at least one of the highly specific signs on chest radiographs (apical cap, lateral band, meniscus, layering opacity, gradient opacity, or subpulmonic opacity). Complete opacification of a hemithorax with ipsilateral mediastinal shift was found in only three patients, and CT showed that all three of these patients had ipsilateral effusions and atelectasis. Homogeneous opacity was the single most sensitive finding of pleural effusion on bedside chest radiographs, 68% (319/468) of effusions exhibiting some kind of homogeneous opacity, and was the finding most likely to indicate the presence of small and moderate-sized effusions (Table 4). Atelectasis, however, can occasionally mimic the pleural veil sign on chest radiographs, accounting for most of the false-positive findings in this study.

**Parenchymal Opacities**

CT showed 146 pulmonary opacities, 65% (381/584) of which were predicted by the readers on chest radiographs with a specificity of 89% (193/216) for all readers combined. Individual readers had sensitivities varying from 56% to 77% and specificities varying from 81% to 96% with no significant trend based on level of experience. The area under the ROC curve varied from 0.815 (second-year resident) to 0.872 (fourth-year resident) (Table 5). Most of the misdiagnosed pulmonary opacities (93%, 150/161) on chest radiographs were erroneously predicted to be normal lung bases with no effusion or discrete opacity.

**Discussion**

Bedside supine and semierect chest radiography of ICU patients has low and intermediate sensitivity in the detection of small and moderate effusions (53% and 71%, respectively) but is highly sensitive and specific in the detection of large effusions (92% and 89%). Accordingly, large effusions usually can be excluded with high confidence, but small and medium effusions often are not identified because they are misdiagnosed as parenchymal opacities (45%) or are not seen (55%).

The 66% overall sensitivity for all pleural effusions in our study is slightly lower than previously reported sensitivities ranging from 67% to 82% [6, 7]. However, the previous studies may have shown falsely elevated sensitivities due to the methods of verifying effusion, including decubitus radiography and ultrasound, which are not as sensitive as CT in the detection of small effusions. Excluding the small effusions in our study increases the sensitivity to 78% (190/244) in the detection of effusion, and this rate is comparable with previously reported values.

Diagnostic accuracy for effusion did not differ significantly between readers, whose levels of experience varied. Although there was only one reader in each category, our results suggest that the ability to diagnose pleural effusions on bedside radiographs is a basic skill that can be learned quickly during residency. The results also suggest that because of suboptimal visualization on bedside radiographs, 66% overall sensitivity for all pleural effusions in our study is slightly lower than previously reported sensitivities ranging from 67% to 82% [6, 7]. However, the previous studies may have shown falsely elevated sensitivities due to the methods of verifying effusion, including decubitus radiography and ultrasound, which are not as sensitive as CT in the detection of small effusions. Excluding the small effusions in our study increases the sensitivity to 78% (190/244) in the detection of effusion, and this rate is comparable with previously reported values.

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**TABLE 2: Reader Accuracy in Diagnosis of Pleural Effusion**

<table>
<thead>
<tr>
<th>Reader</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Area Under ROC Curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attending</td>
<td>59 (69/117)</td>
<td>95 (79/83)</td>
<td>0.844</td>
</tr>
<tr>
<td>Fellow</td>
<td>62 (72/117)</td>
<td>90 (75/83)</td>
<td>0.843</td>
</tr>
<tr>
<td>Fourth-year resident</td>
<td>76 (89/117)</td>
<td>86 (71/83)</td>
<td>0.878</td>
</tr>
<tr>
<td>Second-year resident</td>
<td>66 (77/117)</td>
<td>93 (77/83)</td>
<td>0.855</td>
</tr>
<tr>
<td>Average</td>
<td>66 (309/468) a</td>
<td>89 (295/332) a</td>
<td>0.852</td>
</tr>
</tbody>
</table>

Note—Values in parentheses are raw numbers. ROC = receiver operating characteristic.

**TABLE 3: Average Reader Accuracy for Detecting Pleural Effusions of Different Sizes With Bedside Chest Radiography**

<table>
<thead>
<tr>
<th>Size of Effusion</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>53 (117/220)</td>
<td>89 (295/332)</td>
</tr>
<tr>
<td>Moderate</td>
<td>71 (131/184)</td>
<td>89 (295/332)</td>
</tr>
<tr>
<td>Large</td>
<td>92 (59/64)</td>
<td>89 (295/332)</td>
</tr>
<tr>
<td>Total (n = 117)</td>
<td>66 (309/468) a</td>
<td>89 (295/332) a</td>
</tr>
</tbody>
</table>

Note—Values in parentheses are raw numbers.

aTotal number of effusions multiplied by four readers.
pleural effusion from conditions such as pneumonia, atelectasis, and contusion, cause parenchymal opacities and often contain a mixture of aerated and un aerated lung that causes homogeneously increased attenuation. In this study, the presence of a homogeneous opacity seen in isolation or superimposed on a heterogeneous opacity was a moderately specific indicator of the presence of pleural fluid, having 86% specificity. This finding was the most sensitive (68%) for pleural effusion on bedside chest radiographs and was the finding most likely to indicate the presence of small and moderate-sized effusions. However, atelectasis occasionally causes homogeneously increased attenuation indistinguishable from that of pleural fluid on chest radiographs. It accounted for most of the false-positive findings (73%) in this study.

The readers’ accuracy in detecting parenchymal opacities was rather low, only 65% of the opacities being correctly predicted on chest radiographs. Most of these misdiagnosed opacities (93%) were simply not seen and were interpreted as a normal lung base with no effusion or focal opacity. On CT scans, however, many of these missed opacities were visualized as small areas of subsegmental atelectasis or focal ground-glass opacities, which are findings of dubious clinical significance. In a small percentage of cases (7%), the opacity was mistaken for effusion.

Several limitations to our study should be noted. The retrospective design in which only patients undergoing chest CT were selected as participants may have biased the sample to include patients who are the most ill and more likely to have pleural effusions. The high prevalence of both pleural effusion and pulmonary opacity in this ICU sample prevents generalization of these results to populations of patients who are not critically ill. However, patients who are not critically ill can undergo standard upright radiography. In addition, the 200 hemithoraces were treated as separate entities, and the radiographic findings of large ipsilateral pleural effusion might have biased the readers toward predicting the presence of a small contralateral effusion in equivocal cases.

Bedside supine and semierect chest radiography of ICU patients is reliable for differentiating large pleural effusions from pulmonary opacities. Small and medium effusions, however, often are misdiagnosed as parenchymal opacities (45% in this study) or are not seen (55% of cases in this study). Pleural effusion is present in most ICU patients in whom effusion is suspected (89% specificity in this study). Large effusions can be excluded with high confidence on supine and semierect chest radiographs. A considerable portion of pulmonary opacities are misdiagnosed (34% in this study), most of which are simply not seen. An opacity is infrequently mistaken for an effusion (7% of cases in this study).

References