




Challenges in Image-Guided Drainage of Infected Pleural Collections: A Review

Ashu S. Bhalla¹ Manisha Jana¹ Priyanka Naranje¹ Swish K. Singh¹ Irshad Banday¹

¹Department of Radiodiagnosis, All India Institute of Medical Sciences, Ansari Nagar, New Delhi, Delhi, India

Address for correspondence Priyanka Naranje, MD, DNB, MNAMS, Department of Radiodiagnosis, All India Institute of Medical Sciences, Ansari Nagar, New Delhi, 110029, Delhi, India (e-mail: priyanka11sh@gmail.com).

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Abstract

Infected pleural fluid collections (IPFCs) commonly occur as a part of bacterial, fungal, or tubercular pneumonia or due to involvement of pleura through hematogenous route. Management requires early initiation of therapeutic drugs, as well as complete drainage of the fluid, to relieve patients' symptoms and prevent pleural fibrosis. Image-guided drainage plays an important role in achieving these goals and improving outcomes. Intrapleural fibrinolytic therapy (IPFT) is also a vital component of the management. The concepts of image-guided drainage procedures, IPFT, and non-expanding lung are discussed in this review.

Keywords

- ▶ pleural effusion
- ▶ empyema
- ▶ image guided drainage
- ▶ drainage
- ▶ pigtail drainage

Introduction

Infected pleural fluid collections (IPFCs) can be the result of various organisms, the most frequent being bacterial or mycobacterial (tubercular), much less frequently fungal, and are rare in viral infections. This article focuses on IPFCs associated with bacterial pneumonia. In other forms of IPFCs caused by organisms, such as tuberculosis/fungi, basic presentation and treatment remain the same but recommendations may vary in terms of time of intervention. IPFCs associated with bacterial pneumonia may develop in the setting of community-acquired pneumonia (CAP), as well in hospital-acquired pneumonia (HAP). Pneumonia can be complicated by parapneumonic effusion, complicated parapneumonic effusion (CPE), or empyema which are defined subsequently. However, there are a significant number of cases of empyema or CPE that do not have an underlying pneumonia. Moreover, their bacteriologic spectra are not always similar. Other possible causes of empyema include hematogenous spread of infection and contiguous spread from subdiaphragmatic pathologies and trauma.^{1–4}

Management of CPE or empyema requires early and complete drainage, not only to relieve the patient's symptoms but also to prevent long-term complications of pleural fibrosis, resulting in compromised pulmonary function. Notable existing guidelines in terms of management include those of the British Thoracic Society (BTS)⁵ and American Academy for Thoracic Surgeons (AATS).⁶ The purpose of this review is to highlight key concepts and knowledge essential for optimal interventional radiology (IR) management of CPEs and empyema, to improve short- and long-term patient outcomes.

Diagnosis and Terminology

A concept that needs to be understood is that not all infected pleural fluid collections are empyemas. These could also be complicated parapneumonic/synpneumonic effusions. The differences between these two entities are illustrated in ▶ **Table 1**.^{7–10} Further, terms which are employed are related to the clinical settings in which the empyema occurs. These are very similar to the settings of the underlying pneumonia. For example, CPE occurs as a complication of

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Table 1 Differences between empyema and complicated parapneumonic effusion

	Definition	Pitfalls/fallacies ⁷⁻¹⁰
Empyema	Pleural collection, containing either <ul style="list-style-type: none"> • Pus • Culture/gram stain positive fluid 	<ul style="list-style-type: none"> • Glucose <40 mg/dL suggestive of empyema • However, laboratory results not always foolproof; clinical context should be taken into consideration
Complicated parapneumonic effusion	Clinical evidence of infection, and pleural fluid collection with the following features: <ul style="list-style-type: none"> • pH < 7.2 or • Glucose < 60 mg/dL 	<ul style="list-style-type: none"> • Laboratory values may be variable • pH may be elevated by urease-producing organisms such as <i>Proteus</i>

CAP, while health care associated empyema (HCAE) is associated with HAP.

While the detection of IPFCs is largely clinical ± imaging based, the diagnosis of empyema versus CPE relies largely on the pleural fluid aspiration. Pleural effusions associated with an underlying pneumonia should have a diagnostic tap, if the pneumonia does not respond to 48 to 72 hours of antibiotic treatment.^{5,11} A diagnostic tap should also be performed if a patient with sepsis has a pleural fluid of >10-mm thickness on chest radiograph/ultrasound or >20 mm on computed tomography (CT)⁶; or in elderly patients. The aspirated fluid may be serous/serosanguinous or frank pus. The analysis of pleural fluid has two components: biochemical and microbiological.

Biochemical analysis depends on pleural fluid pH, glucose, and lactate dehydrogenase (LDH). It should be kept in mind that the yield of pleural fluid in cases of CPE may only be approximately 50%, whereas blood cultures are reported to have higher yield. Whenever possible, blood culture specimens should also be obtained. Several ways have been described to enhance the microbiological yield of pleural fluid, such as direct inoculation of the pleural fluid, into a blood culture bottle after aspiration at the bedside. Another method is adopting Polymerase chain reaction (PCR) technique for pleural fluid samples/biopsy. This is especially useful for anaerobes. However, since the microbiological confirmation rate is markedly low, empiric antibiotic therapy is often started depending on the specific clinical scenario. Microbiological analysis of empyema/CPE fluid may yield variable bacteriologic spectra. While *Streptococcus* predominates the CAP fluid, methicillin-resistant *Staphylococcus aureus* (MRSA) and gram negative and anaerobic bacteria constitute a large part in HCAE.^{10,12,13}

Imaging of Infected Pleural Fluid Collections

While the complete discussion of this topic is beyond the scope of this review, imaging is critical in detection, quantification, guiding drainage, and follow-up.

