Chapter 12
Role of Interventional Pulmonology in Miscellaneous Conditions

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In this chapter, we discuss the emerging role and current status of interventional pulmonology techniques in management of several conditions that have traditionally required more invasive interventions. We first discuss the current role of bronchoscopy in diagnosis and management of broncholithiasis, bronchogenic cysts, and lung abscess. Finally, we discuss current role of bronchoscopy in diagnosis and management of central carcinoid tumors.

At the outset, it is important to point out that bronchoscopic procedures have not replaced thoracic surgery in majority of the entities covered herein. However, these techniques are providing a less invasive adjunct or alternative to more invasive procedures in a carefully selected group of patients with results that are nearly equivalent to the traditional treatments. It is important is to make sure that long-term outcome is not compromised in any way when bronchoscopic treatment modality is

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chosen over surgery. In fact, due to emergence of bronchoscopic treatments, a close collaboration between the bronchoscopist and the thoracic surgeon has become more critical than ever before.

Broncholithiasis

Broncholithiasis is an uncommon condition in which calcified peribronchial lymph nodes erode into the airway lumen [1]. The calcified material within the airways is called a broncholith. Intraluminal broncholiths and associated granulation tissue cause endobronchial obstruction and a variety of clinical symptoms. Calcified perihilar or mediastinal lymph nodes are nearly always found in patients diagnosed to have broncholithiasis. Some authors have included bronchial compression or distortion within the working definition of broncholithiasis [2]. However, an overwhelming majority of such calcified lymph nodes never cause any symptoms. Our discussion is limited to the cases in which a free or partially eroded broncholith is visible to the operator during bronchoscopy.

The majority of calcified mediastinal lymph nodes that cause broncholithiasis result from healed granulomatous infections. Histoplasmosis is the most common cause in the United States [3].

In the rest of the world including Europe, tuberculosis is the leading cause of broncholithiasis [4, 5].

Silicosis is the most common noninfectious cause of broncholithiasis [6]. Intraluminal calcified foreign body and endobronchial actinomycosis infection are also identified as causes of broncholiths in rare instances [7, 8].

Calcified lymph nodes compress and gradually erode adjacent bronchi due to their movement with respiratory activity and cardiac pulsations. Invariably, the presence of calcified material in endobronchial tree causes irritation and evokes chronic inflammatory changes. Granulation tissue is a universal finding on airway inspection. In some instances, granulomatous reaction is so pronounced that it becomes difficult to differentiate it from endobronchial malignancy. Bronchoscopic biopsies are needed to exclude malignancy in these cases. In some cases, broncholiths are entirely intrabronchial, loosely attached to the airway wall. In other cases, only a small part of calcified lymph node is present within the airway lumen. In these cases, the endobronchial component only represents the tip of the iceberg with the majority of calcified mass outside the airways. In many instances, broncholiths are firmly embedded or even entirely covered with the granulation tissue. Such broncholiths are easily missed on airway examination.

Many broncholiths are asymptomatic and are discovered as an incidental finding on chest computed tomography (CT) or bronchoscopy [9]. In symptomatic patients, chronic cough and hemoptysis are the most common symptoms. Hemoptysis is usually mild and intermittent, but broncholithiasis is known to cause massive and life-threatening airway bleeding in some patients. Endobronchial obstruction due to broncholith and granulation tissue causes atelectasis and recurrent pneumonia in

some patients. Focal bronchiectasis may also develop due to obstruction and repeated bronchial infections. Spontaneous expectoration of broncholiths, called lithoptysis, is an uncommon symptom, reported in 3 (16%) patients in a series of 19 cases [10]. Lithoptysis is often ignored and is rarely self-reported by patients unless directly inquired by physician [11].

Broncholithiasis is an important cause of right middle lobe syndrome (Fig. 12.1). Therefore, chest CT and bronchoscopy must be performed to exclude broncholithiasis in any patient with recurrent right middle lobe atelectasis. Other symptoms include dyspnea, chest pain, and wheezing. Since clinical presentation is rather nonspecific, the majority of patients remain undiagnosed for an extended period of time. It is not unusual for some patients to be treated for a mistaken diagnosis of difficult asthma for years before the correct underlying pathology is identified.

Chest radiographs may disclose calcified hilar or mediastinal lymph nodes in close proximity to the major airways. Chest CT is more sensitive than plain radiography for this purpose. A high-resolution chest CT is advised in every patient suspected to have broncholithiasis (Fig. 12.2). Administration of intravenous contrast is not needed. In one study, CT showed calcified lymph node in all 15 cases of broncholithiasis [12]. In ten patients proven to have intraluminal broncholiths on bronchoscopy in this study, the lymph nodes on CT appeared to erode the airways in six patients and appeared peribronchial in four patients. Atelectasis was detected in six patients, focal bronchiectasis in four patients, post-obstructive pneumonia in four patients, and air trapping in one patient. Broncholiths are more often seen on the right side.

Chest CT provides additional information that is helpful in treatment planning. Important findings in this context are presence of fistulous connections with surrounding mediastinal structures such as the esophagus and proximity of calcified lymph node to the pulmonary artery. It is important to determine whether the eroding lymph node is attached to the surrounding vessels or other mediastinal

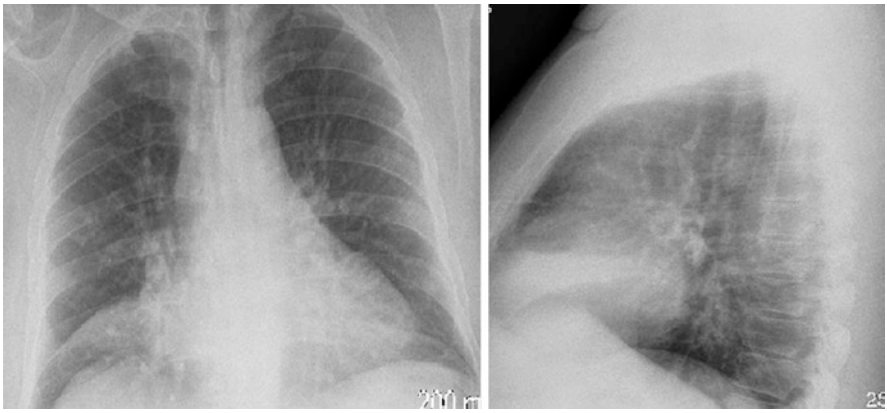

Fig. 12.1 PA and lateral chest radiographs showing right middle lobe atelectasis in a patient with recurrent episodes of cough, purulent sputum, and minor hemoptysis

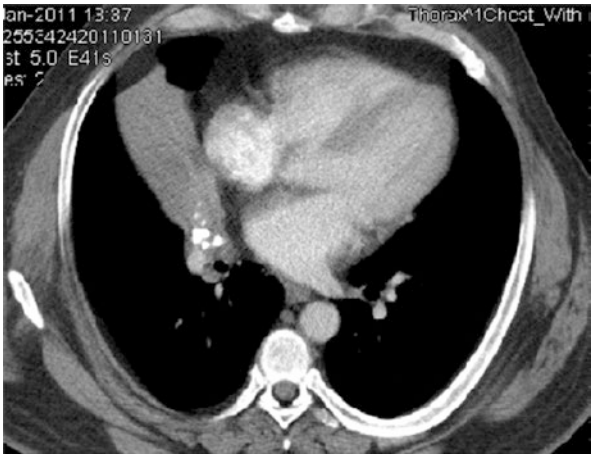

Fig. 12.2 Chest computed tomography in the same patient showed right middle lobe atelectasis and calcified material in right middle lobe bronchus

structures. Any attempts at bronchoscopic extraction of such broncholiths may lead to catastrophic airway bleeding or injury to the mediastinal structures. Worsening of broncho-esophageal fistula has been observed after extraction of broncholiths in one report [13].

Management

Broncholithiasis is rare and there are no clinical guidelines for management. The majority of practicing physicians have no firsthand experience in managing these cases. It may be worthwhile to consider an early referral to a tertiary care center. Bronchoscopy is the usual next step in patients suspected to have broncholithiasis on the basis of clinical and radiological findings in order to confirm the diagnosis. Early consultation with a thoracic surgeon is strongly recommended to determine the best long-term management strategy, which may involve extraction by rigid bronchoscopy or surgery.

