34 Bronchoscopy and Interventional Pulmonology: Reflections on the Past, the Present, and the Future

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Introduction

The clinical application of bronchoscopy has been available for over a century [1]. In its infancy at the tail end of the nineteenth century, the technique was used on an infrequent basis. As it has matured over the years, bronchoscopy is now frequently utilized to diagnose and treat a vast range of pulmonary disorders. Significant advances in the instrumentation, techniques, and ever-increasing indications over the past century have established bronchoscopy as an essential tool not only in the practice of pulmonary medicine but also in critical care medicine, thoracic surgery, rhinolaryngology, and pediatric pulmonology. Currently, bronchoscopy is perhaps the most commonly employed minimally invasive diagnostic procedure in pulmonary diseases.

The ever-expanding indications and the specialized tools required to manage certain clinical conditions now require advanced training and practice before the clinical application can begin. Several of these techniques are inherently time consuming and call for well-developed skills beyond that required in standard or "routine" bronchoscopy procedures. To denote these aspects of bronchoscopy practice, the term "interventional pulmonology" is being used more frequently. This area encompasses not only bronchoscopy but also minimally invasive procedures to diagnose and treat the disorders of the pleural space and percutaneous tracheostomy. Some experts believe that esophageal ultrasound-guided needle aspiration of lymph nodes in lung cancer staging be considered under the term interventional pulmonology. In this chapter, the term bronchoscopy–interventional pulmonology (B-IP) will apply to procedures performed by the pulmonary specialists.

As the vast field of medicine and medical research continues to expand at a rapid pace, it is natural to wonder and contemplate what the distant future holds in the B-IP field. Before one embarks on this speculative endeavor, it is essential to trace back the origins of this field and acknowledge the remarkable contributions made by our predecessors and the trials and tribulations they encountered.

The Past

Interest in the Airways

The references to the study of the human airways and their diseases have been attributed from Hippocrates (460–370 BC) to subsequent generations of scientists through the successive centuries. Concerted efforts to study the human tracheobronchial tree based on scientific principles began in

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the early part of the nineteenth century. The inquisitiveness of medical practitioners to examine the internal cavities led to development of early instruments which were basically made of metallic tubular instruments. Subsequently, polished mirror plates were used to take advantage of the external sunlight for inspection.

In 1807, the German army surgeon Philipp Bozzini developed the *lichtleiter* or "light conductor," precursor of the endoscope for examination of bodily orifices [2]. Neither Bozzini's paper nor his inventions, the lichtleiter described as "the magic lantern in the human body," were taken seriously by his peers. During Bozzini's short life, others continued their work to visualize the larynx with the help of various lighting devices. Benjamin Guy Babington, a British physician, is credited by some for the invention, in 1828, of the "glottiscope," the precursor of the laryngoscope [3]. Manuel Garcia, a Spanish music teacher, singer, and vocal pedagogue, is also credited for being the first to perform laryngoscopy [4, 5]. The next subsequent developments in endoscopy did not appear for at least two decades following Bozzini's death in 1809 at the age of 36 years from typhus.

Advent of the Endoscope

In 1828, Horace Green demonstrated that the larynx could tolerate the presence of a foreign object without endangering the life of the patient [6]. Green became quite adept at catheterizing the larynx and trachea. He subsequently inserted a gum-elastic catheter through the larynx and into the lower bronchi. When Green presented his technique and results of his work at the Surgical Society of New York in 1847, the technique was condemned as "an anatomical impossibility and an unwarranted innovation in practical medicine." As a result, Green was subsequently expelled from the society [7]. Several decades later, Green's technique and clinical usefulness were universally approved. In 1867, Johnson used a laryngoscope to extract a penny coin impacted in the throat of a child [8].

