Sonographic Guidance in Diagnostic and Therapeutic Interventions in the Pleural Space

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One hundred eighty-seven diagnostic and therapeutic interventional procedures in the pleural space were performed by using sonographic guidance. These consisted of diagnostic aspiration (118), drainage of malignant and nonmalignant effusions (41), empyema drainage (17), pleural sclerotherapy with tetracycline or bleomycin (7), and pleural biopsy (4). Diagnostic aspiration was performed with 20-gauge needles, and therapeutic and empyema drainages were performed by trocar technique with either a 7-French Sacks catheter or a specially designed empyema drainage catheter. Pneumothoraces were seen in 3% of the patients, and most of these were treated by the radiologist with placement of a Heimlich valve.

We conclude that the use of sonography allows rapid localization of pleural fluid collections and instant monitoring of drainage of noninfected fluid collections and empyemas.

Sonographically guided interventions in the pleural space have been reported infrequently [1, 2]. Both CT and fluoroscopy have been emphasized as the primary techniques for diagnosis and treatment of a variety of pleural abnormalities [2–4]. Yet, because of its ability to visualize superficial fluid collections and its real-time capability, sonography has the potential to be an ideal imaging procedure for monitoring interventional procedures in the pleural space [5–9].

We describe a retrospective review of 187 sonographically guided procedures in the pleural space. The success rate of these procedures approached 95% with a complication rate of 3%.

Materials and Methods

Between January 1983 and February 1986, 187 procedures were performed in the pleural space of 170 patients by using sonographic guidance. Of these, 25% were performed on an outpatient basis and 4% were done on the wards with a portable sonographic unit.

Interventional Procedures

The four types of interventional procedures were diagnostic aspiration, therapeutic drainage, empyema drainage, and miscellaneous interventions.

Diagnostic aspiration.—Diagnostic aspiration was performed in 118 patients. The most common indication was to exclude empyema in febrile patients who had effusions that were not responding to antibiotic therapy (87 cases). Twenty-seven of these were postsurgical patients, 24 had associated preexisting pneumonia, and 36 had multisystem disease. Radiologic guidance was requested because the patient's effusion was not free flowing, because nonguided attempts had already failed, or because the collection was thought to be too small to permit unguided sampling (Fig. 1). Initially (in the first 40 patients), these were the sole reasons for the use of sonographic guidance. However, as it became apparent that diagnostic aspirations could be performed more accurately, more quickly, and with less discomfort to the patient by using sonography, most of the remaining 47 patients were immediately referred

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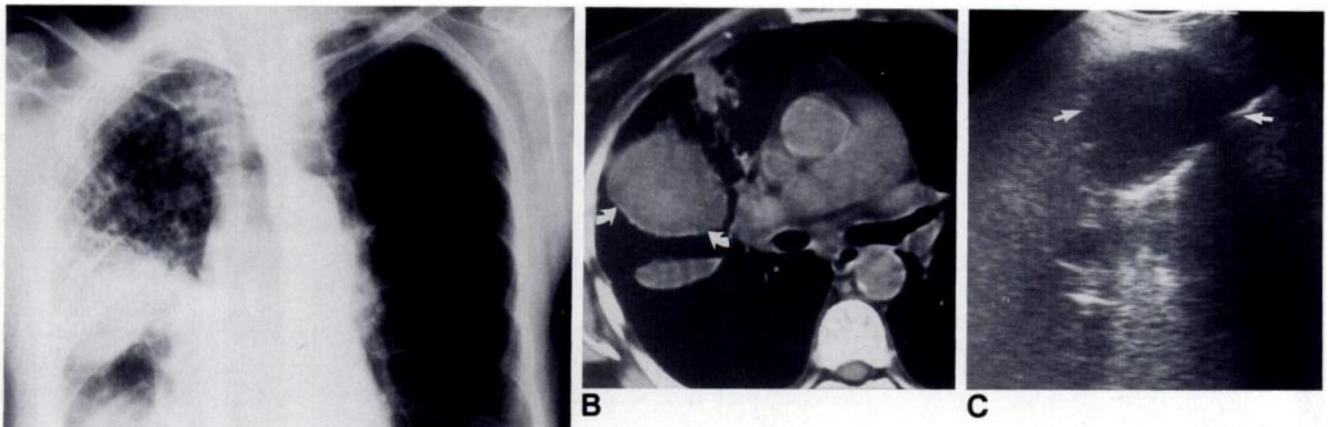

Fig. 1.—Use of sonography to localize a postpneumonic fluid collection that was in a difficult location for aspiration.