Role of Bronchoscopy

Bronchoscopy has a key diagnostic role in patients with broncholithiasis. Bronchoscopy is more sensitive than CT in these patients. An important goal of bronchoscopy is to determine whether the entire broncholith is freely located within the airway lumen or whether only a part of calcified lymph node is eroding through the bronchial wall. Airways must be carefully examined for any suggestions of fistulous connection with the esophagus or other mediastinal structures.

Bronchoscopy in broncholithiasis is a difficult procedure. First, excessive coughing during the procedure is very common. Second, the correct diagnosis may not be possible because some broncholiths are fully covered with granulation tissue and surrounding inflammation (Fig. 12.3). The bronchoscopic findings closely mimic endobronchial tumor in many instances. Third, some patients with broncholithiasis have tendency to bleed excessively after endobronchial biopsies, which can be massive and life-threatening in some instances. A prior history of hemoptysis is thought to be associated with a greater risk of bleeding during bronchoscopy in these patients. Caution is warranted when excessive bleeding is observed with initial biopsies or minimal manipulation of the broncholith. It should alert the operator to a possibility of large volume airway bleeding with further attempts at bronchoscopic extraction of the broncholith.

Bronchoscopy has important therapeutic role in selected patients with broncholithiasis. In a retrospective review from Mayo Clinic, bronchoscopic extraction was attempted in 71 of 127 (56%) broncholiths [14]. Bronchoscopic removal was attempted in 46% (48 of 104) of partially eroding broncholiths and 100% (23 of 23) of loose broncholiths. Successful extraction was feasible in 48% (23 of 48) of partially eroding broncholiths and 100% (23 of 23) of loose broncholiths. Significant complications included severe dyspnea in one patient due to obstruction of the trachea with a large broncholith and massive airway bleeding in another patient requiring urgent surgical intervention.

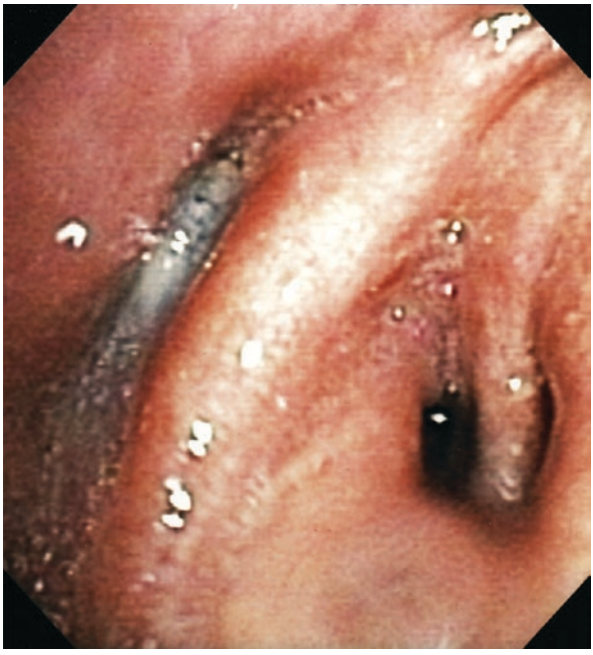

Fig. 12.3 Bronchoscopy in patient with broncholithiasis showing marked inflammation and swelling of opening of middle lobe bronchus. Broncholith was not visible but grating was felt when probed with biopsy forceps. Patient underwent right middle lobectomy with complete resolution of symptoms

In a more recent series, Cerfolio and associates performed rigid bronchoscopy in 34 patients with broncholiths [15]. All 29 mobile broncholiths were successfully retrieved via bronchoscopic route. Surgery was needed in three patients with fixed broncholiths and two patients with broncho-esophageal fistula. No procedure-related complications were encountered. Only three patients required additional bronchoscopic extraction over a median follow-up period of 4.2 years. A similar experience was reported in a Korean study in which flexible ($n = 2$) or rigid ($n = 13$) bronchoscopy was successful in removing all 15 intraluminal broncholiths. However, bronchoscopic removal failed in every case of mixed broncholith where the calcified lymph node was partly located within and partly outside the airway lumen [16]. These and several other short reports establish the feasibility and safety of removing mobile broncholiths with bronchoscopy [17, 18]. The main danger with bronchoscopic removal of broncholiths is major bleeding, but this is fortunately a rare occurrence. [19]

An important question when contemplating removal of broncholiths is whether to use a flexible or rigid bronchoscope. Several studies have established feasibility using a flexible bronchoscope for this purpose. A flexible bronchoscope is also used to retrieve distal broncholiths that are beyond the reach of a rigid bronchoscope. However, there can be little doubt about superior ability of a rigid bronchoscope in removing broncholiths compared to the flexible bronchoscopes. As expected, Olson and associates reported a 67% success with rigid scope compared to 30% success with flexible bronchoscope for complete extraction of broncholiths [14]. The same can be said about the usefulness of a rigid bronchoscope to control brisk airway bleeding that is sometimes encountered during bronchoscopic extraction of broncholiths. A rigid bronchoscope is also more effective than a flexible scope in extracting a large broncholith that is acutely obstructing the central airways. Due to these reasons, having rigid bronchoscopy readily available is a necessity rather than an option in this situation.

Some broncholiths are too large to be removed via bronchoscopic route. A majority of these patients require surgical treatment. In highly selected cases, Nd:YAG laser can be used to dislodge or break the broncholith into smaller fragments to facilitate bronchoscopic extraction. [20, 21]

Laser treatment has also been used to remove obstructing granulation tissue surrounding the broncholiths [22]. Restoration of the airway lumen with this approach is helpful in controlling post-obstructive pneumonia and distal atelectasis. A further application of Nd:YAG laser in these patients is in control of spontaneous or post-biopsy airway bleeding.

There are isolated reports of using cryotherapy for management of bronchiolithiasis [23, 24]. Granulation tissue is particularly suitable for removal using a cryorecanalization technique. Large broncholiths firmly attached to airways cannot be removed using this technique.

Surgery for Broncholithiasis

Surgery is needed in many patients with symptomatic broncholiths who are not suitable for bronchoscopic therapies. Indications for surgery are large broncholiths that cannot be removed via bronchoscope, suspected adhesions with the mediastinal structures, esophageal fistula, recurrent pneumonia and atelectasis, symptomatic focal bronchiectasis, and massive hemoptysis [18]. Surgery is also needed in some patients to exclude an underlying malignancy. Surgery can be technically challenging due to extensive mediastinal adhesions, but a successful operation provides lasting relief from symptoms [25].

Surgical options for broncholithiasis include bronchotomy and broncholithectomy with removal of calcified lymph nodes. Lung-sparing surgery, such as a segmentectomy, is recommended when feasible [26]. Lobectomy and rarely, pneumonectomy are needed in some cases [14, 27]. Incision and curettage without removing the outer shell may be the most suitable intervention if lymph nodes are firmly adhered to the mediastinal structures. Clearly, surgery is more invasive than bronchoscopic interventions, but sometimes it is the best option. Postoperative complications can include pneumonia, prolonged air leak, and bronchopleural fistula. Thus, the decision for the best approach should be made after a detailed multi-specialty evaluation.

Conclusions

Appropriate management of broncholithiasis is not easy. Asymptomatic broncholiths may be followed with interval symptom assessment and radiography. While bronchoscopy is successful in many carefully selected patients, an ill-advised attempt to remove broncholiths during bronchoscopy can lead to serious hemorrhage and poor patient outcome. Surgical treatment can also have challenges due to adhesions, fibrosis, and fistulae. Optimal results require a close collaboration between an interventional pulmonologist and thoracic surgeon from the outset.

Bronchogenic Cysts

Bronchogenic cysts are rare congenital disorders of the tracheobronchial tree. Cystic lesions constitute around 15–20% of all mediastinal disorders. Bronchogenic cysts account for 40–50% of all mediastinal cysts [28]. Overall, bronchogenic cysts account for about 5–10% of all mediastinal pathologies [29]. Appropriate diagnosis and treatment of this disorder requires experience and expertise of a multidisciplinary team consisting of a thoracic surgeon, pulmonologist, and thoracic radiologist.

Bronchogenic cysts arise from abnormal budding of primitive foregut [30]. Development of human lungs starts around the fourth week of gestation with formation of a diverticulum from the ventral wall of primitive foregut. The distal end of lung bud divides into two parts forming right and left mainstem bronchi for each lung. Abnormal separation of a part of lung bud during this process leads to formation of bronchogenic cysts [31].

