Chapter

Advancements in Endobronchial Ultrasound

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Abstract

Endobronchial ultrasound (EBUS) is a diagnostic procedure that allows for the diagnosis and staging of lung cancer and other lung-related diseases such as tuberculosis, sarcoidosis, and sarcoma. The radial probe for the EBUS device was first introduced to visualize the inside of the lungs and airway structures, and identify the extent of tumor invasion in the airway and surrounding lymph nodes. The EBUS transbronchial needle aspiration (TBNA) is an acceptable first test in the pretreatment staging of lung cancer to appropriately understand the prognosis for curative therapies. In the future, EBUS is likely to become widely available and accessible to patients, given its low cost and minimal risk of complications compared to other diagnostic and therapeutic procedures. The development of more advanced EBUS technologies, such as radial EBUS, virtual bronchoscopy, fluorescence-guided bronchoscopy, and artificial intelligence will allow for improved visualization of the lungs and adequate lymph node yield, leading to more accurate diagnoses and better treatment outcomes. In conclusion, the future of EBUS modalities combined with the additions of bronchoscopic advances is expected to further improve the accuracy and precision of the procedure while limiting morbidity, and complications, and improving clinical workflow availability in the outpatient setting.

Keywords: endobronchial ultrasound (EBUS), diagnostic imaging, bronchoscopy, endoscopic ultrasonography (EUS), electromagnetic navigational bronchoscopy (ENB), tumor sampling

1. Introduction

Bronchoscopy is a procedure by which physicians examine a patient's tracheobronchial tree. Generally, a bronchoscopy is conducted by traversing the vocal cords with the bronchoscope instrument through a patient's nasal, oral, or tracheal orifice. The most common type of bronchoscopy is that which utilizes a flexible bronchoscope. Certain conditions may arise that may require a different type of bronchoscopy such as rigid bronchoscopy in cases such as hemoptysis or obstructing lesions, or adjuncts such as endobronchial ultrasound (EBUS) or electromagnetic navigation bronchoscopy (ENB). In this chapter we will discuss the various types of bronchoscopies, adjunctions, indications, contraindications and procedural steps.

2. Flexible bronchoscopy

The flexible bronchoscope is one of the most widely utilized modalities for diagnosis and treatment of bronchopulmonary diseases due to its ability to reach distal airways, ease of use, and low risk procedural state in some cases only requiring mild to moderate sedation [1]. The outer diameter of the scope is anywhere between 2.2–6 mm, while the inner (working) diameter of the scope is between 1 and 2.2 mm [2]. The flexible bronchoscopy can be used for both diagnostic and therapeutic purposes. Indications for diagnostic purposes include refractory symptoms such as chronic cough, small volume hemoptysis, stridor, or pulmonary infections. Other diagnostic indications include unresolved pneumonia, interstitial lung disease, masses located in the lung, endobronchial or mediastinal, and chemical or thermal injury to the airways. Therapeutic indications for flexible bronchoscopy include tumor debulking, balloon dilation in benign central airway obstruction, abscess drainage, aspiration of cyst as well as airway stenting. Flexible bronchoscopy has a reported death rate of 0–0.04% in greater than 68,000 procedures, making it relatively safe. Major complications are equally infrequent with less than 1% of cases and if they occur could include respiratory distress, arrhythmias, cardiopulmonary arrest, major bleeding, and pneumothorax. This procedure is contraindicated in those that have preexisting arrhythmias and those who are hemodynamically unstable. This procedure also may be performed with moderate sedation which could cause an increase in heart rate that may induce ischemia in a small number of patients.