Kirstein, Killian, and Jackson and Protégés

Alfred Kirstein of Germany is credited for the first direct visualization of the vocal cords in 1895, using a modified esophagoscope which he named the *autoscope* [9]. In 1897, Gustav Killian (1860–1921) of Freiburg used the Kirstein laryngoscope to examine the trachea and main stem bronchi of a hospital janitor [10]. In the same year, Killian used an esophagoscope to extract a bone from the right main stem bronchus of a 63-year-old farmer [11]. One year later, Killian extracted tracheobronchial foreign bodies in three patients and coined the word "directe bronkoscopie" to describe the procedure [12]. In 1898, Algernon Coolidge of Harvard Medical School used an open urethroscope, a head mirror, and reflected sunlight to remove a hard-rubber canula from the right main bronchus [1]. Subsequently, several clinicians took up the procedure and almost all procedures involved removal of aspirated foreign bodies [13–15]. As Gustav Killian was instrumental in introducing the technique, he is generally considered the father of bronchoscopy.

In the 1920s, Chevalier Jackson, a laryngologist from Philadelphia, made several modifications to the rigid bronchoscope. Because of his many innovations and contributions to the field of bronchoesophagology, he came to be known as the father of American bronchoesophagology. Jackson and his protégés popularized bronchoscopy and modified the rigid bronchoscope [1]. One of Jackson's students, the British laryngologist Victor Negus, modified one of Jackson's endoscopes, subsequently known as the "Negus bronchoscope." Chevalier Jackson and his son Chevalier Lawrence Jackson, also a laryngologist and better known as C. L. Jackson, wrote several books on bronchoscopy and esophagoscopy [16]. C. L. Jackson further popularized bronchoesophagology by founding the Pan American Association of Otolaryngology and the International Bronchoesophagological Society.

For the next five decades, the rigid bronchoscope and the esophagoscope and their many modifications reigned supreme in the exploration of the airways and the esophagus. Over the years, several newer developments were incorporated into the rigid bronchoscope. In 1904, Chevalier Jackson had introduced a bronchoscope with a small light at the distal end. Edwin Boyles, another Jackson protégé, developed the optical telescope with forward and angle viewing which permitted inspections of the upper as well as lower lobes of the lung. Paul H. Holinger introduced bronchoscopic photography to document the visual findings [17]. Other developments included instruments for pediatric patients, better lighting and illumination techniques, photographic documentation, and improved anesthetic drugs. The rigid bronchoscopy practice quickly spread to other countries including Japan.

Among the main indications for bronchoscopy, airway foreign body topped the list [16]. The bronchoscope was primarily used as a therapeutic instrument to remove airway foreign bodies, treat atelectasis, drain post-tonsillectomy pulmonary suppuration, and treat bronchitis, asthma, and pneumonia. The Mayo Clinic records indicate that in 1943, of the 436 rigid bronchoscopes performed, the main indication was the foreign body [18]. In 1965, Howard Andersen of the Mayo Clinic employed the rigid bronchoscope and a biopsy forceps to obtain lung parenchymal samples in patients with diffuse lung disease [19]. Andersen termed this technique "transbronchoscopic lung biopsy." A report of 450 cases in 1972 documented the safety of transbronchoscopic lung biopsy using the rigid bronchoscope [20]. However, these advancements in technology could not address the rigid bronchoscope's difficulty in the visualization of the upper lobe bronchi.

Fiberoptics and Shigeto Ikeda

The ability to convert the light rays from their natural predisposition to travel in straight lines to bend them with the fiberoptic technology had its origins in the early 1800s. The physical properties of glass fibers were first described by John Tyndall in 1872. The rod and lens fiberoptic lighting technique was adopted as cold light source for the rigid bronchoscopes in 1963 [21, 22]. Further refinements by countless investigators eventually culminated in the development of a clinically useable fiberoptic system. In 1957, Basil Hirschowitz at the University of Michigan presented the first gastrofiberscope at the Gastroscopic Society of America [23, 24].