A, Posteroanterior chest radiograph in a 56-year-old man with pneumococcal pneumonia. There is a parenchymal abnormality in the right upper and lower lobes and fluid in the major fissure. Patient was febrile and secondary empyema was suspected. Numerous unguided attempts at aspiration had failed.

B, CT scan shows pleural fluid to be in lateral and cephalad portion of chest (*arrows*).

C, Sonographic localization was easily performed and showed typical sonolucent and convex appearance of loculated pleural fluid (*arrows*). Actual needle placement was 1 cm inferior and lateral to right nipple.

for the procedure without attempts on the ward. The second most common indication was in patients with known or suspected malignancy who presented with a new effusion (31 cases). Again, the first 20 patients in this group were referred because of presumed small effusions (i.e., those that were difficult to perceive on lateral decubitus chest radiographs or difficult to detect clinically by percussion of the chest). The other 11 were referred as a direct result of our success with previous chest aspirations.

Therapeutic drainage.—Therapeutic drainage in uninfected collections was performed in 41 cases. These patients had pleural effusions from metastasis, abdominal inflammatory disease (i.e., pancreatitis), and/or severe congestive heart failure, and drainage was performed to relieve dyspnea and associated chest discomfort. The first 25% of patients were referred for sonographically guided drainage because of incomplete drainage done in the ward or office. Ninety percent of the remaining 30 patients were outpatients, and referral was again based on previous success and the perceptions of both clinicians and patients that using sonographic guidance for the procedures caused less patient discomfort.

Empyema drainage.—This procedure was performed in 17 cases with infected postsurgical or postpneumonic collections (Fig. 2). Six (35%) of seventeen drainages were referred because drainage by surgically placed, large-bore chest tube was incomplete. Eleven (65%) of seventeen were referred primarily because the collection visualized by sonography and/or chest radiograph was small (suspected to be less than 100 ml) and would be better localized and drained by sonographic guidance.

Miscellaneous interventions.—These included pleural sclerotherapy (seven patients) and pleural biopsy (four patients). These patients were all referred because previous attempts at sclerotherapy or pleural biopsy without guidance had failed. Seven patients underwent chemical sclerotherapy after the catheter had been placed for removal of malignant effusions. These consisted of injections of 50–100 ml of tetracycline at a dosage of 50–75 mg/ml, or bleomycin at a dosage varying between 60 and 180 mg diluted in saline [10]. In all cases, the agent was injected through the percutaneously placed catheter, which was then immediately removed. The patient was turned 360°, and no attempt was made to withdraw the injected fluid. Pleural biopsies were performed on four patients. These were done with a Cope reversed bevel needle (Becton-Dickinson, Rutherford, NJ). A subpleural mass was biopsied with an 18-gauge spinal needle after sonographic localization.

Data analysis.—For all four types of procedures, data concerning the type of equipment used, the anatomic location of the abnormality, the technique used for guidance, the radiologic findings, and the quantity and character of any specimens obtained were abstracted from the procedure note and radiologic report. Results of laboratory examination of specimens were available in 58% of the patients. These included Gram stain, cell count, bacterial or fungal cultures, cytologic or pathologic examination, and chemistry determinations such as pH, glucose, and protein count. Information concerning the remaining 42% of the patients was obtained either by direct chart review while the patient remained in the hospital or by follow-up through the referring physicians.

For the purpose of defining complication rates, a pneumothorax was defined as air in the pleural space that resulted in symptoms or required insertion of a chest tube. Small amounts of air that were asymptomatic or loculated and that resolved spontaneously were not considered as true complications.