3. Rigid bronchoscopy

Rigid bronchoscopy is one of the oldest medical procedures in the thoracic field, however, use of this modality has declined with the introduction and ever increasing use of flexible bronchoscopy [2]. It actually has been recorded that the first use of this bronchoscope was in 1898 for the removal of a pork bone from the airways. Rigid bronchoscopy utility remains in the armamentarium of pulmonologist and thoracic surgeons given many of its benefits such as ability to both ventilate and stent open airways similar to that of an endotracheal tube but the opportunity to diagnose independently or simultaneously providing conduit for flexible bronchoscopy. The diameter of the scope measures from 3 to 18 mm for the outer scope while the inner (working) diameter of the scope is between 2 and 16 mm, making it larger than the flexible bronchoscope. In the setting of foreign body obstruction, the large diameter of the scope permits rigid bronchoscopy to remain advantageous for safe extraction compared to other modalities. Other therapeutic indications include management of malignant and benign central airway obstruction (CAO), and most importantly the management of massive hemoptysis. Due to large amounts of blood volume that can be lost in massive hemoptysis, a patient may develop asphyxia and hypoxia, leading to a life-threatening event. The rigid bronchoscope is used to stent an airway open, while providing therapeutic modalities to debride, debulk, or coagulate or irrigatethe airways for intraluminal patency.

Overall the rigid bronchoscopy is a life-saving therapy indicated for patients who have tacheobrnchial obstruction with inability to reliably ventilate. Potential complications include, injury to upper airway structures during intubation, hypoxia and hypercarbia, bleeding, and airway perforation. The most common symptoms reported after the procedure include a sore throat and neck pain.

	Flexible bronchoscopy	Rigid bronchoscopy
Diagnostic indications	Evaluation of: • Non-resolving pneumonia. • Ventilator-associated infections. • Diffuse lung disease. • Atypical chronic interstitial lung disease. • Parenchymal nodules or masses. • Confirmation of endotracheal tube position.	• Extraction of foreign bodies. • Evaluation of airway control during hemorrhage. • Airway stenosis. • Evaluation of the airway for tracheal resection. • Collection of large specimens for lung biopsies. • Examination of the subglottic airway in the neonatal population.
Therapeutic indications	• Placement of self-expandable airway stents. • Hemostasis of centrally located bleeding lesions. • Abscess drainage. • Use of ablative technique modalities.	• Management of bronchopulmonary hemorrhage. • Management of central airway obstruction (CAO) (both malignant and benign). • Placement of airway silicone stents. • Use of ablative technique modalities.

Table 1.
Indications for flexible bronchoscopy vs. rigid bronchoscopy.

The most common contraindications for this procedure are associated with the general anesthesia administered to the patient rather than the scope. Patients with very high oxygen requirements and those with high levels of positive end-expiratory pressure (PEEP) would typically not undergo this type of procedure. However, if the patient has CAO, and all other methods of oxygenation and ventilation have failed, rigid bronchoscopy would be performed to treat the patient's airways. Hypercoagulable states, cardiac conditions, facial trauma, neuromuscular conditions that can be worsened by anesthesia, and factors associated with atlantoaxial subluxation and instability should all be considered prior to this procedure (**Table 1**).

4. Endobronchial ultrasound (EBUS)

Endobronchial ultrasound (EBUS) is a procedure that combines the flexibility of a flexible bronchoscopy with a probe that specifically provides an angulated ultrasound image. The radial probe for the EBUS device was first introduced to visualize the inside of the lung's airway structures, and to identify the extent of tumor invasion in the central airway and the surrounding lymph nodes. EBUS is now routinely paired with the transbronchial needle aspiration (TBNA) procedure acquiring biopsies in a lesser invasive modality. EBUS transbronchial needle aspiration (TBNA) is an acceptable first diagnostic modality in the identification and pretreatment staging of lung cancer to appropriately understand the prognosis for curative therapies [3].

4.1 Physics

There are two types of EBUS probes: the radial catheter probe (RP-EBUS) and the convex probe EBUS (CP-EBUS). The RP-EBUS uses a thin catheter that contains a small probe and is passed through the working channel of the bronchoscope.

