Ultrasound-Guided Thoracentesis*

Is It a Safer Method?

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Study objectives: The objectives of this study are as follows: (1) to determine the incidence of complications from thoracentesis performed under ultrasound guidance by interventional radiologists in a tertiary referral teaching hospital; (2) to evaluate the incidence of vasovagal events without the use of atropine prior to thoracentesis; and (3) to evaluate patient or radiographic factors that may contribute to, or be predictive of, the development of re-expansion pulmonary edema after ultrasound-guided thoracentesis.

Design: Prospective descriptive study.

Setting: Saint Thomas Hospital, a tertiary referral teaching hospital in Nashville, TN.

Patients: All patients referred to interventional radiology for diagnostic and/or therapeutic ultrasound-guided thoracentesis between August 1997 and September 2000.

Results: A total of 941 thoracenteses in 605 patients were performed during the study period. The following complications were recorded: pain (n = 25; 2.7%), pneumothorax (n = 24; 2.5%), shortness of breath (n = 9; 1.0%), cough (n = 8; 0.8%), vasovagal reaction (n = 6; 0.6%), bleeding (n = 2; 0.2%), hematoma (n = 2; 0.2%), and re-expansion pulmonary edema (n = 2; 0.2%). Eight patients with pneumothorax received tube thoracostomies (0.8%). When >1,100 mL of fluid were removed, the incidence of pneumothorax requiring tube thoracostomy and pain was increased (p < 0.05). Fifty-seven percent of patients with shortness of breath during the procedure were noted to have pneumothorax on postprocedure radiographs, while 16% of patients with pain were noted to have pneumothorax on postprocedure radiographs. Vasovagal reactions occurred in 0.6% despite no administration of prophylactic atropine. Re-expansion pulmonary edema complicated 2 of 373 thoracenteses (0.5%) in which >1,000 mL of pleural fluid were removed.

Conclusions: The complication rate with thoracentesis performed by interventional radiologists under ultrasound guidance is lower than that reported for non–image-guided thoracentesis. Premedication with atropine is unnecessary given the low incidence of vasovagal reactions. Re-expansion pulmonary edema is uncommon even when >1,000 mL of pleural fluid are removed, as long as the procedure is stopped when symptoms develop.

Key words: pleural effusion; pneumothorax; re-expansion pulmonary edema; thoracentesis; ultrasound

Pleural effusion is a commonly encountered clinical entity. Most patients will undergo thoracentesis in an attempt to delineate the etiology of the fluid collection or to relieve symptoms. While thoracentesis is commonly practiced, complications do occur and have been extensively documented.1–14 Potential complications of thoracentesis include pain, pneumothorax, shortness of breath, cough, and vasovagal reaction. Other less common complications of thoracentesis include re-expansion pulmonary edema, inadvertent liver or splenic puncture, bleeding from a lacerated intercostal vessel, induction of a pleural infection, subcutaneous emphysema, air embolism, a sheared-off catheter in the pleural space, as well as subcutaneous hematoma.

Ultrasound-guided thoracentesis offers a potentially safer alternative to thoracentesis without direct imaging guidance. The physical examination finding of dullness to percussion or the presence of a density on a chest radiograph can sometimes be misleading. Ultrasound allows documentation of the pleural fluid and rules out other etiologies such as atelectasis, consolidation, mass, or an elevated hemidiaphragm.
Currently, most clinicians reserve ultrasound-guided thoracentesis for more difficult cases, such as patients (1) receiving mechanical ventilation, (2) with less-than-ideal body habitus, or (3) with small fluid collections. While the incidence of complications from bedside thoracentesis is well known, the incidence of complications from ultrasound-guided thoracentesis is less well documented.

The purposes of this study are as follows: (1) to determine the incidence of complications from thoracentesis performed under ultrasound guidance by interventional radiologists in a tertiary referral teaching hospital; (2) to evaluate the incidence of vasovagal events without the use of atropine prior to thoracentesis; and (3) to evaluate patient or radiographic factors that may contribute to, or be predictive of, the development of re-expansion pulmonary edema after ultrasound-guided thoracentesis.