Table 2 Quantification of IPFCs on imaging

Modality	Technique
USG	The Goecke 2 formula "Estimated volume (EV) $mL = (X + LDD) \times 70$ "
CT	
AP depth at midclavicular line	Mild: 3 cm Moderate: 3–10 cm Large: >10 cm
AP quartile	Mild: first quartile (0–25%) Moderate: second (25–50%) Large: third (50–75%) and fourth (75–100%)

Abbreviations: AP, anteroposterior; CT, computed tomography; IPFC, infected pleural fluid collection; LDD, lung to diaphragm distance; USG, ultrasonography.

Quantification of Pleural Fluid Collection

Quantification of pleural fluid guides the decision for drainage. Pleural effusions can be quantified on ultrasound and CT using various methods which are summarized in ►Table 2. On ultrasound, the Goecke 2 formula measured in erect position of the patient is reported to most closely correlate with actual fluid drained. Ultrasonography (USG) image is obtained keeping probe longitudinally oriented along dorsolateral/posterolateral aspect of chest wall, and cranio-caudal extent (X) and the lung base to middiaphragm distance (LDD)/subpulmonary height is measured. Volume of effusion is measured using formula "estimated volume (EV) $mL = (X + LDD) \times 70$ "¹⁴ (►Fig. 1A–D).

Computed tomography: one method is to measure anteroposterior (AP) depth at the midclavicular line on axial CT image where the maximum fluid is seen and quantify according to ►Table 2 (►Fig. 1E). Another method is to divide hemithorax in a quartile wherein first AP quartile represents 0 to 25% fluid occupying the hemithorax and suggest effusions are small, second AP quartile represents 25 to 50% effusions that are moderate, and third 50 to 75% or fourth 75 to 100% AP-quartile effusions are large¹⁵ (►Fig. 1F). CT volumetry software tool may also be used for estimation.

Staging of Infected Pleural Fluid Collection

Empyema is diagnosed on CT when there is a pleural fluid collection with enhancing visceral and parietal pleural layers, giving rise to "split pleura sign." Classically, IPFC has been divided into three stages; exudative phase, fibrinopurulent stage, and empyema stage.¹⁶ CT findings indicating the stages¹⁷ are shown in ►Table 3 and ►Fig. 2. CPE on USG may appear as clear fluid or fluid with fine internal echoes and on CT may show early pleural thickening.

However, the imaging findings may not always correspond to empyema in pleural fluid analysis. The final diagnosis is made by thoracentesis. Sinusoid sign on USG represents the appearance of wavy pattern on M-mode demonstrated when the visceral and parietal pleura are separated by free fluid (►Fig. 3). It may be absent when there is a dense or multiseptated collection.

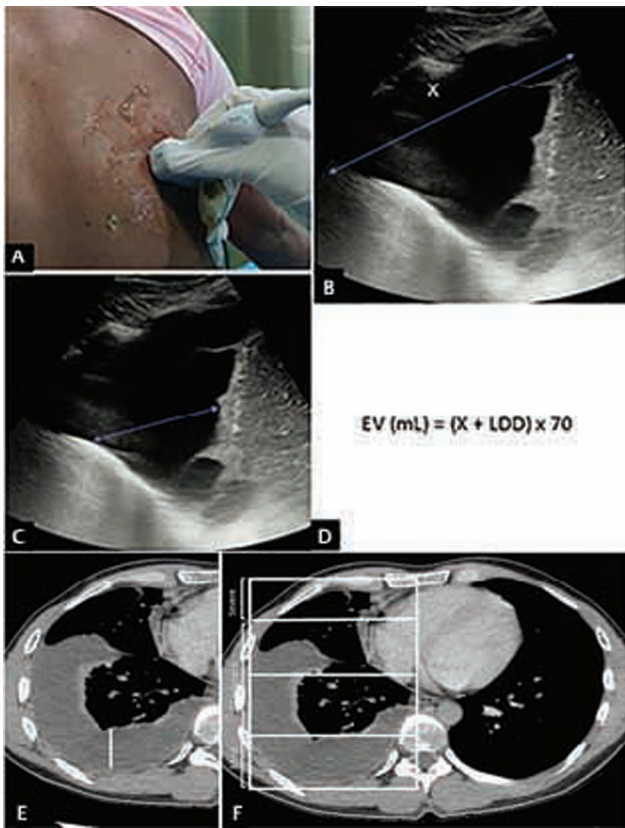


Fig. 1 Quantification techniques of pleural effusion. (A-D) Ultrasound quantification (A) Probe position on dorsolateral aspect in erect/sitting position; (B) Image showing measurement of X, craniocaudal extent in centimeter of the effusion; (C) Lung to diaphragm distance (LDD), lung base to middiaphragm distance/subpulmonary height of the effusion (cm); and (D) Formula used to calculate the volume. (LDD: lung base to middiaphragm distance) EV is the estimated effusion volume (mL) and 70 is the empirical factor/constant. (E and F) Computed tomography (CT) quantification technique of pleural effusion. (E) Anteroposterior (AP) depth of the pleural effusion at mid clavicular line where the maximum fluid is seen; and (F) Axial CT image with superimposed AP quartiles dividing the hemithorax to quantify the pleural effusion into mild, moderate and severe categories. CT showing right moderate effusion (Occupying 25th to 75th quartile of the right hemithorax).