Intervention Technique

Patient positioning.—For most pleural interventions, patients were positioned, when possible, sitting on the side of a stretcher, facing away from the radiologist with arms crossed and resting on a bedside table. Patients who could not tolerate this position were placed in the lateral decubitus position with the diseased side up.

Localization and preparation.—A point of entry in the chest was chosen just above the rib nearest the collection as seen sonographically. A special biopsy transducer was not necessary. Standard aseptic technique and local anesthesia were used. Anesthetizing the periosteum overlying the nearest rib was helpful. The pleura is difficult to anesthetize, but attempts should be made before insertion of the needle.

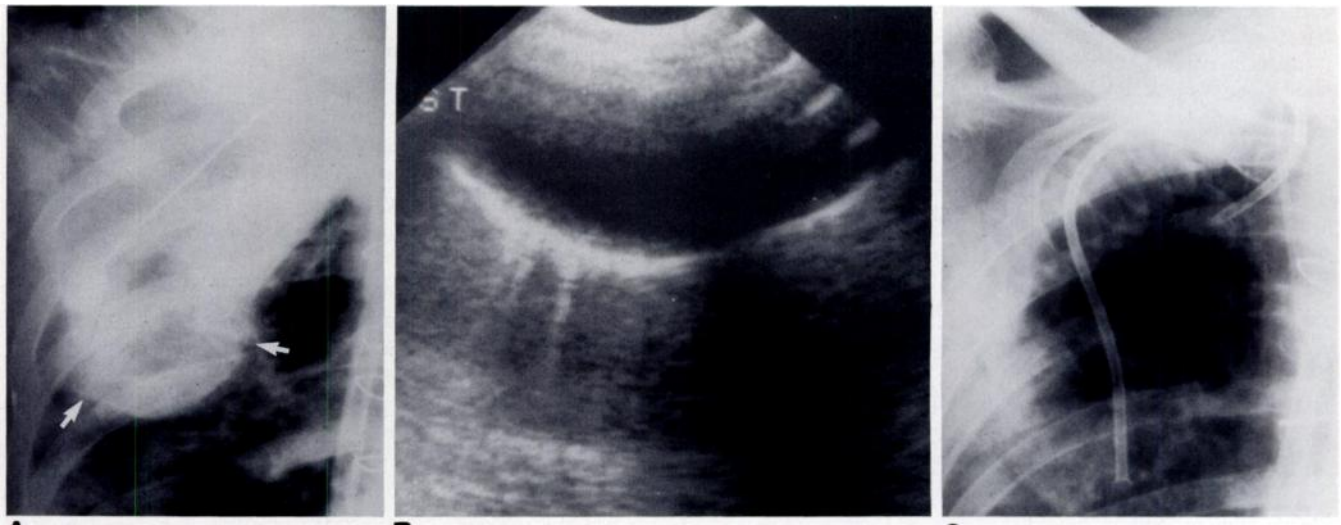

Fig. 2.—Empyema drainage guided by sonography in a 64-year-old man performed 6 days after major mediastinal surgery and tracheal reconstruction. Procedure was performed at patient's bedside in the intensive care unit.

***A*, Portable anteroposterior chest radiograph shows sharply marginated and homogeneous opacity in right upper hemithorax (*arrows*).**

***B*, Sonographic localization 2 cm inferior to right clavicle revealed an ellipsoid sonolucent abnormality in anterior lateral chest corresponding to abnormality on chest radiograph. After initial needle aspiration confirmed presence of purulent material, a 10-French Cook empyema catheter was introduced at bedside and 40 ml of pus were aspirated.**

C, Anteroposterior chest radiograph 3 days after procedure showed location of drainage catheter overlying right upper lobe. Pleural collection in right upper chest was gone, and patient was afebrile.

Diagnostic sampling.—A 20- or 22-gauge spinal needle with or without a 12-ml syringe attached was inserted to the estimated depth of the collection. If a large volume of fluid was to be removed, a three-way stopcock might be inserted between the needle and the syringe. When sufficient material had been collected, the needle was withdrawn. Samples were sent immediately for Gram stain and culture. Cell count of the fluid might be obtained when a traumatic tap is suspected or if the effusion is bloody. In cases of suspected malignancy samples, cytology was routinely performed. Special laboratory studies may be appropriate in suspected diseases such as tuberculosis, rheumatoid arthritis, or systemic lupus erythematosus.