The cysts are located along tracheobronchial tree when the separation of bud occurs in early gestation. Nearly 75% of bronchogenic cysts are found in the mediastinum, most commonly in subcarinal and paratracheal locations [32]. Delayed separation of the lung bud is associated with the remaining 25% of bronchogenic cysts that develop within the lung parenchyma. Indeed, bronchogenic cysts are known to develop anywhere along the developmental route of the primitive foregut. Unusual locations for bronchogenic cysts include the pericardium, diaphragm, abdomen, stomach, pancreas, and skin. Bronchogenic cysts in the lung parenchyma need to be differentiated from lung abscess, hydatid cyst, infected emphysematous bulla, traumatic cyst, and tuberculosis. The treatment of parenchymal bronchogenic cysts is surgical resection. There is no role of interventional bronchoscopy procedures in these patients. Such is not the case with bronchogenic cysts located in the mediastinum. Our subsequent discussion will mainly focus on patients with mediastinal bronchogenic cysts.

While a majority is unilocular, some bronchogenic cysts are multi-loculated. Histological examination reveals ciliated pseudostratified columnar epithelial lining, similar to normal human airways. The cyst wall contains variable amounts of hyaline cartilage, smooth muscles, elastic fibers, fibrous connective tissue, nerve trunks, and bronchial glands [33]. It is not unusual for the cyst wall to have fibrous attachments with surrounding structures such as the esophagus, trachea, pleura, and pericardium. The majority of mediastinal cysts have no direct connection with an airway lumen. Infection and attempts at needle aspiration may lead to development of communication between the bronchogenic cyst and the tracheobronchial tree. The gross appearance of fluid in bronchogenic cysts is highly variable. It may appear milky and gelatinous; green and mucoid; brown, white, and translucent; and yellow and pus-like and serous [34]. In some instances, the cyst fluid is described as milk of calcium. Cytology reveals nonhemorrhagic fluid with bronchial epithelial cells and mucus. There are no neutrophils, lymphocytes, acid-fast bacilli, or malignant cells in uncomplicated cysts.

The clinical presentation of bronchogenic cysts is highly variable. The majority of pediatric patients experience symptoms of cough, stridor, acute respiratory distress, and respiratory infection [35, 36]. Compression of mediastinal structures such as central airways, pulmonary arteries, and cardiac chambers is a major concern in these patients. In adults, 30–70% of bronchogenic cysts are asymptomatic, discovered as an incidental radiological finding in the second to fourth decade of life [37].

Nevertheless, a majority of asymptomatic patients managed conservatively can be expected to develop symptoms at a future date. For instance, in one series, 24 of 37 (65%) of adults with a bronchogenic cyst developed new symptoms while being

watched without any specific intervention [38]. Symptoms of bronchogenic cysts in adults are nonspecific and include chest pain, cough, dyspnea, dysphagia, and recurrent lung infections.

Complications of bronchogenic cysts among adult patients are reported in up to 25% of patients. These include central airway compression, superior vena cava syndrome, superimposed infection, airway fistula formation, and hemorrhage. Compression of mediastinal structures is more often seen in pediatric patients than in adults with bronchogenic cysts. The potential for future complications is the main argument for early surgical intervention in bronchogenic cysts in asymptomatic patients. An additional concern is malignant transformation of bronchogenic cysts [39, 40]. In an extensive review of literature, 5 of 683 (0.7%) of bronchogenic cysts were found to have malignant cells [41]. Though opinions may vary, such low risk of malignant transformation of bronchogenic cysts may not be clinically as important as previously thought [42].

Bronchogenic cysts are often detected as an incidental radiological finding [43, 44]. Chest radiographs may show round or oval densities in right paratracheal or subcarinal areas. However, plain radiographs have a low sensitivity and computed tomography is often needed for further evaluation. On CT, bronchogenic cysts are seen as circumscribed homogeneous masses with thin and smooth walls (Fig. 12.4a). The majority of mediastinal cysts are located in the middle mediastinum. Nearly one-half of these have a water density with CT attenuation values of 0–20 Hounsfield units [34]. Remaining cysts have a higher soft tissue attenuation values due to presence of mucus, protein, and calcium oxalate [45]. Superimposed infection and hemorrhage may also cause attenuation values as high as 120 Hounsfield units on CT in bronchogenic cysts. [46, 47]

Soft tissue density raises a concern for malignancy at the first sight. A contrast-enhanced chest CT is helpful in these patients. Soft tissue masses show inhomogeneous enhancement, whereas the uncomplicated bronchogenic cysts remain unchanged after administration of contrast agent. This is different for infected bronchogenic cysts that may demonstrate peripheral and sometimes inhomogeneous enhancement on post-contrast CT images. An air-fluid level in bronchogenic cysts indicates presence of infection or fistulous connection with the airway. Overall, a confident diagnosis of uncomplicated mediastinal cysts can be made with chest CT in up to two-thirds of all cases.

Magnetic resonance imaging (MRI) is also useful in patients suspected to have bronchogenic cysts. A marked increase in signal density similar to cerebrospinal fluid on T2-weighted images establishes the cystic nature of the lesion. Cysts containing serous fluid have a low density, and those with high protein fluid have a high signal density on T1-weighted images [48]. Gadolinium administration is not required. In one study, MRI correctly identified bronchogenic cysts in all nine patients previously thought of having solid or indeterminate lesions on CT imaging. This suggests that MRI may be superior to CT in assessment of bronchogenic cysts. However, for all practical purposes, CT remains the most widely used initial imaging modality in these patients.

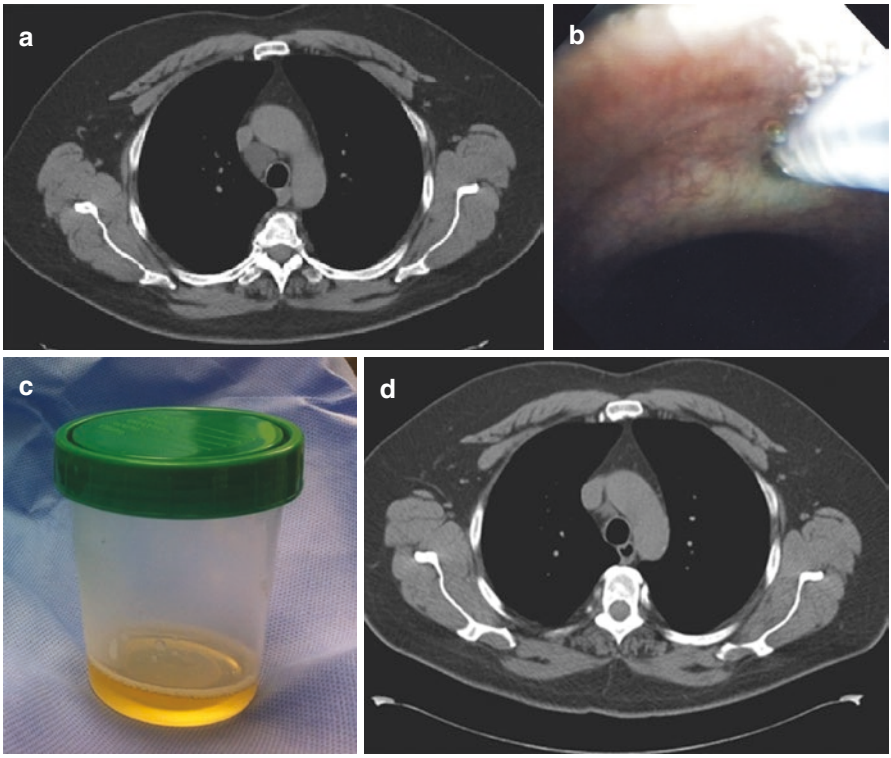

Fig. 12.4 (**a**–**d**): Chest CT (**a**) showing bronchogenic cyst in an asymptomatic patient. Patient initially declined surgery. He underwent a transbronchial needle aspiration (**b**) that yielded about 20 ml of straw-colored fluid (**c**). A repeat CT after the procedure showed a significant decrease in size of the cyst. After a few months, patient underwent successful surgery due to re-accumulation of fluid

A confident diagnosis on the basis of radiological findings cannot be made in every patient. In fact, in some series, a correct diagnosis on preoperative imaging was suspected in less than one-half of patients confirmed to have bronchogenic cysts after the surgery.