Management

Management of IPFCs has two main modalities: surgery and percutaneous intervention (tube drainage and intrapleural fibrinolytic therapy [IPFT]). Most available literature sug-

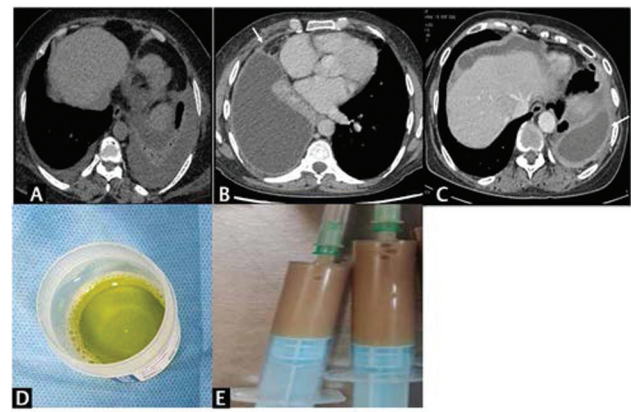


Fig. 2 Characterization of pleural effusion on CT. (A) Exudative phase-dependent, biconcave free fluid in pleural space, consolidation in left lung. (B) Fibrinopurulent phase—biconvex collection with smooth enhancing pleural thickening (split pleura sign). Edema of extrapleural soft tissue (arrow). (C) Organized phase showing residual fluid with left pleural thickening (arrow) and mild volume loss of hemithorax with rib crowding. (D, E) Types of aspirated pleural fluid. (D) Serous—clear straw colored fluid in exudative phase; (E) Pus—thick turbid fluid in fibrinopurulent phase.

gests surgery as the second line management option, after failure of conservative management or tube thoracostomy. Exceptions to this are presence of sepsis or septic shock or a suspected lung abscess. Very few trials analyzed the efficacy of upfront minimally invasive video-assisted thoracic surgery (VATS) in comparison to tube drainage.¹⁸ This article will describe the interventional management: goals of treatment are two folds, relieving sepsis and preventing long-term complications (e.g., fibrosis and trapped lung).

Time to Intervene

Timing and nature of surgery is beyond the scope of this article. Interventional management is discussed here. However, not every parapneumonic effusion needs drainage. If the effusion is mild and the patient is responding to antibiotics, it should not be drained. Unlike diagnostic tap, no volume cut-off is available for IPFT.

Parapneumonic effusion has classically been described to evolve through three stages: exudative, fibrinopurulent, and organizing.¹⁹ The time duration of each stage is variable, and delay in thoracentesis may result in increased morbidity. The diagnostic thoracentesis should be performed proactively in

Table 3 CT findings indicative of various stages of IPFC

Stages	Exudative stage	Fibrinopurulent stage	Organizational stage
CT findings	<ul style="list-style-type: none"> Dependent, biconcave free fluid in pleural space Consolidation in ipsilateral lung No or mild pleural enhancement 	<ul style="list-style-type: none"> Parietal pleural thickening is always present Split pleura sign present Loculations Biconvex/lenticular shape Internal septations Air foci/air-fluid level (hydropneumothorax) Edema of extrapleural soft tissue 	<ul style="list-style-type: none"> Smooth grossly thickened pleura Residual fluid may be present Pleural calcification Extrapleural fat proliferation Volume loss of hemithorax with rib crowding

Abbreviations: CT, computed tomography; IPFC, infected pleural fluid collection.

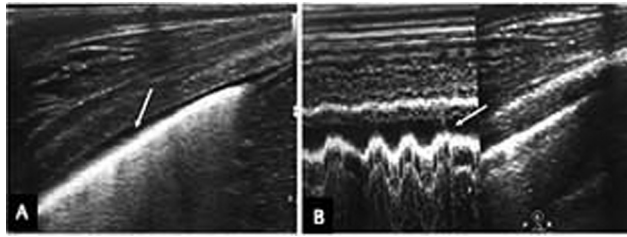


Fig. 3 Sinusoid sign. (A) Ultrasound showing minimal pleural effusion (arrow). (B) In same patient, M mode showing presence of sinusoid sign (arrow).

the earliest suspicion of nonresponse to antibiotics (see “Diagnosis and Terminology”). Similarly, a tube thoracostomy should also be performed at an early stage of the disease, so as to avoid subsequent complications.^{20,21}

Tube Drainage

While surgical drainage enables one to use larger bore tubes (up to 32–40 Fr), image-guided drainage is typically described to suffer from the drawback of smaller size of the tubes. Though there is no consensus on the size of the optimal chest tube for drainage, for most IPFCs, a small-bore catheter of size 10 to 14 F will be adequate. With the advances in percutaneous drainage tube technology, larger bore tubes, even up to 32 Fr (Thal-Quick, Cook Medical, United States),²² are now available and can be used for thick stubborn collection not responding to small bore catheter drainage. In cases with rib crowding, it is advisable to measure the intercostal space and calculate tube size accordingly. Pigtail catheter is commonly preferred due to the presence of multiple side holes. Malecot catheter is also another preferred self-retaining drainage catheter.