Therapeutic drainage.—Drainage for symptomatic relief in patients with large or loculated benign or malignant fluid collections was performed using a trocar 7-French Sacks catheter with multiple side holes (Electro Cath Group, Rahway, NJ). Once the collection had been localized with sonography, the skin was anesthetized and a small incision was made with a #11 scalpel blade to prevent catheter binding or buckling. The catheter system was introduced into the pleural space to the depth at which fluid was expected. In patients with a thick pleural rind, the catheter might buckle slightly as it meets pleural resistance. For easier catheter placement, an 18-gauge spinal needle can be inserted through the pleura into the fluid collection to create a preliminary tract. The 18-gauge needle was then removed and catheter insertion was attempted. Fluid was withdrawn to confirm proper location. The catheter itself was then advanced over the stiffening cannula into the collection, and a three-way stopcock was attached. Extension tubing was used to connect the stopcock to a sterile vacuum bottle to facilitate rapid drainage of the fluid. When drainage stopped, the catheter could be manipulated to reestablish flow. Once sufficient fluid had been removed to permit the lung to come into contact with the catheter, the patient often had discomfort or coughing. In some cases, a postprocedure sonogram was obtained before removal of the catheter to ensure that residual fluid remained. A postprocedure chest radiograph was obtained in all patients.

Empyema drainage.—If the sample was grossly purulent or if Gram stain indicated the presence of organisms and white cells, a drainage procedure was undertaken with the intent of leaving the catheter in place. Early in our experience, 8.3-French Ring catheters (Cook, Bloomington, IN) were placed using the Seldinger technique. More recently, a specially designed 10- to 12-French empyema catheter (Cook, Bloomington, IN) has been employed, with most of the catheters being placed by trocar technique. This catheter is designed for trocar insertion, has a soft curved tip and distal side holes, and is made of polyethylene that is sufficiently rigid not to be compressed by the ribs. After the catheter was placed in the empyema cavity, irrigation with sterile saline was performed as with standard abscesses.

The catheter was then attached to a standard three-bottle, water-sealed, chest-tube-suction apparatus (Pleur-E-Vac, Deknatel, Division of Pfizer, Hospital Products Group, Queens Village, NY) prepared before insertion. The volume of drainage from the catheter was monitored, and the catheters were inspected daily. A repeat sonogram was obtained 3–5 days after drainage to ensure that no empyema fluid had reaccumulated or remained undrained. Once the drainage stopped, suction was discontinued, and the catheter was placed on water seal for 24 hr and removed if a repeat chest radiograph showed no pneumothorax. The patients were seen on the wards 24–48 hr after chest-tube removal to ensure that no clinical symptoms had recurred.

Treatment for Pneumothorax

If the patient complained of increased dyspnea during the procedure, the catheter was left in place and a chest film was obtained. A symptomatic pneumothorax was treated immediately by connecting a Heimlich valve (Cook, Bloomington, IN) directly to the catheter. The one-way valve chamber outlet may be left open to ambient air or connected to a standard three-bottle, water-sealed, chest-tube-suc-

tion system. Patients were followed with expiration chest radiographs every 30–60 min until complete reexpansion of the lung was determined. The Heimlich valve was left in place but turned off (via a three-way stopcock) for 30 min after the lung was reexpanded. A repeat chest radiograph was performed at 30–60 min, and if the lung remained expanded, the tube was removed and the patient was sent back to the ward or home.

Results

Results can be analyzed in four main categories: diagnostic aspiration, therapeutic drainage, empyema drainage, and miscellaneous (pleural sclerotherapy and biopsy).

Diagnostic Aspiration

Aspiration of fluid was successful in 114 (97%) of 118 patients referred for diagnostic taps. In these patients, the amount of fluid ranged from 1.5 to 350 ml. Significantly, several patients with less than 10 ml of fluid had successful diagnostic aspiration.