Management

Complete surgical removal is the most definitive therapy. There is limited role of bronchoscopic treatment in highly selected situations. Early consultation with a thoracic surgeon is strongly recommended.

Surgery for Bronchogenic Cysts

Complete surgical excision is recommended for all symptomatic bronchogenic cysts. Although there is some debate, most experts would also recommend surgical resection for asymptomatic bronchogenic cysts discovered incidentally. There are several arguments for recommending surgery in every case of bronchogenic cyst. These are (1) surgical exploration and excision of a cyst removes any doubts regarding accuracy of the underlying diagnosis; (2) most asymptomatic patients would develop symptoms and surgery would eliminate the future development of symptoms; (3) surgery is curative and eliminates any future risk of complications such as enlargement of the cyst, compression of mediastinal structures, infection, hemorrhage, and malignant transformation; and (4) surgery is easier and less complicated in asymptomatic patients than in symptomatic patients who have already developed a cyst-related complication such as infection, adhesions, and airway fistula [37, 38, 44, 49].

Thoracic surgeons approach mediastinal bronchogenic cysts located in paratracheal and subcarinal locations through either posterolateral thoracotomy or minimally invasively. Alternative approaches may be required for cysts located elsewhere in the mediastinum. The goal is to perform total enucleation of the cyst because delayed recurrence has been reported after incomplete excision. Stripping and removal of epithelial lining is an acceptable alternative when adhesions with the surrounding structures preclude total enucleation of the cyst.

Video-assisted thoracoscopic surgery (VATS) or robotic-assisted thoracic surgery (RATS) provides a less invasive approach to surgical removal of bronchogenic cysts and has become the preferred approach in many advanced medical centers [50, 51]. Complete excision was feasible in up to 95% of patients in some series. Conversion to formal thoracotomy is reported in a small proportion of patients [52]. The advantages of VATS or RATS approach are less postoperative pain, shorter hospital stay, lower complication rate, and better cosmetic results.

Role of Bronchoscopy

Bronchoscopic transbronchial aspiration is feasible for many mediastinal bronchogenic cysts [53, 54] (Fig. 12.4b–d). Successful aspiration can be achieved both with standard “blind” transbronchial needle aspiration (TBNA) and endobronchial ultrasound-guided transbronchial needle aspiration (EBUS-TBNA). One review on this subject identified 32 patients from 26 different studies who underwent TBNA procedure for bronchogenic cysts [55]. Nineteen of 32 patients were symptomatic at

presentation. Cyst was located in paratracheal location in 14 patients. Aspiration was performed with therapeutic intent in 19 patients and diagnostic or palliative purpose in the remaining patients. Thirty-one cysts were drained using either conventional TBNA ($n = 16$) or EBUS-TBNA ($n = 15$). Complications were reported in five (16.1%) patients. Infection of mediastinal cysts was encountered in two patients. No recurrence was reported during a median follow-up period of 14 months.

On its face value, transbronchial needle aspiration may look like an attractive treatment option for mediastinal bronchogenic cysts. The procedure is technically straightforward and can be accomplished without much difficulty under conscious sedation. However, it would be a grave mistake to consider bronchoscopic aspiration as an alternative to surgery for definitive management other than in cases in which there is a contraindication to surgery. Transbronchial aspiration is not curative. Re-accumulation of fluid has been reported in prior reports. There is no information on incidence of future recurrence after bronchoscopic aspiration because long-term follow-up studies are not available. Most importantly, there is potential for introduction of infection in the cyst and mediastinitis that can be life-threatening. [56–58] Some investigators recommend routine administration of antibiotics prior to aspiration of mediastinal cysts to prevent this complication [59]. However, the efficacy of prophylactic antibiotics for aspiration of bronchogenic cyst has not been studied. In this regard, it is also important to stress that a routine practice of aspirating a bronchogenic cyst prior to surgical intervention to "confirm diagnosis" is ill-advised, and there is nothing to be gained with this practice.

So, what could be the role of bronchoscopic TBNA in bronchogenic cysts? We can think of three situations in which bronchoscopic TBNA could be offered to these patients. First, a rapid decompression of cyst with TBNA may provide immediate relief in distressing symptoms due to airway or cardiac compression by a large or enlarging bronchogenic cyst [60–62]. Acting as a bridge, bronchoscopic TBNA may allow definitive surgery in a more controlled setting in these patients. Second, bronchoscopic TBNA can be used for draining an infected mediastinal bronchogenic cyst [63, 64]. Effective drainage and antimicrobial therapy may control sepsis and pave the way for future resection of the cyst. Finally, bronchoscopic TBNA can also be offered to symptomatic patients who decline or are medically unfit to undergo surgery. A case can also be made for management of recurrent bronchogenic cyst with bronchoscopic aspiration after an incomplete prior surgical excision [65]. At least, a short-term relief from symptoms can be expected with bronchoscopic aspiration in a majority of these patients.

We cannot emphasize enough that extreme caution is needed before choosing bronchoscopic treatment over surgery. A particularly difficult situation arises when an asymptomatic cyst is detected in a patient who declines surgery or cannot undergo surgery for medical reasons. Bronchoscopic drainage can be offered to these patients. However, our recommendation is to watch these patients with serial imaging for a few months and perform bronchoscopic drainage only if the cyst increases in size or the patient develops symptoms.

Conclusion

Surgical removal is recommended for the majority of patients with mediastinal bronchogenic cysts. Surgery is diagnostic and curative in these patients. In highly selected situations, a temporary relief in symptoms can be accomplished with bronchoscopic aspiration of the cyst. Although the bronchoscopic approach is technically simple, it cannot be considered a viable alternative to surgery due to the potential for introducing infection and lack of information on long-term outcome with this therapy.

Lung Abscess

Lung abscess is a result of destruction of the lung parenchyma that leads to development of cavities filled with pus or necrotic material [66]. Patients with lung abscess present with cough, fever, and purulent sputum. Radiological imaging reveals air-fluid level in a cavity surrounded by variable degree of consolidation (Fig. 12.5). The majority of lung abscesses are due to aspiration of oropharyngeal secretions into the lung. Important predisposing causes are altered mental status, chronic alcoholism, poor dental hygiene, uncontrolled diabetes, malnutrition, swallowing disorders, and immunocompromised state. Airway obstruction due to lung cancer is also an important cause of lung abscess. An inhaled foreign body may also cause endobronchial obstruction and lung abscess in certain situations. The majority of primary lung abscesses due to aspiration of oropharyngeal contents are polymicrobial in nature. Oral anaerobic organisms are most often implicated [67]. Other important

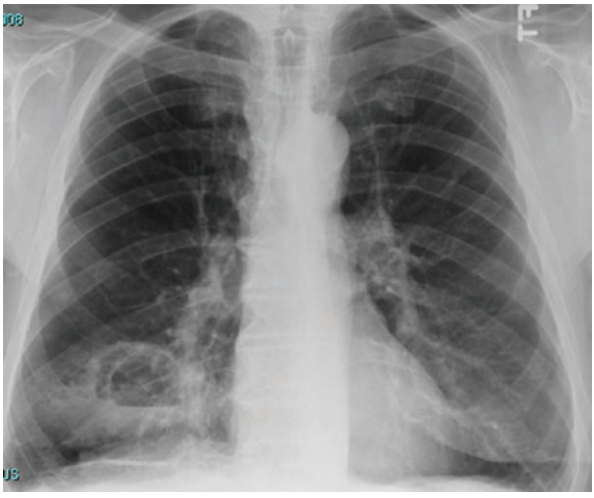

Fig. 12.5 Chest radiograph showing a lung abscess in a patient presenting with cough, fever, and purulent sputum. All abnormalities resolved with a 4-week treatment with amoxicillin-clavulanic acid

etiological agents include *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, group A streptococcus, enteric gram-negative rods, and *Streptococcus pneumoniae*. Mycobacterium tuberculosis, endemic fungal infections, and parasitic infections should also be considered in certain epidemiological settings.

Lung abscess is a serious infection [68]. A review of 184 lung abscess cases in 1983 showed an overall mortality of 25% [69]. More recent experience suggests an improvement in survival, but a mortality of 5–10% can be expected in patients with lung abscess [70].