Technique principles of standard trocar and Seldinger’s techniques of tube insertions are similar to all drainage procedures elsewhere in the body. Complete discussion of the techniques is beyond the scope of this review. A few points specific to thoracic drainage are emphasized. Standard site of catheter insertion is along the midaxillary line in fifth or sixth intercostal space and direction of insertion being superior to inferior. However in case of loculated effusions, such universal approach will have to be modified according to site of loculation. Care should be taken that no air is introduced into the pleural space during entire procedure and use of three ways are helpful. After the catheter is placed, it should be connected to an underwater seal drainage bag. USG along with fluoroscopy is a good combination modality for guiding the procedure. CT also can be adapted accordingly, especially in case of rib crowding and when USG visualization is poor.

Outcome of empyema having frank pus vis-a-vis CPE may not be largely different. Whereas it has been demonstrated that frank pus does not essentially imply a tube thoracostomy failure, absence of pus is usually associated with a good outcome of tube thoracostomy.^{21–26} Larger bore tubes have higher pain scores but offer no additional advantage in terms of prevention of surgical intervention or mortality.

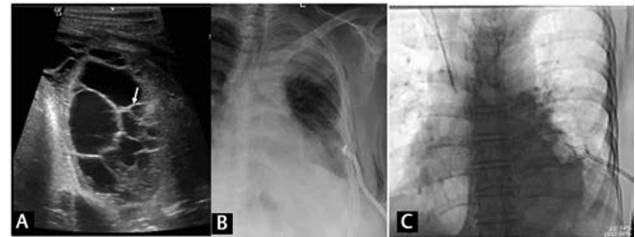


Fig. 4 Failure of tube drainage. (A) Ultrasonography (USG) showing multiple loculations due to thick septations (arrow). (B) Frontal CXR showing catheter tip at the level of lateral thoracic wall suggestive of displaced drain. (C) Postdisplacement, Malecot catheter was inserted.

Catheter removal: although literature states, for removal of tube, the output volume to be 200 ml/day in general,²⁷ the decision of tube removal in clinical practice is based on combination of factors such as radiological reduction in size of pleural fluid collection, clinical resolution of sepsis, and fever with no significant drainage output for 48 to 72 hours. Hence, the catheter can be retained even with output <200 ml/day, as several of these collections do not have large volumes.

Reasons for inadequate drainage include thick, viscous collection and presence of loculations. Postinsertion monitoring consists of output monitoring, checking for any tube kink and regular flushing of the tube. Simple saline irrigation has been proven to be useful.²⁸ It has been found superior to tube drainage alone. Thrice daily irrigation with 200 mL of saline for 3 days is recommended.²⁸ Due to improper fixing or accidental misplacement, there may be tube displacement (►Fig. 4). Repeat chest X-ray (CXR) can be helpful. In the authors’ experience, a low-dose CT can be used in the follow-up before repositioning of catheters.

Intrapleural Fibrinolytic Therapy

While IPFT forms an important component in the management of IPFCs, their use is very variable among institutions. This topic will be discussed under the following headings: Indications, choice of pharmacologic agent, benefits, adverse effects, and cost-effectiveness issues.

Indications

The primary indication for IPFT is organizing phase of empyema with loculations and fibrin deposition which may not resolve completely with tube thoracostomy alone; resulting in nonexpansion of underlying lung. IPFT aims to lyse the loculations caused by fibrin deposition.

Choice of Pharmacologic Agent

Streptokinase/urokinase are the pharmacologic agents used in the earlier trial (multicenter intrapleural sepsis trial [MIST] 1). In comparison to placebo, they were not found to have any improved outcome (in terms of death, surgical referral or duration of hospital stay). Tissue plasminogen activator (tPA) acts by virtue of its fibrinolytic property. It can either be used alone or in combination with other agents. The viscosity of empyema fluid is caused by extracellular DNA. Deoxyribonuclease (DNase) is another agent which acts by

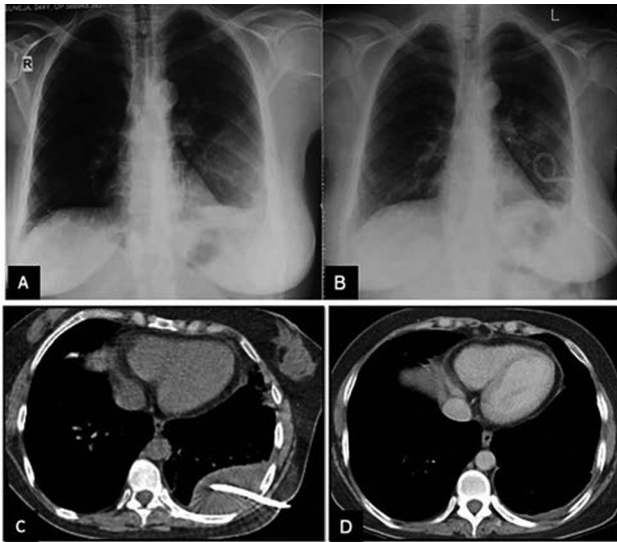


Fig. 5 Benefits of fibrinolytic agents. (A–C) Pretreatment—chest X-ray (CXR) and noncontrast computed tomography (CT) showing loculated left pleural collection with pigtail in situ. However, the collection was not drained in spite of drain in situ. (D) Post-streptokinase treatment—Image at similar level showing complete resolution of collection.