The probe rotates 360 degrees and captures ultrasound images of the lung parenchyma and the target lesion. This probe does not allow real-time needle biopsy; instead it is able to precisely locate pulmonary nodules or masses based on differences in echogenicity between normal lung tissue and other lesions [4]. RP-EBUS is a useful tool for lesions that are less than 2 cm or those commonly found in the smaller branches of the airway. The Convex-probe EBUS (CP-EBUS) has a linear ultrasound probe and an instrument channel on the tip of a bronchoscope, enabling an angulated needle biopsy under real-time ultrasound guidance [5]. The ultrasound mechanism utilizes high-frequency sound waves to create images of internal structures. The transducer within the device at the top of the bronchoscope, sends and receives ultrasound waves of the surrounding tissue and organs. The frequency of the sound waves used in EBUS are typically between 5 and 15 megahertz (MHz) with higher frequencies providing better resolution however superficial and in contradistinction, lower frequencies penetrating deeper however with lower resolution. Utilizing optimal depth and resolution, EBUS provides excellent visualization of structures adjacent to the airways, including lymph nodes and blood vessels, and for guiding biopsies of these structures. Based entirely on density and stiffness, EBUS ultrasound waves distinguish varying tissues while allowing less invasive specimen biopsy methodology for further testing. The thin CP-EBUS has improved accessibility to peripheral bronchi with excellent operability and is capable of sampling lobar and segmental lymph nodes using the aspiration needle.

5. Comparison of other techniques for tumor sampling

Surgical resection is traditionally the gold standard for obtaining mediastinal lymph node biopsy samples as well as curing early-stage lung cancer. Surgery can be performed with the traditional open approach (ex: thoracotomy) or by a minimally invasive approach. Video-assisted thoracoscopy (VATS) is a minimally invasive approach that is the preferred approach for surgical resection [6]. However, the needle techniques tend to be less expensive, less invasive, and have a smaller risk of complications when compared to surgical methods. Techniques for biopsy include previously mentionedEBUS-TBNA, Endoscopic Ultrasonography (EUS), mediastinoscopy, and Video-Assisted Thoracoscopic Surgery (VATS).

5.1 Endoscopic ultrasonography (EUS)

The EUS equipment consists of an ultrasound processor connected to an echoendoscope, with an ultrasound transducer attached at the distal tip of the instrument. The endoscope in return is connected to a standard video processor, permitting the endoscopic visualization [7]. This allows for simultaneous endoscopic and ultrasound imaging. EUS can use both a radial scope or linear scope to stage lung cancer in the mediastinum. However, radial scopes are most commonly used to stage lung cancer, while the linear scope is used for targeted EUS–fine-needle aspiration (FNA). EUS staging of lung cancer almost always requires FNA of lymph nodes in order to achieve greater accuracy. EUS can identify lymph nodes in the posterior and inferior mediastinum.

An advantage of EUS is that it can detect metastatic disease to subdiaphragmatic sites such as left adrenal, celiac lymph nodes, and liver. EUS-FNA is performed through the esophagus which presents as a limitation because ultrasonic rays cannot penetrate air-filled structures. This means the EUS-FNA cannot visualize or detect areas immediately anterior to the trachea [8].

5.2 Indications EUS versus EBUS

Patients that present with enlarged lymph nodes in the mediastinum on imaging should proceed to have an EUS or EBUS performed as the next step in the staging procedure [8].

Endobronchial ultrasound (EBUS) and endoscopic ultrasound (EUS) are two different procedures that use ultrasound imaging to visualize structures within the body. While they share some similarities, they have different indications and applications. The choice of EUS or EBUS is dependent on the location of the enlarged lymph node. Patients with enlarged lymph nodes in the posterior inferior mediastinum or subcarinal area are recommended to undergo EUS as the first staging procedure. Whereas patients with anterior, superior, or paratracheal lymphadenopathy may benefit from EBUS as the first staging test [8].