We hypothesized that: (1) the incidence of pneumothorax requiring tube thoracostomy in patients undergoing thoracentesis by an interventional radiologist with ultrasound guidance would be low; (2) the incidence of vasovagal reactions would be uncommon even if atropine was not administered; and (3) re-expansion pulmonary edema would be uncommon even when > 1,000 mL of pleural fluid were removed.

**Materials and Methods**

After approval by the institutional review board, all patients referred to interventional radiology for a diagnostic and/or therapeutic ultrasound-guided thoracentesis between August 1997 and September 2000 were enrolled in this study and evaluated prospectively. The decision to perform ultrasound-guided thoracentesis was made by the patient’s referring physician. Symptoms as reported by the patient or complications as noted by the interventional radiologist performing the procedure were recorded in a log book, and a procedure note was entered into the hospital computer system. Patients routinely underwent preprocedure and postprocedure chest radiography (upright posteroanterior), and no restrictions were placed on the amount of fluid that could be removed. Atropine was not administered prior to the procedure. The following variables were noted prospectively: preprocedure diagnosis, volume of fluid removed, color of the fluid, clinical indicators of complications, side of fluid removal, patient sex, and laboratory characteristics of the fluid. The charts and radiographs of all patients with complications were reviewed.

Thoracentesis was performed by one of seven interventional radiologists with the patient in a seated position. The pleural fluid collection was located and marked by the radiologist under real-time ultrasound guidance (ATL Ultrasound; Advanced Technology Laboratories; Bothell, WA). Multiple scans were obtained in transverse, oblique, and sagittal planes. Once the location of the pleural fluid was identified, the area was cleaned with povidone-iodine and local anesthesia (1% lidocaine without epinephrine) was injected intradermally, subcutaneously and into the parietal pleura. A 14-gauge plastic catheter needle system (Thor-Fara Tray, Pharmaseal; McGraw Park, IL) was used to enter the pleural space. Once the pleural space was entered, the needle was withdrawn and fluid was removed through the catheter. Continuous ultrasound observation of needle entry into the fluid collection was not routinely done. Once fluid flow was established and then either became interrupted or less than expected, ultrasound was again utilized to evaluate for the presence of additional fluid or to determine if patient repositioning or a new entry site was necessary. Fluid removal was terminated when one of the following six events occurred: (1) when no more fluid could be removed, (2) pain, (3) excessive cough, (4) vasovagal event, (5) shortness of breath, or (6) excessive bleeding at the entry site.

As the administration of anesthesia for thoracentesis is not entirely painless, pain was defined as more than minor discomfort after the administration of local anesthesia. A vasovagal event was characterized by the sensation of lightheadedness, nausea, diaphoresis, or the sudden transient loss of consciousness associated with a drop in postural tone followed by recovery. Dyspnea was defined as an unpleasant or uncomfortable sensation of breathlessness that may or may not have been associated with tachypnea or desaturation. Excessive cough was characterized by coughing of sufficient frequency or intensity as to be troubling to the patient. Each of the above served as an indicator to discontinue the procedure. Pneumothorax was defined as any new air demonstrated in the pleural space on a postprocedure radiograph.

Patients with small pneumothoraces (< 20%) on postprocedure radiographs were followed up with serial radiographs obtained every 6 to 8 hours for 24 hours, and tube thoracostomy was utilized if the pneumothorax was noted to be enlarging or the patient became symptomatic. The size of the pneumothorax was quantitated by the radiologist interpreting the postprocedure radiograph.

**Statistical Analysis**

The median volume of fluid removed from patients with and without various complications was compared using the Mann-Whitney rank sum test since the volumes were not normally distributed. The proportion of patients with complications on the first or subsequent thoracentesis was compared using chi-square analysis with Yates correction for continuity. A \( p \) value < 0.05 was considered significant. All data were analyzed with statistical computer software (SigmaStat, version 2.03; SPSS; San Rafael, CA).

**Results**

Between August 1997 and September 2000, 605 patients were enrolled in the study and underwent a total of 941 procedures. These included 668 initial procedures and 273 repeat procedures. Because of multiple procedures, it was possible for patients to appear in both groups; because of bilateral thoracenteses, there were more initial procedures than patients. The volume of fluid removed from the patients ranged from 1 to 3,800 mL (median, 800 mL). In three patients, < 10 mL fluid was removed; in an additional four patients, between 10 mL and 20 mL of pleural fluid were removed.