degrading them. Also, they help destroy bacterial biofilm. DNase is reported to increase the efficacy of streptokinase or tPA. A combination of tPA and DNase was reported to be more effective than any other combinations with respect to a reduction of surgical referral and morbidity.

Frequency and Dosage

Various recommendations exist, ranging from 2 to 100 mg of tPA,^{29,30} for dwell time varying from 30 minutes to 4 hours.^{31,32} MIST2 trial recommends twice daily administration of a dose of 10 mg of tPA and 5 mg of DNase; instilled sequentially with a gap of 2 hours. Individual dwell time for each agent is 1 hour. In case of simultaneous administration of two agents; a dwell time of 2 hours should be allowed. The duration of treatment is also not uniform, and mostly individualized. However, a duration of 3 days is recom-

mended by MIST2 trial; and any prolongation of treatment duration does not lead to improved outcome.

Benefits

Improved outcome of tube drainage in terms of reduced rate of surgical intervention and death (–Fig. 5).

Adverse Effects

Intraleural administration of tPA does not cause systemic bleeding because they do not have significant systemic absorption. However, they can cause local (pleural) hemorrhage, especially at a higher dose. The maximum safe dose is variable according to different studies, ranging from 20 to 100 mg. Intraleural hemorrhage is mostly treatable with conservative measures and stoppage of IPFT. Anaphylaxis to streptokinase is also a documented adverse effect which can be life threatening.

Cost-Effectiveness Issues

IPFT reduces the rates of surgical referral and, therefore, the surgical cost. However, the additional period of hospital stay and the cost of fibrinolytics should also be taken into consideration. A recent meta-analysis did not show any benefit of IPFT in terms of duration of hospital stay.³³ This is more relevant in resource-constrained countries like India.

The summary of the pharmacologic agents and their dosage is further listed in –Table 4.

Important Trials on Intraleural Fibrinolytic Therapy

The topic of the efficacy of IPFT is a matter of perpetual confusion. Several large studies/trials have taken place in the last few decades, a few of them are being discussed hereinafter.

Multicenter Intraleural Sepsis Trials 1 and 2

These two large trials originated from the United Kingdom. MIST1 trial was conducted between 1999 and 2002 on 454 patients, with the objective of establishing the efficacy and safety of intraleural streptokinase in patients of empyema and CPE. This study concluded that intraleural streptokinase

Table 4 Comparison of pharmacologic agents for IPFT

Agent name	Mechanism of action	Dosage	Side effects
Streptokinase/urokinase	Promotes fibrinolysis by activation of plasmin	250,000 units dissolved in 30 mL saline and instilled through thoracostomy tube once/twice daily for six doses	<ul style="list-style-type: none"> Anaphylaxis (uncommon, with streptokinase only, not urokinase) Generalized bleeding tendencies
tPA	Activation of plasminogen to form plasmin and degrade fibrin	10 mg of t-PA through thoracostomy tube, followed by a dwell time of 1 hour. Twice daily for 3 days	<ul style="list-style-type: none"> Local site pain Erythema/rash Intraleural hemorrhage Hemoptysis
DNase	Degrades bacterial biofilm and reduces viscosity of pus (it contains extracellular DNA)	5 mg through thoracostomy tube, followed by a dwell time of 1 hour. Twice daily for 3 days	<ul style="list-style-type: none"> Local site pain Erythema/rash Intraleural hemorrhage Hemoptysis

Abbreviations: DNase, deoxyribonuclease; IPFC, infected pleural fluid collection; tPA, tissue plasminogen activator.

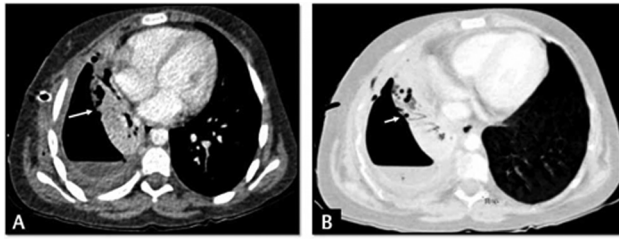


Fig. 6 Lung entrapment versus trapped lung: pathogenesis and clinical manifestations.

did not improve mortality, rate of surgery or length of the hospital stay, and was associated with significant adverse effects.²⁴ MIST2 trial, conducted from 2005 to 2008, evaluated the efficacy of other intrapleural fibrinolytic agents (tPA and DNase) on 210 patients (► **Supplementary Table S1**; available in the online version). This trial had four arms (tPA alone, DNase alone, combination, and placebo). The investigators concluded that intrapleural t-PA–DNase therapy improved fluid drainage and reduced the frequency of surgical referral, and hospital stay. Treatment with DNase alone or t-PA alone was ineffective.²⁵ Another meta-analysis comparing IPFT with placebo reported that IPFT reduces the need for surgical referral and low risk of overall mortality.³⁴ A flowchart summarizing the indications for various intervention steps is depicted in ► **Fig. 6**:

Special Situations

Bronchopleural Fistula

Bronchopleural fistula (BPF) can develop after lung resections (commoner) and as a complication of necrotizing pneumonia (rare). The incidences of BPF after pulmonary resections have reduced with the advent of good antibiotics. The reported incidence of BPF is higher in cases of pneumonectomy rather than lobectomy. Several other factors govern the risk of developing a postoperative BPF.