EBUS is performed through a bronchoscope and is used to visualize structures within the airways and lungs, including mediastinal and hilar lymph nodes. EBUS is primarily used for the diagnosis and staging of lung cancer, as well as for the evaluation of mediastinal lymphadenopathy. On the other hand, EUS is performed through an endoscope and is used to visualize structures within the gastrointestinal tract and adjacent organs, including the pancreas, liver, and lymph nodes. EUS is primarily used for the evaluation of gastrointestinal and pancreatic diseases, as well as for the diagnosis and staging of pancreatic cancer. While both EBUS and EUS use ultrasound imaging to visualize structures within the body, they have different areas of focus and applications. EBUS is more focused on the lungs and airways, while EUS is more focused on the gastrointestinal tract and adjacent organs. The choice of procedure depends on the specific clinical situation and the structures that need to be evaluated.

In general, EUS is most appropriate for evaluation of the posterior inferior mediastinum, whereas EBUS is better for the lymph nodes in the anterior superior mediastinum.

5.3 Medianstinoscopy

Mediastinoscopy is a surgical procedure that uses a mediastinoscope to examine the mediastinum— the space in the thoracic cavity between the lungs. In this procedure, the surgeon makes a horizontal cut 1 cm above the sternal notch to develop an anterior plane along the trachea. The surgeon then inserts the mediastinoscope and is able to sample and biopsy paratracheal and hilar lymph nodes. This procedure is useful for tissue sampling, mediastinal lymph node biopsy, and TNM staging. Mediastinoscopy has a high sensitivity (>80%) and specificity (100%) in the staging of lung cancer [9]. It can be classified into 2 different procedures: Cervical mediastinoscopy and Anterior mediastinotomy.

Cervical mediastinoscopy provides access to the pre-tracheal, paratracheal, and anterior subcarinal lymph nodes. However, it has limited access to the inferior and posterior mediastinum and the aortopulmonary window [8]. Anterior mediastinotomy is a procedure that allows for dissection of the aortopulmonary lymph nodes. Complications associated with this surgical procedure include pneumothorax, bleeding, nerve injury, and transient ischemia. The safety of the mediastinoscopy procedure versus EBUS are

Evaluation of sarcoidosis:	EBUS can be used to diagnose and evaluate the extent of sarcoidosis, a multisystem inflammatory disease that often involves the lungs and mediastinal lymph nodes.
Identification of tracheobronchial lesions:	EBUS can also be used to identify lesions or masses within the tracheobronchial tree, such as tumors or foreign bodies.
Treatment of obstructive lung diseases:	EBUS can be used therapeutically to relieve obstruction in the airways caused by conditions such as lung cancer, granulomas, or lymphoma.
Diagnosis and staging of lung cancer	Indications for EBUS include diagnosis and staging of lung cancer via sampling of central tumors, endobronchial specimen, mediastinal or hilar lymph nodes.
Distinguishing between benign and malignant lymph nodes	Etiologies of lymphadenopathy for which investigative efforts may be necessary include distinguishing between benign and malignant lymph nodes and guide biopsy for further testing. EBUS-TBNA is reported to have a sensitivity of 85–100%, a specificity of 100% and an accuracy of over 96% in distinguishing benign from malignant mediastinal lymph nodes in patients with lung cancer [8].

Table 2.
Indications for EBUS.

comparable with a mean cost of EBUS that is less costly ($P < 0.001$) and an associated lower risk of complications when performed as isolated procedures (Verdial et al).

5.4 Video-assisted thoracoscopic surgery (VATS)

VATS is described as a "keyhole' surgery in which 3 small incisions are made to perform the procedure. A 10 mm incision is made posteriorly to allow for the insertion of instruments, an additional 10 mm incision is made to allow the video thoracoscope to look inside of the thorax, and lastly a 3–4 cm incision is made to pull out the resected lobe [6].

VATS can only examine one side of the mediastinum at a time, because one of the patient's lungs often needs to be collapsed after general anesthesia. When the left mediastinum is being studied, nodal stations 5 (subaortic) and 6 (para-aortic) can be accessed. When the right mediastinum is being studied, nodal stations 2 and 4 (upper and lower paratracheal), station 7 (subcarinal) and stations 8 and 9 (para-esophageal and pulmonary ligament) can be accessed (**Table 2**) [8].