The overall incidence of complications in our study was low. With the 941 procedures, a total of 86 complications (incidence 9.1%) occurred in 70 patients. There was not a close relationship between
the amount of fluid removed and the rate of complications; the number of complications in the four quartiles (lowest to highest amount of fluid removed) was 20, 22, 17, and 26. Complications included pain, pneumothorax, shortness of breath, cough, vasovagal reaction, bleeding at the puncture site, hematoma, and re-expansion pulmonary edema (Table 1). The median amount of fluid removed from patients with any complication (1,100 mL) was significantly (p = 0.005) greater than that removed from patients without a complication (800 mL).

Postthoracentesis pneumothorax occurred in 24 patients, for an incidence of 2.5%. The median volume of fluid removed from patients with pneumothorax was 1,100 mL, which was not significantly (p = 0.10) greater than the median volume of fluid removed from those without pneumothorax (800 mL). Eight of the 24 patients (33.3%) with pneumothorax were symptomatic; 4 patients had pain and 4 patients had shortness of breath. Four of these eight symptomatic patients received a tube thoracostomy.

Of the 24 patients with pneumothorax, 8 patients were managed with tube thoracostomy. Two patients received tube thoracostomy because the pneumothorax was noted to be enlarging on serial radiographs. Three patients received tube thoracostomy because of marked dyspnea, desaturation, or both. The remaining three patients received tube thoracostomy because of the extent of the pneumothorax was ≥25%. The median volume of fluid removed (1,480 mL) in the eight patients with pneumothorax requiring tube thoracostomy was not significantly (p = 0.29) higher than the median volume of fluid (1,100 mL) removed in the patients with pneumothorax who did not receive tube thoracostomy. Six of the eight patients receiving chest tubes had pneumothoraces > 20%. The majority of the remaining patients not receiving tube thoracostomy had pneumothoraces < 10% (10 of 16 patients), and none had a pneumothorax > 20%.

Twenty-five patients (2.7%) had pain during the procedure, and 4 of these patients (16%) were subsequently noted to have pneumothorax. Nine patients (1.0%) had shortness of breath, with four patients (57%) subsequently noted to have pneumothorax. Eight patients (0.8%) had cough, and no pneumothoraces were noted in this group. Vasovagal reactions occurred in six patients, for an incidence of 0.6%. All vasovagal events occurred during the procedure and were manifested as either lightheadedness, hypotension, nausea, and/or transient bradycardia, none of which required atropine. Recovery time was quick, and there were no other explanations such as postural changes. The reactions were managed by placing the patient in a recumbent position and elevating the lower extremities. Two patients experienced significant bleeding at the puncture site, and a hematoma developed in two patients (0.2%) at the site of thoracentesis, though none required treatment. Re-expansion pulmonary edema after thoracentesis occurred in two patients (0.2%). The volumes of fluid removed from these two patients were 1,000 mL and 1,200 mL, respectively. In both patients, re-expansion edema was noted on postprocedure radiographs and was not associated with symptoms or an increase in oxygen requirements. More than 1,000 mL of fluid were removed with 201 procedures, > 1,500 mL with 119 procedures, and > 2,000 mL removed with 53 procedures.

There was no significant difference in the incidence of complications with initial thoracentesis compared with repeat thoracentesis (p = 0.828, χ² = 0.047). For comparison of complications with initial vs repeat thoracentesis see Table 1. There