A necrotizing pneumonia can occasionally give rise to BPF (► **Fig. 7**). Long-term tube thoracostomy is recommended. A word of caution worth mentioning is that in empyema associated with BPF, IPFT is contraindicated. Studies have demonstrated the utility of apposing the serratus anterior muscle in the chest cavity for the closure of fistula during thoracoscopic debridement in children.³⁵

Unexpandable Lung

Unexpandable lung is a term used to define the condition when the visceral and parietal pleura do not appose even after adequate pleural fluid drainage. It can occur as a result of empyema, CPE, malignant pleural effusion, uremic effusion, hemothorax, and radiation-induced or pleurodesis-induced pleural damage.

The underlying mechanism of nonexpansion of lung can be as follows:

1. Central obstruction of the subtending bronchus (► **Fig. 8A**).
2. Prolonged atelectasis which leads to inadequate subsequent expansion (► **Fig. 8B**).

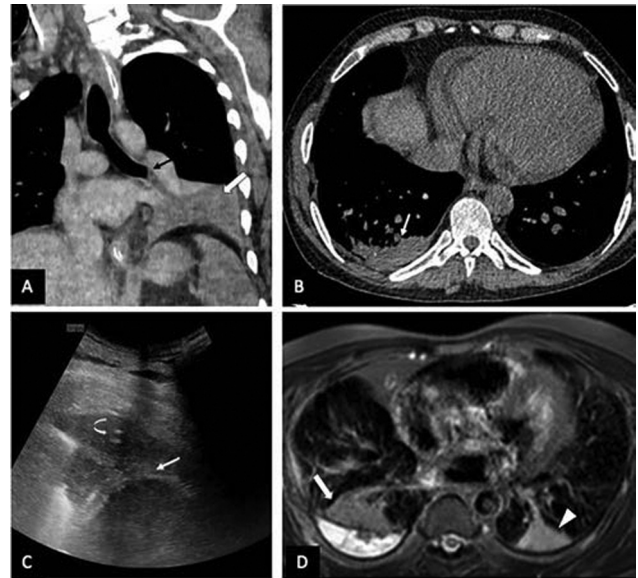


Fig. 7 Bronchopleural fistula. Few subpleural cysts communicating with pleural space: (A) mediastinal window; (B) lung window (arrow).

3. Thick pleural peel which hinders proper apposition of pleural layers (► **Fig. 8C** and **D**).

It is important to understand the difference between two terminologies used in relation to nonexpansion of the lung, “lung entrapment” and “trapped lung.” Failure of apposition of pleural layers can be seen either during an active pleural inflammatory process (or malignancy) or in healed diseases where there is no active inflammation. The term “lung entrapment” is used when active inflammation is present while “trapped lung” is used in cases of healed infections. (► **Fig. 9**)

► **Fig. 10** describes the pathogenesis and clinical manifestations of these two entities. Pleural manometry is useful in differentiating these two entities. Ultrasound demonstrates an absence of normal “sinusoid sign” in both these situations. CT is crucial in identifying the cause of nonexpansion.

The clinical manifestations arise out of the inability of the lung to expand. When a large amount of pleural fluid is drained, and yet the lung cannot expand, it creates a characteristic sharp pain. This pain has been typically described to resolve after injection of air into the pleural space (“therapeutic pneumothorax”). In case of a more pronounced negative intrapleural pressure, small peripheral airways may rupture, leading to pneumothorax (“pneumothorax-ex-vacuo”). This pneumothorax is usually asymptomatic, as it is actually a way to normalize the negative pressure within the pleural cavity. Reexpansion pulmonary edema is also a dreaded complication of excessive pleural fluid drainage in the background of an unexpandable lung.

Empyema in Children

Incidence of CPE and empyema in children is lower than in adults. However, these are different from the adult