6. Role of EBUS in noncancer

EBUS-TBNA has proven to be useful in the detection of diseases such as sarcoidosis and tuberculosis (TB) which are classified by the presence of granulomas in thoracic tissue on biopsy.

6.1 Sarcoidosis

Sarcoidosis is an autoimmune disease that affects multiple organs and occurs mainly in African-Americans between the ages of 20–40. The cause of the disease is unknown, however, it can be diagnosed by the identification of clinical symptoms and lung biopsy. Many cases are asymptomatic (30 and 60%) and are diagnosed incidentally on a chest radiograph. When symptoms present they may include red

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painful bumps on the skin (erythema nodosum), arthritis, parotid enlargement and respiratory symptoms. On biopsy, sarcoidosis is classified by the presence of noncaseating granulomas [10]. EBUS-TBNA has been shown to be useful particularly for the diagnosis of stage I/II sarcoidosis in which the granulomas have spread to the lymph nodes resulting in hilar lymphadenopathy. The diagnostic yield of EBUS-TBNA for sarcoidosis ranges from 54 to 93%, which is higher than conventional transbronchial lung biopsy (TBLB) but still inferior to surgical biopsy. In order to improve the diagnostic accuracy of EBUS-TBNA, it is recommended to pair it with the EBUS-guided intranodal forceps biopsy (IFB) (EBUS-IFB) technique when sampling for tissue. This technique allows for a larger quantity of tissue collection that will contain larger amounts of DNA that is needed for extensive testing for suspected sarcoidosis.

The steps for the pairing of the procedures begin first with the puncture of an airway with a needle as part of the EBUS-TBNA procedure. Next, as part of the EBUS-IFB procedure, the miniforceps are inserted through the puncture site (with sonographic guidance) into the target lymph node to obtain biopsy samples [11]. The reported complication rates of this combined approach are higher than with EBUS-TBNA alone, but lower than with transbronchial or surgical biopsies.

6.2 Tuberculosis

Tuberculosis (TB) is an infection of the lungs caused by *Mycobacterium tuberculosis*. It is characterized by clinical symptoms such as blood-tinged sputum as well as caseating granulomas on biopsy. TB can also cause Benign mediastinal and hilar adenopathy. In a groundbreaking study conducted by Gupta et al., researchers reported that EBUS-TBNA has a high sensitivity (94%) and diagnostic accuracy (53%) in diagnosing TB [12]. The results of this study demonstrated EBUS-TBNA to be an effective and safe diagnostic procedure in patients with intrathoracic tuberculosis lymphadenitis (TBLA). Specific features on endobronchial ultrasound images that indicate tuberculosis lymphadenitis include heterogeneous echogenicity or coagulation necrosis of the lymph nodes. Differentiating tuberculosis from sarcoidosis during EBUS-TBNA is important due different treatment modalities and precautions surrounding tuberculosis [13].

6.3 Rapid on-site evaluation (ROSE) role

With the continued use of EBUS in the performance of lung biopsies for a large array of cancers and diseases, it is important to receive confirmation that the correct tissue sample is being biopsied. This can be accomplished with Rapid On-Site Evaluation (ROSE) to ensure sample adequacy and support a suspected diagnosis [14]. (ROSE) is a technique in which aspiration cytology samples are rapidly stained and screened for diagnostic material during the procedure. To make smears, the material from the needle is transferred onto a glass slide and smeared with a second slide to produce two direct smears (mirror slides). One smear is air-dried and stained immediately with a rapid Diff-Quik [DQ] stain and then evaluated on-site by the cytopathologist, and the second smear slide is fixed immediately in 95% alcohol for permanent cytologic examination using Papanicolaou stain. Inadequate results are samples that are reported as non-diagnostic, blood only, no tissue material, no nodal tissue, or scant tissue sampling [15].