Antimicrobial therapy, postural drainage, and nutritional support are the mainstays of lung abscess treatment. The majority of lung abscess patients show clinical and radiological improvement with appropriate antimicrobial agents and supportive care [65]. Subjective improvement and resolution of fever can be expected in 7–10 days. However, 10–20% of patients fail to show clinical response. Suboptimal clinical and radiological response with 2 weeks of appropriate medical therapy should prompt a review of management strategy. Resistant or unusual organism, ineffective cough reflex, immunocompromised state, and endobronchial obstruction are the leading causes of treatment failure and poor outcomes in such patients [71].

Antimicrobial therapy must be reviewed and altered if resistant organisms are suspected or isolated. Drainage of lung abscess and surgical resection are important considerations in patients who are not responding to the therapy [72–74]. Drainage of lung abscess can be accomplished via percutaneous or bronchoscopic routes. Failure of drainage procedure is an indication for surgical treatment. Choosing the most appropriate intervention is a complex clinical decision. A multidisciplinary discussion is very helpful in selecting the most effective therapeutic approach.

CT-Guided Drainage in Lung Abscess

An important reason of treatment failure is inability to expectorate purulent contents of abscess cavity due to endobronchial obstruction secondary to inflammatory edema. CT-guided percutaneous drainage can be useful in such patients.

Several case series have reported usefulness of CT-guided drainage of abscess cavity in patients with poor response to antibiotics. In one study, CT-guided catheters were placed in 19 lung abscess patients who had persistent sepsis despite appropriate antimicrobial therapy. Clinical and radiological response was observed in all patients. However, three patients still required surgery. The procedure was complicated by hemothorax in one patient [75]. In another study, 40 patients with failed response to antibiotics underwent a CT-guided drainage [76]. Lung abscess resolved completely in 33 (83%) patients. Remaining seven patients required surgical intervention. The procedure was complicated by pneumothorax in five (12.5%) patients.

In a literature review that included 21 studies, data from 124 lung abscess patients undergoing percutaneous drainage were examined [77]. Treatment success was defined by control of sepsis, avoidance of surgical therapy, and improvement in radiological findings. Overall, 104/124 (83.9%) of study subjects has a successful treatment outcome with percutaneous drainage. Complication rate was 16.1%. Pneumothorax was the most common complication. Other complications included bleeding, hemothorax, and empyema. The overall mortality in this series was 4%. This is lower than 14–18% mortality reported after surgical therapy [78]. However, the mortality comparison between percutaneous drainage and surgical treatment is not valid because surgery is performed in more complicated and sicker patients, often after percutaneous drainage has already failed to achieve the desired clinical outcome.

Percutaneous drainage also provides specimens for microbiological studies which are helpful in choosing appropriate antimicrobial therapy. Antimicrobial therapy was modified in 43% and 56% of patients who underwent a percutaneous drainage of lung abscess in two separate studies [79, 80].

Unfortunately, in the absence of any controlled trials, the indications and timing of percutaneous drainage of lung abscess remain poorly defined. Failure of clinical response with 2 weeks of antimicrobial therapy, persistence of worsening of sepsis, and size of abscess >4–8 cm are accepted indications for consideration of CT-guided drainage. Similarly, how long to continue percutaneous drainage is uncertain and needs to be determined on case-by-case basis. Percutaneous drainage can be accompanied by persistent broncho-cutaneous fistula, which can result in the need for a prolonged drainage tube or the need for surgical procedures such as a Clagett window. Therefore, consultation with a thoracic surgeon prior to percutaneous drainage may facilitate long-term success and potentially avoid complications. Successful outcome in multi-loculated and thick-walled cavities is less likely, and in the absence of prompt clinical response, a surgical referral is indicated in these patients.

Bronchoscopy in Lung Abscess

Bronchoscopy was frequently performed for drainage of lung abscess in pre-antibiotic era [81, 82]. However, with availability of effective antimicrobial agents, a routine bronchoscopy is no longer indicated in all cases of lung abscess. In fact, extreme caution is warranted during bronchoscopy due to risk of sudden flooding of airways with purulent material in patients with lung abscess [83]. Nonetheless, in carefully selected patients, bronchoscopy has important diagnostic role in management of lung abscess. Less often bronchoscopy may also be used for drainage of lung abscess, especially in cases where an obstruction is present.

Diagnostic Role of Bronchoscopy

Bronchoscopy is indicated in patients with lung abscess when endobronchial obstruction due to tumor or airway foreign body is suspected. In a series of 184 patients with lung abscess, 7.6% of patients had proximal obstructing tumor [69]. In some instances, bronchoscopy is needed for collecting specimens for microbiological studies. Mostly, this is needed when patients are not responding to antimicrobial therapy and there is suspicion for tuberculosis and fungal or parasitic infections. Bronchoscopy is also indicated in lung abscess patients with significant hemoptysis. We also advise bronchoscopy in any patient who is being considered for percutaneous drainage or surgical therapy for lung abscess.

The most common findings on bronchoscopy in lung abscess are inflammation, swelling, and edema of the segmental bronchus leading to the abscess cavity. Purulent material may be seen in endobronchial tree. Mucosal friability and some granulomatous changes may be observed. In some patients, differentiating these changes from submucosal and endobronchial spread of tumor may not be possible without biopsies and careful follow-up.

Therapeutic Role of Bronchoscopy

There are limited data on the role of bronchoscopic drainage of lung abscess. As such, the concept of bronchoscopic drainage of lung abscess is not new. Several short series and case reports in the 1970s established feasibility of bronchoscopic drainage of lung abscess [84, 85]. However, in the absence of controlled studies, the indication and timing of such intervention remains poorly defined. Still, in carefully selected patients, bronchoscopic drainage of lung abscess provides an effective and minimally invasive approach to drainage of lung abscess not responding to antibiotic therapy (Fig. 12.6a–f).

Several studies have established technical feasibility of bronchoscopic drainage of lung abscess. For example, Rowe and associates used brush forceps and angiographic catheters to drain ten patients with lung abscesses [86]. Rapid clinical response was observed in all patients. Multiple microbial agents were cultured from the pus drained from abscess cavity. The complete resolution of abscess was observed in seven patients on radiological imaging 3 months after the procedure. No procedure-related complications were encountered. Similarly, Jeong and associates performed bronchoscopic drainage of lung abscess in 11 patients who did not show expected clinical and radiological improvement with antimicrobial therapy [87]. The cavity sizes ranged from 4 to 15 cm. The investigators introduced a flexible polyethylene catheter into the abscess cavity and aspirated pus with a 30-cc syringe. Six patients had significant clinical and radiological improvement. In those who