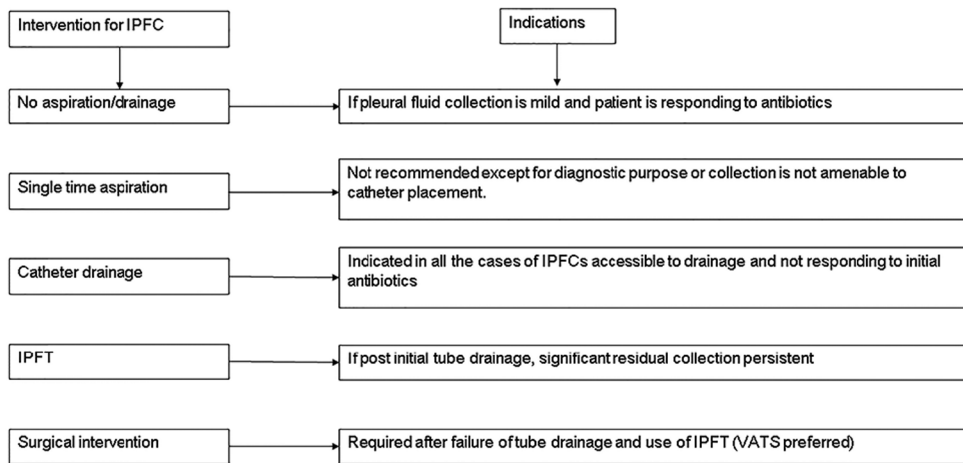


Fig. 8 Unexpanded lung (different patients) (A) Central obstruction: contrast-enhanced computed tomography (CECT) thorax oblique coronal image showing hypodense mucus plug (black arrow) causing complete occlusion of left main bronchus (LMB) which resulted in collapse of left lower lobe (black arrow); (B) Prolonged atelectasis (arrow) (C) Thick pleural peel (arrow) and collection with drain in situ (curved arrow). (D) Chest MRI (Short TI inversion recovery sequence (STIR)) shows unexpanded segments of lung adjacent to chronic loculated pleural effusion/thickening on right side (arrow) and due to chronic atelectasis on left side (arrowhead).

counterpart, both in terms of epidemiology, as well as management strategies.

First, decision of tube thoracostomy is usually based on clinical (failure to respond to appropriate antibiotic treatment) and imaging parameters. CT is not routinely recommended. A baseline CT may be performed. However, USG is

preferred for monitoring. Echogenic contents, debris, loculations, and pleural thickening should call for escalation of management. In follow-up, USG is preferred as ultrasonographic visualization is much better in children owing to thinner chest wall musculature.

Second, the procedure of tube drainage should always be performed under proper sedation (in older children) and general anesthesia (in case of very small children). In case of procedure under sedation in an interventional radiology suite, proper patient monitoring should be ensured.

Third, there is no consensus recommendation regarding the optimal tube size in children. Several large studies have produced conflicting reports.^{35–38} In a large single-center study from the United Kingdom,³⁹ smaller bore tubes were recommended in children. The advantages include superior patient comfort, less pain and reduced hospital stay. The same study has recommended a size of 8.5 Fr for older children,³⁹ and even smaller bore tubes in younger children.

Lastly, several technical nuances are worth noting in pediatric procedures. Single step trocar technique is often preferred over Seldinger's technique in children.³⁷ The aspiration of pleural fluid should be gradual (maximum: 10 mL/kg) to avoid reexpansion pulmonary edema. In children, adhesive devices are preferred over sutures. Fibrinolytic dosage is also different in children. The recommended dose is 10,000 U urokinase diluted in 10 mL of normal saline in infants and 40,000 U urokinase in 40 mL of normal saline in older children. A dwell time of 4 hours should be followed by an 8-hour drainage at a negative suction of 10 to 20 cm H₂O.

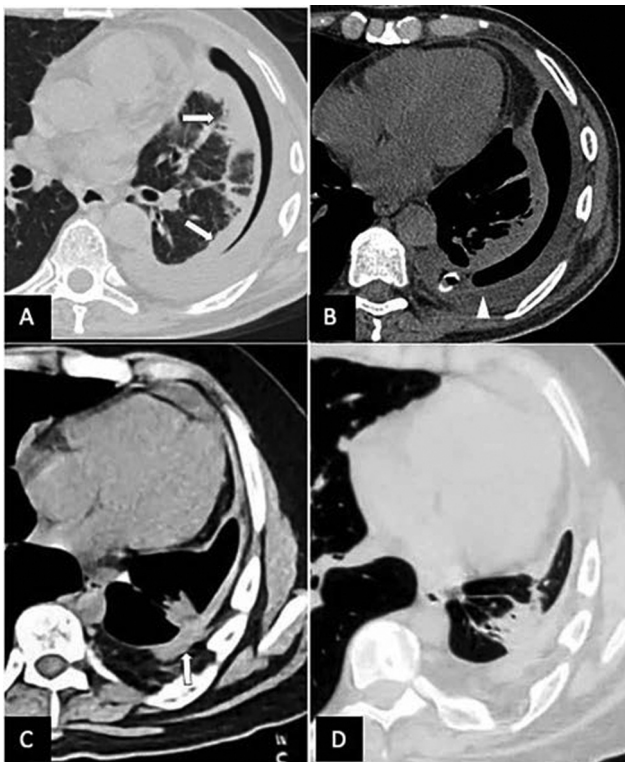


Fig. 9 (A, B) Lung entrapment: nonexpanded left lung parenchyma (arrow) due to pleural thickening and inflammation (arrowhead in B). Intercostal draining catheter is seen in situ; (C, D) **Trapped lung:** long standing pleural thickening without inflammation (arrow) resulting in left lung volume loss.

Summary of Guidelines

Several guidelines are available regarding diagnosis, management, and pharmacologic choices in IPFCs. Herein, we shall summarize the salient points from the AATS guidelines (► **Table 5**).