The confirmation of a suspected diagnosis with ROSE provides guidance for subsequent samples and can result in reduced sampling, TBNA passes, and/or endobronchial biopsies. ROSE also reduces procedure time, exposure to anesthetic agents, and related complications that may occur due to the prolongation of the procedure [14]. These benefits can be seen across all indications for EBUS-TBNA, including sarcoidosis.

6.4 Possible complications

EBUS-TBNA is considered to be a safe procedure, with a reported incidence of 0.5% for infectious complications [16] and 0.05% risk for major complications in systematic reviews [8]. The risk of infection is very rare but increases dramatically in cases with target lesions of necrosis seen on chest CT. Necrosis typically occurs due to injuries, infection, or ischemia, and this provides an environment for decreased bacterial clearance leading to an increased risk of infection. The risk of infection also increases when EBUS-TBNA is combined with EUS-B-FNA. Oral and esophageal bacteria can be transported into the mediastinum during the passing of the needle in EUS-B-FNA [16]. Major complications of EBUS-TBNA include pneumothorax and respiratory failure requiring ventilation [8]. Recently additional complications related to needle breakage during the EBUS-TBNA procedure have been reported [17]. Needle breakage is rare; however, inhaling or swallowing a broken needle tip has the potential to cause serious complications to the patient.

6.5 Hybrid procedures

The outlook of EBUS as a less invasive diagnostic modality looks bright as it is expected to become an even more essential tool in the diagnosis and treatment of lung cancer and other lung diseases as it is combined with additional technologies such as navigational platforms and robotics. The development of newer and more advanced EBUS technologies, such as radial EBUS and virtual bronchoscopy, will allow for improved visualization of the lungs and adequate lymph node yield, leading to more accurate diagnoses and better treatment outcomes for lung cancer and other lung diseases.

6.6 Electromagnetic navigational bronchoscopy (ENB)

Electromagnetic navigational bronchoscopy (ENB) is a minimally invasive procedure that uses advanced imaging technology and navigation systems to guide interventionalists, thoracic surgeons, and bronchoscopists through the airways of the lungs to specific locations identified on cross-sectional imaging where possible tumors exist [18]. This technology allows for the diagnosis and treatment of lung cancer and other lung diseases with greater accuracy and precision than traditional bronchoscopy methods and the ability to access nodules and masses up to near the edge of pleural using nearby small bronchi.

A disadvantage of this procedure is that it can only be performed after obtaining a dedicated CT scan. This additional factor increases the patient's exposure to radiation and cost of treatment for the scan and software when compared to CT-guided biopsy. However, there are fewer complications when compared to a CT-guided biopsy including a pneumothorax rate as low as 1% [18]. ENB is indicated in the evaluation of peripheral pulmonary diseases, however it can also be used for evaluation of mediastinal lymphadenopathy, and is superior to the conventional TBNA [18].

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7. Emerging bronchoscopy technologies

New and emerging technologies utilizing EBUS technologies are expected to further improve the accuracy and precision of the procedure as they are combined with 3D generated models utilizing virtual bronchoscopy from cross-sectional image rendering, fluorescence-guided bronchoscopy, and artificial intelligence.

7.1 Virtual bronchoscopy

As a new modality with great promise that is still evolving, virtual bronchoscopy is a technology that utilizes computed tomography (CT) images to create a 3D rendering model of the airways. This technology allows for the visualization of the airways in a way that is similar to traditional bronchoscopy, without the use of an actual bronchoscope as a non-invasive modality that can guide the utility of EBUS positioning to access distal samples.

7.2 Fluorescence-guided bronchoscopy

Fluorescence-guided bronchoscopy is a technology that utilizes fluorescent dyes to highlight abnormal tissue during the time of bronchoscopy. This modality allows for the detection of early-stage lung cancer and other lung diseases, and can improve the accuracy of biopsy and other diagnostic procedures. Combined with CT imaging and aided by EBUS tissue sampling detection of clinically occult neoplasms as well as symptomatic tumors are feasible [19].