Shigeto Ikeda of Tokyo, Japan, was responsible for developing and introducing the flexible fiberoptic bronchoscope into clinical practice in 1968 [25, 26]. In 1970, the first Olympus model became commercially available. Ikeda traveled widely and disseminated the technique and popularized it. As a result, the flexible fiberoptic bronchoscope moved rapidly into clinical practice and revolutionized the practice of pulmonology. The ability to reach and visualize the distal bronchial tree in all segments of all lobes permitted the diagnosis of endobronchial lesions and other abnormalities. Ancillary instruments that could be introduced into the working channel enabled the bronchoscopist to obtain brushings and biopsies of not only the endobronchial lesions but also the lung parenchyma. Simultaneous use of real-time fluoroscopy made it possible to more precisely direct the instruments to the lesion in question. Special cameras to capture both still and video images were developed to complement the system. Within a brief period after its introduction into clinical practice, the flexible bronchoscope became an important aspect of pulmonary practice.

Professor Ikeda continued his work to develop newer techniques and instruments. His work eventually led to the development of the flexible video bronchoscope in the late 1980s. The main difference between the fiberoptic bronchoscope and the video bronchoscope is the mode of capture and transmission of the bronchoscopic images. With fiberoptic system, the images are directly carried by the fiberoptic bundles through the bronchoscope to the objective lens and then viewed by the examiner. The video bronchoscope uses a charge-coupled device (CCD) to capture the digital images which are transmitted to a processor and then projected on to a larger video screen. This has resulted in our ability to capture still and video images with far greater resolution for documentation and educational purposes. Smaller-diameter bronchoscopes are available to examine pediatric patients with respiratory disorder. Further refinements in the ancillary instruments have improved specimen collection from the respiratory tract. At present, over 95% of all bronchoscopies are performed with the flexible bronchoscope. Ikeda who introduced the flexible bronchoscope continued to work on improvements in and modifications to the flexible bronchoscope until his death on December 25, 2001 [27]. His legacy continues, carried on by a countless number of bronchoscopists from around the world who benefited from his invention in the management of thousands of patients with respiratory disorders.

Revival of the Rigid Bronchoscope and Dumon

The continued improvements in flexible bronchoscopy and associated equipment vastly increased the indications for bronchoscopy. As the popularity of the flexible bronchoscope grew, it became universally accepted as the instrument of choice for airway diagnostics. Nevertheless, thoracic surgeons and laryngologists continued to use the rigid bronchoscope for procedures involving the major airways and for the extraction of airway foreign bodies. Several pulmonologists continued to use the standard rigid bronchoscope for traditional indications such as extraction of airway foreign bodies and dilatation of major airway stenosis. Jean Francois Dumon of Marseilles foresaw the need for better rigid bronchoscopes and associated ancillary equipment for the treatment of airway lesions such as obstructing tumors and benign stenosis of trachea and main bronchi. Dumon developed and modified many aspects of the rigid bronchoscope and peripheral equipment. In 1981, Dumon and colleagues reported on the use of YAG laser to treat tracheal lesions [28, 29]. Over the next decade, Dumon developed a newer type of rigid bronchoscope and stent insertion instrument [30]. Many specialists in B-IP became interested in the rigid bronchoscopy technique and its application in clinical medicine. As a result, the rigid bronchoscope regained its importance in the treatment of major airway lesions. A variety of silicone and metal stents have been developed to relieve airway stenosis from benign as well as malignant processes.

The Present

As the past innovations and applications of bronchoscopic techniques have gradually and imperceptibly melded into the present, the current practice wisely utilizes all clinically available and applicable techniques from the past and present to manage a variety of respiratory disorders. This view is reflected by the leading specialists in their excellent rendition of the current status of B-IP in the preceding chapters of this volume. Therefore, this part of this chapter will not dwell on the technical and other details and the nuances of the current practice. However, a few brief summarizing paragraphs might be in order to summarize the current status.

Diagnostic Procedures

In the realm of diagnostic bronchoscopy, the standard indication, namely, the visualization of the airways for suspected and unexpected abnormalities, remains among the main indications for bronchoscopy. Collection of bronchial secretions, washings, and bronchoalveolar lavage for cytologic analysis and culture of pathogenic organisms continues to maintain its importance, especially in immunocompromised patients with pulmonary abnormalities. The standard procedures used are well described in the preceding pages. To summarize, these include visualization and documentation, collection of bronchial secretions, and bronchoalveolar lavage for cultures, cytology, quantitation of cells and cell types, quantitation of hemosiderin- or lipid-laden macrophages, and brushing and biopsy of endobronchial as well as pulmonary parenchymal lesions, bronchoscopic ultrasound-guided needle aspiration of thoracic lymph nodes and masses, electromagnetic navigation to obtain tissue from nodular parenchymal lesions, and many other miscellaneous indications.