Of the patients who underwent diagnostic aspiration to exclude infection, charts were available for review in 58%; the remaining data were recorded by clinical follow-up on the wards or from referring physicians for outpatients. Either (1) a positive Gram stain for WBCs or (2) WBCs with organisms and/or positive culture was considered an indication of infection. Detection of WBCs on a Gram stain was used as a determinant of infection because 41% of the patients were on antibiotics at the time of the aspiration. Any fluid that had WBCs was considered infected and was subsequently drained, or the patient was given a full course of antibiotics. It is difficult to determine the accuracy of these criteria. A prospective study was not carried out to see if the patients would have improved without antibiotic therapy. On the other hand, the absence of both organisms and WBCs on the Gram stain of the fluid was considered evidence of no infection, and no patient who had these findings was found to have an infected pleural space by either reaspiration or clinical follow-up. It is again difficult to follow these patients by size or reappearance of their pleural fluid on repeat examination because over 70% did not have repeat sonograms. Presumably, either the pleural fluid in the patient regressed, or it was the result of other causes such as congestive heart failure and was treated as such when the fluid was determined to be uninfected. The remaining patients either had repeat aspirations that showed no organisms or WBCs on Gram stain, or had less fluid on repeat sonograms or chest radiographs.

It was impossible to determine the false-negative rate of the cytologic results because neither autopsy nor biopsy of the pleura was performed on those with negative thoracentesis. Eighty-seven percent of the patients who had known primary malignant disease and recurrent effusions had positive cytology.

No fluid was obtained in four patients, although sonography and chest radiographs suggested that a small amount of fluid was present. In another patient who had undergone esophageal resection with esophagogastric anastamosis, the initial diagnostic thoracentesis entered an intrathoracic stomach resulting in spurious findings: orange-colored fluid was aspirated, the Gram stain was positive, and culture of the aspirate was positive for yeast. A repeat tap of the actual pleural fluid yielded uninfected fluid.

Therapeutic Drainage

All 41 patients had successful therapeutic drainage of noninfected collections. The amount of fluid removed ranged from 100 to 2500 ml (average, 1000 ml). Eight patients in this group had the procedure two times, four patients three times, and two patients more than three times because of recurring effusions. In four patients, both pleural spaces were drained at one time.

Overall, although postprocedural sonography showed objective evidence of removal of over 90% of the fluid in the pleural space, subjective results were difficult to evaluate. Thirty (73%) of 41 stated that their symptoms had improved, but the other 11 patients noted no change.

Empyema Drainage

Seventeen patients underwent 19 catheter insertions for empyemas. Two patients had two catheters placed because repeat examinations several days after the first catheter placement showed an undrained collection. Of these, 15 had complete resolution of the infected collection and showed clinical improvement over the next 5 days to 3 weeks. Two patients died from unrelated causes, and two underwent surgery for definitive closure of the drained cavity.

Pleural Sclerotherapy and Pleural Biopsy

Only two of the seven patients who had pleural sclerotherapy had an apparent response to chemical pleurodesis. Bleomycin had been injected into both of these patients. The remaining five had subsequent radiographic evidence of recurrent effusion. Three of the four pleural biopsies performed under sonographic guidance yielded pleural tissue and were positive for malignancy (metastases in two cases and mesothelioma in one). In one patient with lymphoma of the pleura (proved at subsequent surgery), a nondiagnostic (false-negative) specimen was obtained.

Complications

Complications were analyzed by the type of procedure performed.

Diagnostic aspiration.—Seven of the patients had asymptomatic, barely detectable air in the pleural space after diagnostic aspiration. None of these patients were symptomatic nor were they treated. Two patients were symptomatic after aspiration and had significant pneumothoraces. One patient was treated with a large-bore chest tube, placed in the usual fashion by a surgeon, and that patient required hospitalization. The other was treated with a radiologically placed Heimlich valve tube, and after several hours of observation was sent home after expansion of the lung.