<table>
<thead>
<tr>
<th>Complications</th>
<th>Patients, No.</th>
<th>Volume Removed in Patients With Complication, mL</th>
<th>Volume Removed in Patients Without Any Complication, mL</th>
<th>Initial Thoracentesis</th>
<th>Repeat Thoracentesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedures, No.</td>
<td>941</td>
<td>1,1000 (650–1,537.5)</td>
<td>800 (475–1,300)</td>
<td>668</td>
<td>273</td>
</tr>
<tr>
<td>Pain</td>
<td>25 (2.7)</td>
<td>1,1000 (800–1,525)</td>
<td>800</td>
<td>17 (2.5)</td>
<td>8 (2.9)</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>24 (2.5)</td>
<td>1,1000 (687–1,587.5)</td>
<td>800</td>
<td>20 (3.0)</td>
<td>4 (1.5)</td>
</tr>
<tr>
<td>Chest tubes</td>
<td>8 (0.8)</td>
<td>1,4800 (1,000–1,850)</td>
<td>800</td>
<td>7 (1.0)</td>
<td>1 (0.4)</td>
</tr>
<tr>
<td>Shortness of breath</td>
<td>9 (1.0)</td>
<td>1,600 (525–1,725)</td>
<td>800</td>
<td>6 (0.9)</td>
<td>3 (1.1)</td>
</tr>
<tr>
<td>Cough</td>
<td>8 (0.8)</td>
<td>1,225 (850–1,800)</td>
<td>800</td>
<td>5 (0.7)</td>
<td>3 (1.1)</td>
</tr>
<tr>
<td>Vasovagal</td>
<td>6 (0.6)</td>
<td>850 (600–1,200)</td>
<td>800</td>
<td>5 (0.7)</td>
<td>1 (0.4)</td>
</tr>
<tr>
<td>Bleeding</td>
<td>2 (0.2)</td>
<td>1,610 (20–3,200)</td>
<td>800</td>
<td>1 (0.1)</td>
<td>1 (0.4)</td>
</tr>
<tr>
<td>Hematoma</td>
<td>2 (0.2)</td>
<td>1,250 (150–1,350)</td>
<td>800</td>
<td>1 (0.1)</td>
<td>1 (0.4)</td>
</tr>
<tr>
<td>Re-expansion pulmonary edema</td>
<td>2 (0.2)</td>
<td>1,100 (1,000–1,200)</td>
<td>800</td>
<td>2 (0.3)</td>
<td>0</td>
</tr>
</tbody>
</table>

*Data are presented as No. of patients undergoing thoracentesis with or without complications (% of patients with complications) or median (25th–75th percentile) unless otherwise indicated.

†p < 0.05, median volume of fluid removed significantly greater than in patients without complications.
were significant differences in the occurrence of complications depending on the volume of fluid removed. When \( > 1,100 \text{ mL} \) of fluid was removed, the incidence of complications significantly increased for pneumothorax requiring tube thoracostomies and for pain (\( p < 0.05 \)). For comparisons of the median volume of fluid removed with each of the individual complications see Table 1.

**Discussion**

The purpose of this study was to determine the incidence of complications with ultrasound-guided thoracentesis performed by interventional radiologists in a large patient population; to determine the necessity for prophylactic atropine; and to determine potential patient or radiographic factors that may contribute to, or be predictive of, the development of re-expansion pulmonary edema. This study demonstrates that ultrasound-guided thoracentesis, when performed by interventional radiologists, is a very safe procedure associated with a low incidence of complications. In addition, the results of this study demonstrate that prophylactic atropine administration is not necessary. Lastly, our study confirms that re-expansion pulmonary edema is uncommon even with removal of \( > 2,000 \text{ mL} \) of pleural fluid, as long as the thoracentesis is stopped when the patient becomes symptomatic.

Pain frequently complicates thoracentesis, with a reported incidence of 15.5 to 28%.\(^1\),\(^2\),\(^10\),\(^11\) The pain that complicates thoracentesis is typically of three types.\(^13\) First, the patient may experience sharp pain as the skin is anesthetized or when the parietal pleural is pierced. Second, the patient may experience chest tightness or a dull pain as fluid is removed. This type of pain usually indicates that the patient’s lung is not re-expanding rapidly and should serve as an indication to stop the procedure. Third, the patient may have pleuritic chest pain after the procedure, which is usually due to the rubbing of the roughened pleural surfaces against each other after the pleural fluid has been withdrawn. The incidence of pain in the present study was \(< 3\%\). Four of these patients (16%) were noted to have pneumothorax on postprocedure radiographs.