Therapeutic Bronchoscopy

Therapeutic bronchoscopy plays a major role in the critically ill patients with respiratory manifestations. The primary indication is the retention of airway secretions, mucous plugs, blood, or blood clots. The flexible bronchoscope is very capable of clearing airways of these obstructing materials. The bronchoscope is now an essential part of the equipment in the intensive and critical care units. Other well-known therapeutic indications for bronchoscopy include airway foreign bodies. The availability of small-diameter bronchoscopes has permitted flexible bronchoscopic extraction of foreign bodies from the pediatric airways. Uncommon indications include treatment of airway fistulae, drainage of lung abscess and cysts, etc.

Bronchoscopy in Lung Cancer

A major role for the bronchoscope is in the diagnosis and treatment of lung cancer. As described in the preceding chapters, fluorescence bronchoscopy is used from time to time in patients suspected of having cancer of the airway mucosa. This technique permits localization of the lesion to obtain biopsies and in the follow-up of patients with persistent cellular atypia or other suspicious cytologic abnormalities. Optical coherence tomography is another technique used for detailed analysis of epithelial surface abnormalities in the airways. Narrow band imaging is yet another method to analyze abnormal mucosal surface. More recent encouraging developments in the diagnosis and treatment of lung cancer are the techniques available to isolate the molecular genetic variations among different histologic types of lung cancers. This advance has led to the development of newer chemotherapeutic agents targeted to treat specific types of lung cancer.

Bronchoscopic ultrasound-guided sampling of abnormal mediastinal and hilar lymph nodes now allows proper staging of lung cancer. The ability to stage lung cancer with the help of the flexible bronchoscope has significantly obviated the need for mediastinoscopy and video-assisted thoracoscopic surgery for staging purposes. It is essential to note that the role of computed tomography and positron emission tomography is important in guiding the bronchoscopist to the abnormal or suspicious areas for biopsy.

Fluoroscopy-guided bronchoscopic brushing and biopsy of peripheral nodular lesions has been in use since the advent of the flexible bronchoscope. During the past decade, electromagnetic navigation technique to localize and biopsy peripheral lung lesions has been used in a limited number of medical centers. Another technique is the virtual bronchoscopic navigational bronchoscopy. This system uses the CT-developed virtual images of the airways to guide the biopsy forceps to the peripheral lesion.

Bronchoscopy techniques offer an important role in the treatment of patients with primary and metastatic malignancies. Many patients with an endobronchial component of the neoplasm present with hemoptysis, increasing dyspnea caused by luminal obstruction, post-obstructive atelectasis with pneumonia, and extrinsic compression of the airway lumen. Control of hemoptysis from a visible bleeding source in the airway lumen can be treated with simple aspiration of blood and repeated iced-saline irrigation. Other methods to stop the hemorrhage include bronchoscopic cauterization of the bleeding point, argon plasma coagulation (APC), cryotherapy, and laser coagulation [31]. Luminal obstruction is more likely to cause dyspnea and respiratory distress if the tumor involves the trachea or the main bronchi. In such situations, the techniques mentioned above can remove the obstruction and improve luminal air flow. Mechanical debridement is also an option.

Patients with respiratory symptoms caused by airway obstruction from the endobronchial component of the cancer can be relieved of the dyspnea with the bronchoscopic use of a variety of techniques. In the early 1980s, Jean Francois Dumon of

Marseille, France, showed that bronchoscopic laser ablation of airway lesions can successfully relieve dyspnea as well as significant endobronchial hemorrhage. Subsequently, Dumon developed silicone stents for insertion in the airways to maintain a patent lumen after laser resection of the lesion [30]. To facilitate the laser resection and placement of airway stents, Dumon modified the rigid bronchoscope and developed a series of rigid bronchoscopes and ancillary instruments.