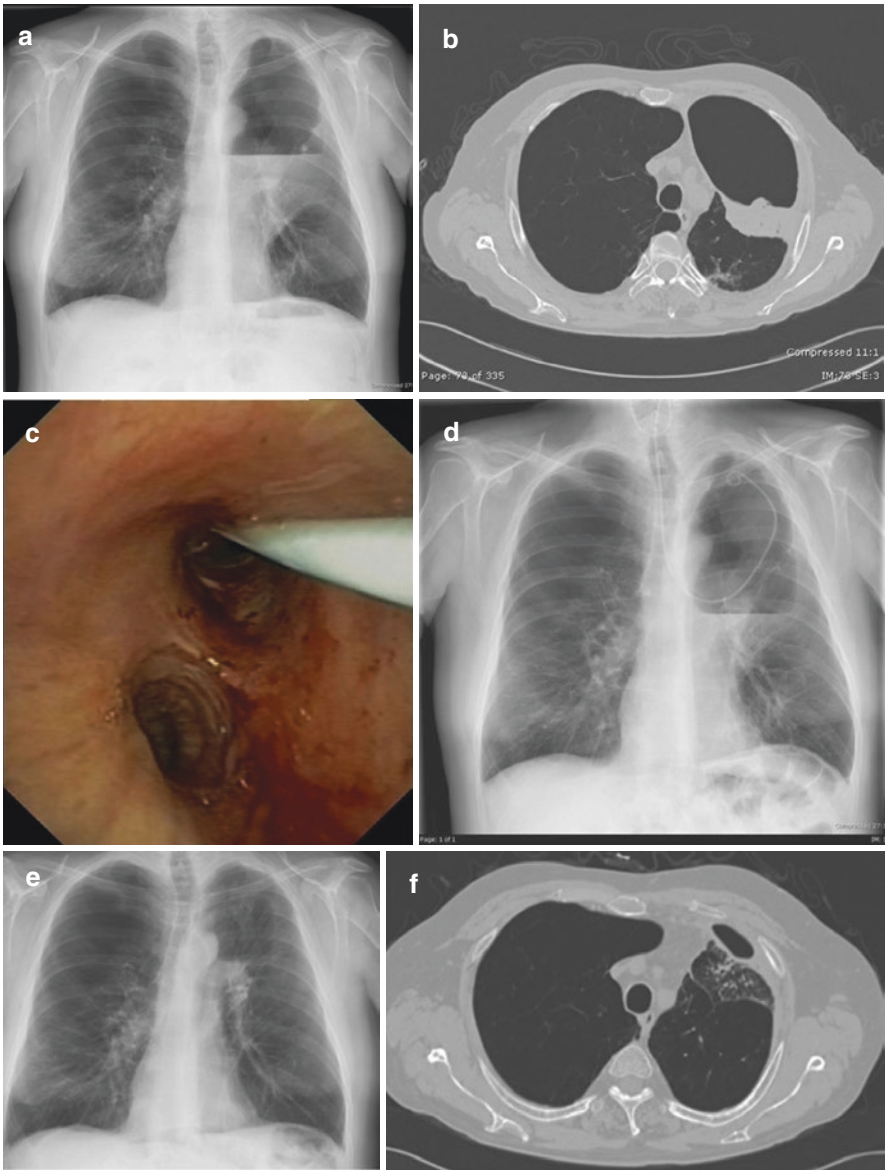

Fig. 12.6 Lung abscess in left upper lobe (after 6 weeks of antibiotic therapy) (**a**). Corresponding CT from the same patient (**b**). Bronchoscopic image of the pigtail catheter entering the left upper lobe (**c**). Chest radiograph showing the pigtail catheter within the abscess cavity (**d**). Chest radiograph (**e**) and CT (**f**) 6 weeks after bronchoscopic drainage. (Reprinted with permission from Herth [147])

responded, the abscess was larger than 8 cm, and air-fluid level was higher than 2/3 of abscess cavity. The amount of aspirate in these patients ranged from 20 to 110 ml. Useful diagnostic information was obtained in two additional patients. No complications were noted. In another report, Schmitt and associates described bronchoscopic placement of an intracavitary indwelling catheter prolonged irrigation and drainage of lung abscess in three patients [88]. The procedure was performed under fluoroscopic guidance. Resolution of infection was achieved in all three cases.

In the largest study on this subject, Herth and associates performed transbronchial drainage in 42 patients who were failing medical therapy for lung abscess [89]. The investigators placed pigtail catheters over guide wire into the cavity during bronchoscopy. The procedure was successful in 38 patients. The abscess cavity was flushed with gentamicin twice a day. All patients responded to therapy after a mean of 6.2 days. Two patients required transient mechanical ventilation. There were no other complications.

In a recent case series from Israel, 15 patients underwent 16 bronchoscopy procedures during which pigtail catheters were placed under fluoroscopy guidance [90]. An adequate drainage could be accomplished in 13 cases. The catheter was kept in the abscess cavity for a median of 4 days. Most patients responded clinically. One patient developed pneumothorax and empyema requiring chest tube drainage. Emergent surgery was needed in another patient who developed significant bleeding after the procedure.

There are isolated reports of using Nd:YAG laser to facilitate placement of catheter into abscess cavity. The experience is very limited and at present, this approach cannot be recommended due to potential risk of bleeding complications [91]. In one case report, argon plasma coagulation was applied to restore patency of airway that facilitated the bronchoscopic drainage of lung abscess [92]. Of great interest are recent reports of aspirating lung abscess using radial probe endobronchial ultrasound (R-EBUS) technology during bronchoscopy [93–96]. The technique is rather simple. After lung abscess is located with R-EBUS, the ultrasound probe is removed and the guide sheath is used to drain the pus from the abscess cavity. Microbiological analysis of drained material in these studies was found to be helpful in identification of causative organisms and choice of appropriate antimicrobial agents. All patients treated using this approach made full recovery without any procedure-related complications. In addition, the recent introduction of robotic bronchoscopy has facilitated the ability to place a scope into very distal airways under visualization, which has potential to allow for easier drainage and sampling. It remains to be seen if this is a practical application of the technology.

Based on review of current literature, it can be concluded that bronchoscopic drainage of lung abscess is technically feasible and clinically useful in many patients. The bronchoscopic approach is most suitable for patients who have a centrally located abscess with a bronchus leading to the abscess cavity. A decision to proceed with bronchoscopic drainage can be made after a multidisciplinary discussion in patients who are failing medical therapy.

Surgical Treatment of Lung Abscess

Surgery was the mainstay of lung abscess treatment before availability of antimicrobial agents [97]. In post-antibiotic era, surgery is needed in less than 10% of patients with lung abscess [69]. Surgery is most often performed when there is failure of both medical therapy and nonsurgical drainage procedures. Immediate surgery may be needed for patients with persistent bronchial obstruction due to lung cancer or embedded foreign body, major hemoptysis, and extension of infection to the pleural space [74]. Lobectomy is the most common surgery for lung abscess [98]. Some patients can be treated with segmentectomy. However, general medical condition, pulmonary reserves, and the very inflamed state of the thoracic cavity may not allow any form of resection in some patients. Cavernostomy can be considered in these patients. In this operation, the abscess cavity is opened and all purulent and infected material is removed. This is followed by immediate closures or marsupialization of cavity. In a cohort of lung abscess patients who required surgical intervention, 28 patients underwent surgical resection and 32 underwent surgical drainage (cavernostomy) [78]. The drainage procedure was performed in sicker patients who could not tolerate resection due to general medical condition. Drainage was also chosen over surgical resection due to technical reasons such as severe adhesions. The complication rate and mortality were 36.3% and 18.2%, respectively, in drainage group compared to 32.1% and 14.3%, respectively, in resection group.

When surgery is a consideration for suppurative lung disease, it is important to differentiate a lung abscess with a single large cavity filled with pus from necrotizing pneumonia and pulmonary gangrene. Lung abscess patients should have a trial of nonsurgical drainage if initial antibiotic therapy is not effective, as discussed above. A clinical and radiological response with this approach would obviate the need for surgery and over the next few weeks. Surgery should be considered when there is failure of clinical response to percutaneous or bronchoscopic drainage. Gangrene of the lung should be approached differently [99]. Radiological imaging in necrotizing pneumonia and pulmonary gangrene shows multiple abscesses within necrotic sloughing of the lung parenchyma [100, 101]. Clinical deterioration despite adequate antimicrobial therapy is a strong indication for surgical consultation in these patients [100]. CT-guided or bronchoscopic drainage has no role in such cases. Appropriate timing of surgery in these cases is a matter of clinical judgment, but it should be performed before development of septic shock or pleural extension of infection as much as possible [102, 103]. Emergent surgery including pneumonectomy has a lifesaving value in these patients [104].

Conclusions

Antimicrobial therapy remains the mainstay of treatment. However, 10–20% of patients who do not respond to the initial therapy require a drainage procedure. Percutaneous drainage is most often used initially, but recent experience has shown

bronchoscopic approach to be as effective but safer in properly selected patients. There is an emerging role of R-EBUS in this regard. Nonsurgical drainage of lung abscess using these techniques has potential to reduce the need for surgical interventions and to improve patient outcomes.

Bronchial Carcinoid

Carcinoid tumors are a low-grade malignancy of neuroendocrine origin [105]. Overall, carcinoid tumors account for 2–3% of all malignant tumors of the lung [106]. The majority of carcinoid tumors arise from large central airways. About 10–15% of carcinoid tumors are peripheral in location [107].

Small localized peripheral carcinoids are most often discovered as an incidental finding on radiological imaging in asymptomatic patients. On chest CT, these are seen as smooth or lobulated solitary nodules in the lung parenchyma with a significant enhancement after administration of intravenous contrast. Central carcinoid tumors account for the remaining 85–90% of cases. As opposed to peripheral carcinoids, the majority of patients with central carcinoid tumors are symptomatic with recurrent post-obstructive pneumonia, cough, hemoptysis, wheezing, or atelectasis [108, 109]. Symptoms of carcinoid syndrome such as flushing, diarrhea, sweating, palpitations, and dizziness are very uncommon, seen in <2–5% of patients [110]. CT imaging in central carcinoids shows endobronchial tumor with or without additional findings such as distal atelectasis, or localized hyperinflation. In many instances, the tumor has a dumbbell shape with the main part of the tumor in the lung parenchyma and a smaller component within the airway lumen.