Prospective studies of thoracentesis without direct imaging guidance have reported higher occurrences of pneumothorax than those reported in our study. In those studies, as many as 4.0 to 30.3% of the patients had pneumothorax, with 20 to 50% of those with pneumothorax receiving chest tube drainage.\(^1\),\(^2\),\(^10\),\(^11\) Studies have reported conflicting results on whether the use of ultrasound guidance decreases the incidence of pneumothorax. Some investigators have demonstrated that ultrasound-guided thoracentesis is associated with lower complication rates than those reported for non–image-guided thoracentesis, though these studies have been limited by low patient numbers.\(^1\),\(^4\),\(^5\),\(^8\) Raptopoulos et al\(^1\) reported that the incidence of pneumothorax was 18% for 154 thoracenteses performed without image guidance, whereas it was only 3% for 188 thoracenteses performed with ultrasound guidance. A second prospective randomized study with a comparable number of patients reported that the incidence of pneumothorax was similar (approximately 5%) whether or not the procedure was performed with ultrasound guidance.\(^16\) Alemen et al\(^5\) reported one pneumothorax in 23 procedures performed with ultrasound guidance for an incidence of 4%, while Peterson and Zimmerman et al\(^17\) reported that ultrasound guidance did not appear to offer protection, as 5 of 36 procedures (13.9%) performed with ultrasound guidance led to a pneumothorax.\(^5\),\(^17\) Our prospective study in a large patient series of ultrasound-guided thoracentesis performed by experienced interventional radiologists demonstrates a low incidence of pneumothorax (\(< 3\%\)). Furthermore, \(< 1\%\) of patients undergoing thoracentesis with ultrasound guidance required tube thoracostomies. In the present study, repeat thoracentesis was not associated with a higher incidence of pneumothorax.

It is possible that operator experience contributed to our low incidence of pneumothorax. Several studies have demonstrated that the incidence of pneumothorax is reduced if experienced individuals perform the procedure\(^1\),\(^2\),\(^5\),\(^11\); however, other studies have reported that operator experience did not impact the occurrence of pneumothorax.\(^13\),\(^17\)

Another factor that could have contributed to our low incidence of pneumothorax is selection bias. The role of selection bias is difficult to evaluate since we did not study thoracenteses performed by other physicians. The fact that 75% of our patients had \( > 650 \text{ mL} \) pleural fluid removed suggests that small effusions were the exception rather than the rule. It is likely that many patients were referred to interventional radiology because bedside thoracentesis is time consuming with low reimbursement. However, complications were evenly distributed over the four different quartiles for the amount of fluid removed. It is unknown whether the referred patients had a higher or lower incidence of loculations.

Though not one of the primary purposes of our study, we did assess the importance of obtaining postprocedure chest radiographs in symptomatic patients. Many studies have been published on the need for a routine chest radiograph after thoracentesis.\(^5\),\(^8\),\(^9\),\(^14\),\(^17\) Alemen et al\(^5\) reported that of 488 patients without symptoms during thoracentesis,
only 5 patients had pneumothorax (1%) and only 1 patient received a chest tube. Doyle et al. reviewed their experience with 174 thoracenteses and concluded that postprocedure chest radiographs were indicated only when a pneumothorax was suspected. In our study, 57% of patients with shortness of breath during thoracentesis and 16% of patients with pain were noted to have pneumothorax on postprocedure radiographs. If the patient is asymptomatic and a pneumothorax is not suspected, the likelihood of a pneumothorax requiring tube thoracostomy is low (3 of 907 cases) in the present series. We have found that assessing whether fremitus over the upper part of the chest has disappeared postprocedure to be a useful yet simple test for the presence of a pneumothorax. If fremitus has been lost, a postprocedure chest radiograph is recommended.

There are three different reasons why pneumothorax develops in patients undergoing thoracentesis. First, air may flow from the atmosphere into the pleural space, as occurs when the negative pressure of the pleural space communicates freely with the atmosphere. This most often occurs as the syringe is removed from a needle or catheter, particularly when the individual performing the procedure is inexperienced. Second, the needle for thoracentesis may lacerate the lung and permit air to enter the pleural space from the alveoli. Third, the decrease in pleural pressure can lead to a rupture of the visceral pleura.

Pneumothorax with thoracentesis does not always require therapeutic intervention. The management of the pneumothorax depends on the mechanisms of the thoracentesis, the symptoms of the patient, and the size of the pneumothorax. If it is thought that the pneumothorax arose from air entering the pleural space through the needle or catheter and the patient is asymptomatic, no treatment is necessary. If the patient is symptomatic in this situation, then simple aspiration of the pleural air is probably the best option. If the lung was lacerated or if the visceral pleura ruptured and the patient is symptomatic, then tube thoracostomy should probably be performed.

The occurrence of excessive cough with thoracentesis has been reported to occur from 9 to 24%.