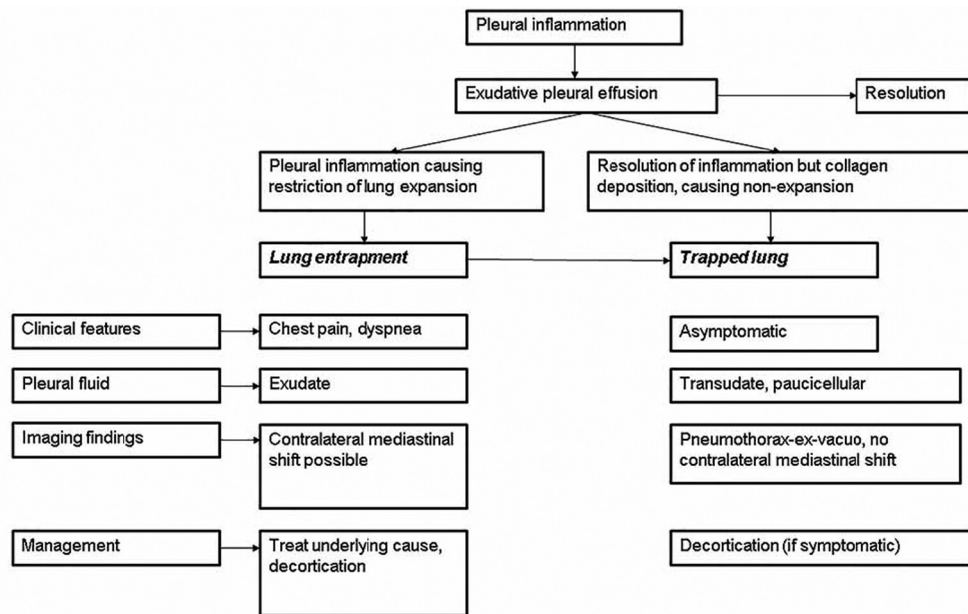


Fig. 10 Lung entrapment versus trapped lung: pathogenesis and clinical manifestations.

Table 5 Summary of recommendations according to AATS guidelines

	Recommendations (class I)	Recommendations (class IIa)	Recommendations (class IIb)	Not recommended (class III)
Clinical diagnosis: when to suspect empyema	CAP/HCAP not responding to appropriate antibiotic therapy			
Pleural fluid analysis	Presence of pus, or Gram stain positive pleural fluid, or pleural fluid pH < 7.2 should indicate presence of empyema	Pleural fluid LDH > 1,000 IU/L, glucose < 40 mg/dL; or presence of loculations		
Imaging evaluation: which study to perform?	CXR and pleural USG to be done routinely; both for diagnostic and for image guided therapeutic procedures	CT should be done in all		
Acute empyema				
Antibiotic treatment in acute empyema	Antibiotic should be chosen based on culture reports, if available (LOE C)	Intrapleural antibiotic treatment is not useful (LOE C)		
Thoracocentesis without tube placement in acute empyema				Not recommended (LOE C)
Image guided drain placement in acute empyema	<ul style="list-style-type: none"> • Helpful in early stages when there are less number of septae (LOE B) • Tube should be regularly flushed to avoid blockage (LOE B) • Follow-up CT and management escalation (if needed) are recommended (LOE C) 	In the presence of thick septae, image guided tube placement can be done in patients not suitable for surgery (LOE C)		

Table 5 (Continued)

	Recommendations (class I)	Recommendations (class IIa)	Recommendations (class IIb)	Not recommended (class III)
IPFT in acute empyema		Should not be routinely used in CPE and early empyema (LOE A) ^a		
Surgical management in acute empyema		VATS should be performed in stage-II acute empyema (LOE B)		
Chronic empyema				
Chronic empyema: tube drainage			May be considered in patients with small chronic empyema/small BPF (if unfit for surgery; LOE C)	
Chronic empyema: decortication		Should be done in all patients who can withstand the surgical procedure		
Empyema in children	Should be treated with small bore tube ^b thoracostomy first (LOE A; with or without IPFT)	Thoracoscopic procedure should be performed in cases of non-response to tube thoracostomy and IPFT (LOE B)		

Abbreviations: AATS, American Academy for Thoracic Surgeons; BPF, bronchopleural fistula; CAP, community-acquired pneumonia; CPE, complicated parapneumonic effusion; CT, computed tomography; CXR, chest X-ray; HAP, hospital-acquired pneumonia; LDH, lactate dehydrogenase; LOE, level of evidence; USG, ultrasonography; VATS, video-assisted thoracic surgery;

^aThis remains a matter of debate; as several prominent trials (e.g., multicenter intrapleural sepsis trial 2) advocate the use of IPFT to improve outcome and avoid surgery. In practice, it largely depends on multiple factors as follows: (1) institutional protocol; (2) availability of experienced thoracic surgeon for decortication which is a major surgical procedure; (3) availability of appropriate surgical infrastructure, especially in emergency hours; (4) patient suitability for undergoing a major surgical procedure; and (5) experience of the interventional radiology team.

^bChoosing an optimum tube size in children is also a controversial topic (discussed in detail above).

Conclusion

IPFCs, secondary to pyogenic infections, require early complete drainage of the fluid in addition to systemic drugs. Image-guided drainage along with IPFT plays an important role in improving outcomes.

Supplementary Material

Supplementary Material

Conflict of interest

There are no financial or nonfinancial conflicts.

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