Therapeutic aspiration.—Eight of 41 cases in this group showed pleural air after aspiration. Of five asymptomatic patients, two had minimal pneumothoraces (<5%) and three had moderate pneumothoraces (>20%). All three had histo-

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ries of interstitial lung disease from tumor associated with pleural effusion. Two of the pneumothoraces were treated with Heimlich valve placement, although both were asymptomatic and there was no change in their appearance on radiographs after 48 hr. The catheters were removed, and the fluid reaccumulated. The third patient was sent home with a pneumothorax and with no symptoms, but, in this case too, the pleural fluid reaccumulated.

Three patients has symptomatic pneumothoraces that were treated on an outpatient basis with Heimlich valve placement. All three remained in the Radiology Department until full reexpansion of the lung was documented.

Empyema and Miscellaneous Groups

None of the patients in the empyema or pleural biopsy group had complications. One patient who underwent pleural sclerotherapy had a temperature of 103°F within 3 hr after introduction of tetracycline. This responded to conservative treatment with oral antipyretics.

Discussion

Interventional procedures in the pleural space have evolved as a natural outgrowth of the use of real-time sonography for drainage and biopsy procedures in the abdomen. The combination of its extreme sensitivity in detecting fluid collections, its flexibility, and its use with a portable unit make sonography the ideal technique for diagnosis and treatment of abnormalities in the chest.

In this series, 118 patients underwent diagnostic aspiration because of clinical uncertainty about the cause of a pleural abnormality (infection, tumor, or sympathetic effusions). Many patients had such small amounts of fluid that unguided or fluoroscopically guided aspiration was impossible, and possibly harmful. Several patients had had unsuccessful unguided aspiration in the past with resultant pneumothoraces. Once examined under sonography, the cause of such failures was frequently evident. The site of the attempted aspiration was often not even in the vicinity of the fluid collection.

Therapeutic drainage under sonographic guidance has become a common procedure because of its ease in diagnosing pleural effusions, patient acceptability, and low rate of complications. Sonography has been helpful in the palliative therapy of malignant effusion, in which a frequent cause of failure of drainage without imaging guidance is the presence of a thick pleural peel or multiple loculations. Initially, sonography was only performed when unguided drainage was incomplete, but because of its success and low complication rate, drainage by sonography has become a primary procedure, even for use on outpatients. A small percentage (10%) of patients (4/41) had the procedure performed on both pleural spaces during one visit.

Patients with empyemas had had previous surgical drainage and presented with small loculated collections. Although CT has been described as the ideal technique for monitoring drainage in these patients [2], in our experience sonography is quicker and can be used for real-time monitoring while the drainage procedure is being performed.

The complication rate from any of these procedures is exceedingly low, and, when a complication does occur, it can be treated by the radiologist. In most patients, the major complication is pneumothorax, and treatment is only necessary if the patient complains of dyspnea. If this occurs after therapeutic drainage, a Heimlich valve can be directly attached to the drainage catheter. If a symptomatic pneumothorax occurs after diagnostic aspiration or after removal of the catheter, a small Sacks catheter or Heimlich-type catheter can be placed in the air space, and a Heimlich valve can be attached. In most cases, these patients can be treated as outpatients with periodic follow-up chest radiographs until the lung reexpands.

We noted a subgroup of patients with malignant effusions who also have a combination of severe interstitial lung disease and pleural fluid in whom asymptomatic pneumothoraces developed after fluid removal. Often, after therapeutic drainage of the malignant effusions in these patients, large volumes of air are aspirated at the end of the procedure. The patients experience no pain and no dyspnea, but have a moderate amount of air in their pleural space on a postprocedure chest radiograph. Further catheter drainage with a Heimlich valve placement or even attachment of the drainage catheter to a Pleur-E-Vac usually accomplishes little. In these cases, the relative stiffness of the lung from the diffuse interstitial disease most likely prevents reexpansion, and any attempts at reexpansion are unsuccessful. Furthermore, removal of fluid, while possible, is often not helpful in reducing symptoms. In these patients, placement of a catheter for treatment of pneumothorax is not necessary.

The relative ease of catheter placement under sonographic monitoring and the availability of a Heimlich valve have made pleural aspiration and drainage using sonographic guidance a practical and useful procedure. The procedure has evolved to the point where almost all diagnostic aspirations and drainages can be performed by the radiologist.

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