In the present series, excessive cough occurred in < 1% of the patients. Of the eight patients with clinically significant cough, none were found to have pneumothorax. In our experience, cough most frequently complicates a thoracentesis done for therapeutic reasons, usually occurs toward the end of the procedure, and should serve as an indication to stop the procedure.

At times, thoracentesis provokes a vasovagal reflex characterized by bradycardia, decreased stroke volume, and a resulting fall in cardiac output and BP. This reaction is blocked by the administration of atropine. In some institutions, atropine is routinely administered prior to performance of procedures including thoracentesis as prophylaxis against vasovagal events. The reported incidence of vasovagal reactions with thoracentesis has varied from 2 to 3.9%. Several randomized studies have found that the routine administration of prophylactic atropine during bronchoscopy was of no benefit. The incidence of vasovagal reactions without the routine preprocedure administration of atropine in our study was < 1%. Moreover, all six patients who had a vasovagal event did not receive atropine and were easily managed in the radiology suite.

Re-expansion pulmonary edema is an uncommon complication characterized by the development of unilateral pulmonary edema, which sometimes progresses to bilateral pulmonary edema, in a lung that has been reinflated following a variable period of collapse secondary to a pleural effusion or pneumothorax. Manifestations vary from an incidental finding on a chest radiograph to variable degrees of hypoxia, which may be life threatening. The exact mechanism responsible for re-expansion pulmonary edema is not known, but it is likely to be multifactorial. In animal studies, re-expansion pulmonary edema occurs only if the lung has been collapsed for several days and if negative pressure is applied to the pleural space. Miller et al. found that re-expansion pulmonary edema occurred only when the pneumothorax had been present for 3 days and the lung was re-expanded with > 10 mm Hg of pleural pressure.

Re-expansion edema is believed by some to be more likely when a large volume thoracentesis (> 1,000 mL) is performed, the chest radiograph demonstrates shift of the mediastinum toward the effusion, or pernicious cough develops. However, re-expansion edema was uncommon in our study in patients who had > 1 L of pleural fluid removed (373 procedures). Only 2 of these 373 patients (0.5%) had re-expansion edema: 1 patient had 1,000 mL of fluid removed, and the other patient had 1,200 mL of fluid removed. Moreover, re-expansion edema did not occur in any of the 53 patients who had > 2,000 mL removed. We believe that the low incidence of re-expansion edema in the present study was due to the fact that the thoracentesis was discontinued if any symptoms developed. No patient or radiographic factors predictive of the development of re-expansion edema were identified.

CONCLUSION

In conclusion, this study demonstrates that ultrasound-guided thoracentesis by interventional radiol-
ologists is associated with a lower incidence of complications than those reported for thoracentesis without direct imaging guidance. Postthoracentesis chest radiographs should only be obtained if a pneumothorax is suspected clinically, when air is aspirated during the procedure, or when tactile fremitus is lost over the superior portion of the aspirated hemithorax. The development of pain or shortness of breath should alert the clinician to the possibility of pneumothorax, as 16% of patients with pain and 57% with shortness of breath had a pneumothorax. This study also demonstrates that the prophylactic use of atropine is not necessary, as vasovagal reactions are uncommon and easily managed. Re-expansion pulmonary edema is uncommon even with large volume thoracenteses when the procedure is terminated if chest pain, shortness of breath, or cough develop.

In view of the above, which patients should be referred to interventional radiologists for thoracentesis? The advantages of thoracentesis by interventional radiologists under ultrasound guidance include an initial demonstration of whether a hypoechoic area is present, suggesting fluid, high diagnostic yield, a low complication rate, performance of the procedure by an experienced individual, and no radiation exposure. Disadvantages of thoracentesis by interventional radiologists under ultrasound guidance include the necessity of moving the patient to the radiology suite and the additional cost of the procedure in the ultrasound suite, which would include the cost of additional imaging and interpretation plus the procedure fee billed by the interventional radiologist. Moreover, ultrasound is not infallible in differentiating fluid from homogenous fibrous thickening. In view of the above, we recommend that patients be referred to interventional radiologists for ultrasound if any of the following conditions are met: (1) if the physician is inexperienced, (2) if the effusion is small, (3) if the presence of the effusion has not been documented with other imaging techniques, or (4) if the effusion is loculated or atypical.

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