Histologically, carcinoid tumors are classified into typical carcinoid and atypical carcinoid [111]. Typical carcinoid tumors have 0–1 mitosis/mm^2 without necrosis. Atypical carcinoids are pathologically defined by ≥2 mitosis/mm^2 with associated focal necrosis. Atypical carcinoid tumors demonstrate a more aggressive biological behavior with greater tendency of metastasis to regional lymph nodes and other distal locations. Typical carcinoids are more indolent and have lower incidence of distal metastatic disease. At the time of diagnosis, up to 20% of patients with atypical carcinoid tumors have evidence of distant metastasis as opposed to less than 5% of patients with typical bronchial carcinoids.

In a recent review of data on 4111 patients with biopsy-proven lymph node-negative typical carcinoid tumor of the lung, 5-year overall survival after lobectomy, sub-lobar resection, and no surgery was 93%, 94%, and 69% respectively. Corresponding disease-specific survival was 97%, 98%, and 88%, respectively [112]. It is important to note that the distinction between typical and atypical carcinoid is possible only in surgically removed tumors. A confident distinction may not be possible on small biopsy obtained with bronchoscopy, as discussed below.

Role of Bronchoscopy in Diagnosis

Peripheral carcinoid tumors are most often diagnosed on histological examination of surgical specimen. A CT-guided biopsy has provided diagnosis in a handful of cases. Bronchoscopy is not helpful in diagnosis of peripheral carcinoids.

In contrast, bronchoscopy is most often used for diagnosis of central carcinoid tumors (Fig. 12.7). Airway inspection reveals a pink to red smooth and glistening endobronchial tumor partially or totally occluding the airway lumen. Some tumors are only loosely attached to the airway wall. Tumors are typically located in mainstem, lobar, or segmental bronchi. Carcinoid tumors are highly vascular. There are reports of excessive bleeding spontaneously or after endobronchial biopsies from carcinoid tumors [113]. The risk of bleeding with bronchoscopic biopsies has varied widely in different studies. For instance, in a series of 23 patients, moderate to severe hemorrhage was observed in 6 (26%) of patients after bronchoscopic biopsies [114]. In another report, excessive bleeding was observed in 12 of 25 (48%) of patients with bronchial carcinoid after endobronchial biopsies. One patient required blood transfusion [115]. Due to this reason, there is some reluctance to perform endobronchial biopsies in suspected carcinoid tumors [116]. However, recent experience indicates that the bleeding risk may not be as great as previously thought. For example, in a recent study, moderate to severe bleeding was encountered in 2 of 35 (5.6%) of patients undergoing bronchoscopic biopsies for central carcinoid tumors [117]. No patient required blood transfusion or emergency thoracotomy for uncontrolled bleeding. The incidence of bleeding after biopsy in this study was very similar to 5.9% bleeding risk in 454 similar patients reported in medical literature [117]. Most experts now agree that bleeding risk should not preclude attempts to obtain tissue diagnosis from suspected carcinoid tumors during bronchoscopy [110]. Nevertheless, it is prudent to have equipment and expertise readily available to manage a large post-biopsy airway bleeding in these patients.

Diagnosis cannot be confirmed with bronchoscopy in every patient with bronchial carcinoid. Diagnostic yield of bronchoscopy has varied from 50 to 70% in different studies [118]. In one series, incorrect diagnosis was given on initial bronchoscopic biopsies in 50% of patients later proven to have carcinoid tumors on surgical specimens [119]. In some instances, carcinoid tumor is mistaken for a small cell lung cancer due to presence of crush artifacts. Ki-67 cell proliferation labeling index is helpful in differentiating small cell lung cancers from carcinoid tumors [120]. In small cell lung cancer, the Ki-67 index is >50%, whereas it is ≤20% in carcinoid tumors. Small size of biopsy specimens also precludes a pathological distinction between atypical and typical carcinoid tumors. Staining for Ki-67 is not helpful in this situation [121, 122]. It is particularly difficult to interpret biopsies from atypical carcinoid tumors. In one study, the majority of tumors identified to be atypical carcinoids after surgery were initially thought to be some other tumor on

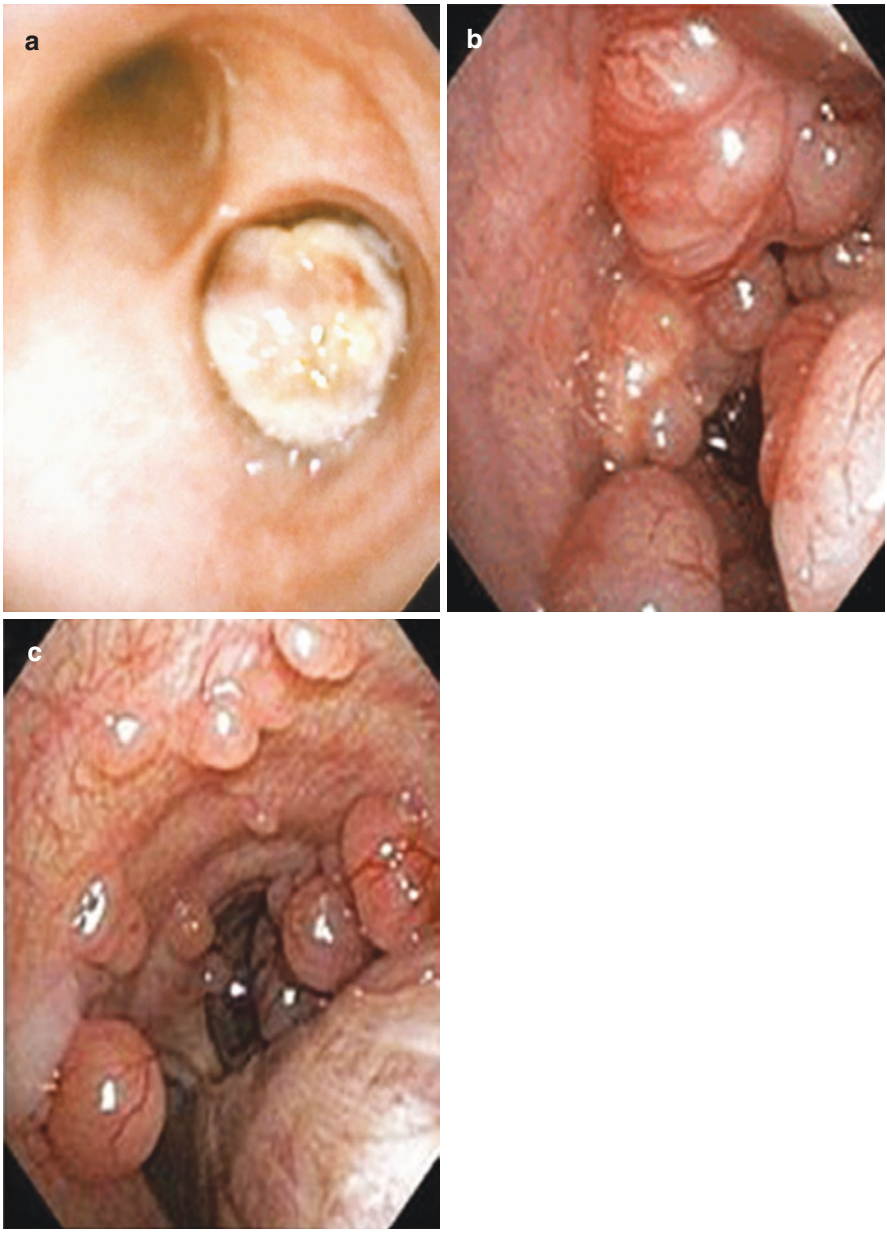

Fig. 12.7 Endobronchial carcinoid tumor completely blocking right main bronchus (**a**). Multiple atypical carcinoid tumorlets involving the trachea in another patient (**b**, **c**)

preoperative bronchoscopic biopsies [123]. There is interest in improving diagnostic yield of bronchoscopy using cryobiopsies in which the tissue specimen is larger than that obtained with usual forceps biopsies. In a small series, cryobiopsies provided diagnostic tissue in all five patients with bronchial carcinoids [124]. Excessive bleeding was not observed in any patient. The results from this study suggest a future role of cryobiopsies in bronchial carcinoids but more work is needed in this area. Clinical presentation in conjunction with a multidisciplinary discussion with a pulmonologist, thoracic surgeon, radiologist, and pathologist can facilitate treatment planning in cases where the diagnosis is unclear.