In addition to the techniques mentioned above, other techniques used include mechanical debridement, balloon dilatation, brachytherapy, and photodynamic therapy [32–35]. An overwhelming majority of these procedures are used for palliative purposes in patients with advanced or inoperable airway malignancies. The success of these procedures depends on the expertise of the operator, equipment available, and their optimal use.

Interventional Pulmonology

What is "interventional pulmonology?" My *PubMed* review of the medical journals and periodicals published in English language revealed that the term was first used in 1997 by Witt and colleagues [36]. It is unclear if the term was used in books published at an earlier date. Initially, interventional pulmonology referred to all aspects of bronchoscopy, especially the more invasive procedures such as rigid bronchoscopy, laser resections, airway dilatational procedures, and stent insertion. Currently, all these and any pleural procedure performed by a nonsurgeon and percutaneous tracheostomy are included under the term interventional pulmonology.

Currently, involvement of the interventional pulmonologists has increased in the management of pleural disorders. Thoracentesis; pleural biopsy; placement of indwelling tunneled pleural catheters to treat recurrent benign and malignant pleural effusion, chylothorax, pneumothorax, and trapped lung; pleuroscopy; and pleurodesis are among the procedures being performed [37–39]. The term "medical thoracoscopy" has been used to describe thoracoscopy performed by nonsurgeons and without subjecting the patient to tracheal intubation and general anesthesia [40–42]. Another procedure included in the interventional pulmonology is the percutaneous tracheostomy in patients who are expected to require prolonged mechanical ventilation. The current trend indicates that an increasing number of interventional pulmonologists will be performing these procedures.

Bronchoscopic lung volume reduction to treat emphysema has undergone multiple trials and is currently being used in many European countries [43–45]. The current status of this technique is such that further work and innovations are required to convince the majority of pulmonologists to consider this in suitable patients. Several chapters in this volume describe the various techniques available and the details of the indications, technique, and the results of clinical studies.

Bronchoscopic thermoplasty is a technique developed to treat patients with refractory asthma [46–48]. While it is approved for clinical use in the USA, the technique has not been universally accepted by asthma specialists. Better definition of indications and long-term results will determine if this procedure will gain significant popularity.

The Future

While it is hazardous to guess and predict what the future holds for B-IP, it is safe to surmise that the prospect for B-IP is very promising. The medical science is advancing rapidly and the advances will determine the indications and for B-IP. As outlined above, the continued technical advances in B-IP have altered the indications and role for the procedures. Newer diseases or increasing prevalence of well-known diseases may bring about important and new indications for B-IP. Advances in technology are another reason for increased use of B-IP procedures. On the other hand, advances in nontechnical diagnostic methods can decrease or entirely eliminate the need for B-IP procedures. Newer therapeutics to treat nonpulmonary disorders can result in respiratory complications which in turn would require B-IP procedures for the diagnosis and treatment of such complications.

Changing Role of Bronchoscopy and Interventional Pulmonology

A further reflection on the above brings to mind some examples from the past three decades. An excellent example is the discovery of acquired immunodeficiency syndrome (AIDS) in the early 1980s. As clinicians quickly recognized, the lung involvement was common in AIDS and the etiologies of these were unknown. Very soon, bronchoalveolar lavage became very important in the diagnosis of lung infiltrates in these patients. The procedure remains an important tool in the management of patients with AIDS. Another group of patients who benefit from B-IP procedures are those who are immunosuppressed because of chemotherapy or medications administered to prevent tissue rejection following organ transplantations. The number of such patients is likely to increase as more and more organ transplants are performed. Major airway stenosis in lung transplant recipients may require frequent bronchoscopic evaluations.