7.3 Robotic bronchoscopy

Robotic bronchoscopy is a technological advancement that combines the precision and degrees of freedom of a robotic arm to control the steering of a bronchoscope. This technology allows for much greater flexibility and accuracy during bronchoscopy, and can improve the safety of the procedure for patients. Artificial intelligence (AI) is expected to play a major role in the diagnostic future of bronchoscopic modalities. AI-based systems can be used to analyze images and data from bronchoscopy procedures, helping to improve the accuracy of diagnosis and treatment [16].

7.4 Possible complications

EBUS-TBNA is considered to be a safe procedure, with a reported incidence of 0.5% for infectious complications [17] and 0.05% risk for major complications in systematic reviews [8]. The risk of infection is very rare but increases dramatically in cases with target lesions of necrosis seen on chest CT. Necrosis typically occurs due to injuries, infection, or ischemia, and this provides an environment for decreased bacterial clearance leading to an increased risk of infection. The risk of infection also increases when EBUS-TBNA is combined with EUS-B-FNA. Oral and esophageal bacteria can be transported into the mediastinum during the passing of the needle in EUS-B-FNA [17]. Major complications of EBUS-TBNA include pneumothorax and respiratory failure requiring ventilation [8]. Recently additional complications related to needle breakage during the EBUS-TBNA procedure have been reported [20]. Needle breakage is rare; however, inhaling or swallowing a broken needle tip has the potential to cause serious complications to the patient.

7.5 Unique case report

Unique case reports have described the use of vascular endobronchial ultrasound (VEBUS) in visualizing the location and characteristics of thromboembolic disease within the peripheral artery, such as chronic thromboembolic pulmonary hypertension (CTEPH). Characteristics identified on the convex probe EBUS include: thickening of the interlobar PA wall, an intraluminal fibrous web, and an intraluminal thrombus. The ability of EBUS to be able to visualize the location/ extent of disease is important for treatment outcomes for the patient. Limitations of VEBUS are due to the size of the EBUS probe which prevents the evaluation of vasculature beyond the branch point of the lobar PAs [18].

8. Conclusion

In conclusion, bronchoscopies are very important in the field of respiratory medicine. This procedure allows us to diagnose and treat a plethora of diseases, cancers, and conditions that may be life saving for the patient. The rigid bronchoscopy was the first technique used in the field and has become an important therapy for treating major hemorrhage. As medicine has continued to evolve, the use of the flexible has become very common and many use it for diagnostic purposes. The next major advance was the invention of the Endobronchial ultrasound (EBUS).

EBUS-TBNA is a widely used and accepted first diagnostic modality in the identification and pretreatment staging of lung cancer and other lung diseases. The concurrent use of ROSE in these procedures helps to increase accuracy and safety. As the indications for EBUS use continue to expand, EBUS is expected to play an even larger role in the diagnosis and treatment of lung cancer and diseases. The development of newer and more advanced EBUS technologies, such as radial EBUS and virtual bronchoscopy, will allow for improved visualization of the lungs and adequate lymph node yield, leading to more accurate diagnoses and better treatment outcomes. Additionally, EBUS is likely to become more widely available and accessible to patients, given the low-cost and with minimal risk of complications compared to other diagnostic and therapeutic procedures.

Furthermore, EBUS can be used for the diagnosis of other lung diseases as well, such as tuberculosis, sarcoidosis, and sarcoma, as the technology of both imaging and EBUS improves diagnostic yield is feasible at earlier disease states thus improving the chances of recovery.

The future of EBUS modalities combined with the additions of bronchoscopic advances is expected to further improve the accuracy and precision of the procedure while limiting morbidity, complications, and improved clinical workflow availability in the outpatient setting. These developments will help to improve patient outcomes, reduce recovery times, and make lung related diagnostics more accessible to patients around the world.

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