Treatment of Bronchial Carcinoid Tumors

Surgical resection is the current standard of treatment for localized bronchial carcinoid tumors. An important goal of surgery is to preserve as much lung parenchyma as feasible [119]. Systematic lymph node dissection or sampling is indicated to ensure appropriate staging and complete anatomic resection. Lymph node involvement is reported in up to 25% of patients with typical and 50% of patients with atypical bronchial carcinoids. Lobectomy and bi-lobectomy are the most common surgical procedures in many large case series [123, 125]. Pneumonectomy is performed in 3–10% of patients. Bronchial sleeve resection or a sleeve lobectomy to preserve the lung parenchyma is strongly preferred over pneumonectomy. A 5-year survival of >90% and a 10-year survival of >80–85% can be expected after surgery in patients with typical carcinoid tumors [116, 123, 126, 127]. Corresponding survival rates are 70% and 50%, respectively, for patient with atypical carcinoids. A multidisciplinary decision-making in diagnostic and therapeutic choices from the outset is associated with better patient outcomes.

Role of Therapeutic Bronchoscopy

There is interest in exploring interventional bronchoscopy procedures for definitive treatment of bronchial carcinoids strictly limited to endoluminal location without evidence of extra-luminal tumor, or mediastinal lymph node involvement. Several studies published over a span of more than two decades have explored this treatment option. Generally speaking, despite considerable progress in this area, bronchoscopic therapies have not replaced surgery for definitive therapy of bronchial carcinoids. There is little doubt that bronchoscopy has much to offer in symptom palliation in these patients. However, the idea of choosing interventional bronchoscopy over surgery as a stand-alone therapy in these patients has not gained widespread acceptance. In the following section, we examine the current literature on this subject.

In 1995, Sutedja and associates from the Netherlands used bronchoscopic therapies in 11 patients with intraluminal typical bronchial carcinoid tumors [128]. Six patients received Nd:YAG laser, one patient received Nd:YAG and photodynamic therapy, and four patients had mechanical debulking using rigid bronchoscope. Six patients who underwent surgical therapy after initial bronchoscopic therapies showed no residual tumor. Remaining five patients remained free of carcinoid over a median follow-up period of 47 months (range 27–246 months). Treatment-related bronchostenosis developed in one patient.

In a subsequent report, the same group highlighted the importance of high-resolution chest CT (HRCT) in selection of patients suitable for bronchoscopic therapies [129]. In this study, 18 patients underwent HRCT prior to bronchoscopic therapy. Nine of ten patients without evidence of peribronchial disease on CT remained free of tumor after bronchoscopic therapy. In five patients, HRCT showed peribronchial disease. Salvage surgery was needed in three of these patients after initial bronchoscopic therapy. HRCT findings were inconclusive in three patients. Absence of peribronchial invasion on HRCT was felt to be useful in selecting patients suitable for bronchoscopic therapy.

Cavaliere and associates reported treating 38 intraluminal carcinoid tumors without mediastinal lymph node enlargement with laser therapy [130]. Selection criteria in this study required tumor to be small (<4–5 cm^2), pedunculated or with implantation base <1.5 cm, and minimum or no infiltration of bronchial wall. Treatment was highly successful in 92% of patients over a median follow-up of 24 months.

In a study from the UK, 28 patients had mechanical removal of endobronchial carcinoid using a rigid bronchoscope [131]. An average of five treatment sessions was needed for complete eradication of the tumor. Patients were followed for a median of 8.8 years. One and 10-year disease-free survival was 100% and 94%, respectively. One patient had a recurrence 80 months after initial treatment and underwent a successful surgical resection. Significant hemorrhage was encountered in one patient but it could be controlled with local measures.

Bertoletti and associates used bronchoscopic cryotherapy to treat 11 patients with isolated endobronchial carcinoid tumors [132]. Both rigid and flexible bronchoscopes were used. Median follow-up period was 55 months. Only one patient had recurrence 7 years after initial therapy. No treatment-related complications such as bronchial stenosis were encountered. Several additional case series have reported similar experience with bronchoscopic therapy of bronchial carcinoids [133–136]. It is important to point out that initial bronchoscopic therapy does not seem to interfere with success of future resectional surgery in these patients.

Brokx and associates have recently reported an update on 112 patients with central carcinoids treated with bronchoscopic treatments [137]. Twenty nine (26%) of subjects had atypical carcinoid tumor. The minimal follow-up period was 5 years. Bronchoscopic treatment was curative in 42% of patients. Emergency pneumonectomy for uncontrolled bleeding was needed in one case. Five-year survival was 97%. Disease-specific 5-year survival was 100%. Overall and disease-specific 10-year survival was 80% and 97%, respectively. Recurrence on long-term

follow-up was encountered in 7.8% of patients initially treated with bronchoscopic treatment. Salvage surgery was not adversely affected by prior bronchoscopic treatment in these patients. In a related report, a tumor diameter of <1.5 cm and the tumor strictly located within the bronchial lumen on computed tomography predicted treatment success on multivariate analysis [138].

Advocates of bronchoscopic therapy have made many pleas to consider it as an initial treatment in selected patients with central bronchial carcinoids [139, 140]. However, many experts and practice guidelines in this area do not agree with their view and continue to recommend surgical treatment for every patient with bronchial carcinoid [108, 109]. Whether bronchoscopic therapy is non-inferior to surgery in at least some of these patients can only be settled with a prospective randomized trial with a long-term follow-up [141]. Such a trial is not a realistic possibility anytime soon. It is worthwhile to recall that a majority of data on surgical therapy for this disease also comes from retrospective case series.

The experience with bronchoscopic treatments accumulated for over more than two decades is difficult to ignore. At a minimum, these data provide enough justification to pursue bronchoscopic therapies in patients who have localized endobronchial carcinoid but cannot tolerate lung surgery due to limited pulmonary reserves or associated comorbidities. Patient preference must also be taken into account with shared decision-making. One might add the caveat that bronchoscopic therapy must only be offered by experienced interventional pulmonologists after a thorough planning, multidisciplinary discussions, thoracic surgery backup, and detailed informed consent. Serious complications are uncommon but an occasional patient has needed emergency thoracotomy to manage severe bleeding. We have reported a case of cardiac arrest due to carcinoid crisis and coronary spasm in one such patient undergoing laser bronchoscopy [142].

The role of bronchoscopic treatment as an adjunct to definitive surgery has also been explored. For example, in one study, nine patients underwent bronchoscopic resection followed by surgical therapy [143]. Removal of endobronchial obstruction led to clearing of distal pneumonia in five study patients. Bronchoscopic treatment was also felt to improve pre-surgical status and allowed a less extensive lung resection in these patients. Similar experience was recently reported in 25 patients with endobronchial carcinoids [144]. Initial endobronchial resection of tumor allowed successful bronchoplasty in all study patients without needing any lung resection. High success with two-stage surgery in this report suggests an interesting future role of bronchoscopy alongside surgical treatment for central carcinoid tumors.

There cannot be much disagreement that bronchoscopy has a role in palliative therapy of central airway obstruction due to inoperable central carcinoid. Many inoperable patients have undergone bronchoscopic treatment with good control of symptoms. Bronchoscopic therapies can also be useful for disease recurrence in patients who had prior surgical therapy [145, 146].

In our view, bronchoscopic therapy for bronchial carcinoids is an important component of overall treatment paradigm, and it should be considered an adjunct or alternative rather than a replacement for surgical resection.

Conclusions

Bronchial carcinoids are low-grade malignant tumors of neuroendocrine origin. At presentation, the majority of bronchial carcinoids are localized to central airways. Surgery is the current standard of care for eligible patients. Bronchoscopic treatments may be considered in carefully selected patients after appropriate multidisciplinary discussion and detailed planning. A careful long-term follow-up including serial bronchoscopies and chest CT must also be established if bronchoscopic therapy with curative intent is chosen. Bronchoscopy also has an important role in palliation of symptoms in advanced and inoperable disease.

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