Newer Technology

The prevalence of asthma as well as the proportion of patients with asthma refractory to aggressive medical therapy has increased. This has been the impetus for the consideration and development of bronchial thermoplasty. Advanced emphysema is another condition that is associated with significant mortality and morbidity. Medical therapy has limited role in alleviating the severe dyspnea and hypoxia in the affected persons. As the surgical lung volume reduction has been associated with high mortality and morbidity, less invasive procedures such as bronchoscopic lung volume reduction have been introduced in clinical practice. As of this date, it is difficult to be certain whether these two procedures will be generally accepted and frequently used.

Lung cancer will continue to be a major condition encountered by pulmonary physicians. Better understanding of genetic mutations in cancer cells has led to targeted chemotherapy in certain histologic types of lung cancer. The general expectation is that improved understanding of the basic abnormalities in genetic mutations may lead to so-called individualized medicine. It is easy to infer that the role of B-IP procedures will increase in the management of patients with lung cancer.

Lessons from the Past and Present

The past history of B-IP shows that some techniques languished for considerable length of time before being accepted by the majority of specialists in B-IP. Bronchoscopic needle aspiration/biopsy is such an example. After the bronchoscopic ultrasound-guided needle aspiration technique and technology became reliable in securing optimal tissue samples from affected lymph nodes, the technique has assumed a very important and essential tool in the nonsurgical staging of lung cancer. Further improvements may increase the indication for the technique. On the other hand, several techniques have yet to gain universal acceptance and widespread use, with only a few medical centers and interested specialists in B-IP using them. These include electromagnetic navigation, virtual bronchoscopic navigation, confocal bronchoscopy, optical coherence tomography, and several miscellaneous techniques. It is important to recognize that many of these require expensive equipment and extensive training. These are major considerations in determining the extent of usage.

Several of the B-IP techniques have established their valuable role in clinical pulmonology. Because of the very nature of the technique, expense, and the limited indications and the limited number of patients who might benefit from their deployment, these techniques are limited to a smaller number of medical centers and B-IP specialists. Included among these are rigid bronchoscopy, airway debridement, laser bronchoscopy, airway stent insertion, medical thoracoscopy, indwelling tunneled pleural catheters, management of complex conditions of major airways, and percutaneous tracheostomy.

The indications for B-IP have significantly decreased following the introduction of improved diagnostic methods in associated procedures in pulmonology. A classic example is the universal availability of high-resolution computed tomography. Based on clinical information and chest CT images, it is now possible to confidently diagnose several interstitial lung diseases and avoid bronchoalveolar lavage and bronchoscopic lung biopsy. Examples of such disorders include idiopathic pulmonary fibrosis/usual interstitial pneumonitis, nonspecific interstitial pneumonitis, lymphangioleiomyomatosis, Langerhans cell granuloma, pulmonary alveolar proteinosis, and certain cases of sarcoidosis. Advances in serologic testing and other tests have obviated the need for bronchoscopic lung biopsy. Previously, lung biopsies were considered essential for the histologic diagnosis of granulomatosis with polyangiitis (also known as Wegener's granulomatosis). Currently, however, biopsy has been replaced by the reliable antineutrophil antibody testing (ANCA). While the advent of video-assisted thoracoscopic surgery (VATS) decreased the number of bronchoscopic lung biopsies, the improvements in bronchoscopic ultrasound guidance have decreased the need for surgical mediastinoscopy. If and when newer and less invasive tests become available for clinical use, the need for B-IP procedures may diminish. These considerations imply that multitude of factors may increase or decrease the need for B-IP procedures. Simultaneously, it is essential to recognize that the competing tests and procedures can also assume complimentary roles.

Education

Proper initial training and ongoing training including didactic and hands-on practice is required to enable the specialist in B-IP to provide optimal care to the patients. The increase in the number of different procedures performed by the specialists in B-IP had led to the establishment of dedicated training programs in B-IP. Ongoing training programs and refresher courses have increased in numbers. All professional respiratory organizations have established hands-on workshops and training programs in B-IP. A major advance is the introduction of simulation centers where the novices as well as experts are trained and retrained in techniques using mannequins or animal models. In this volume, a chapter is dedicated to the discussion on the various modes of teaching and training. The World Association for Bronchology and Interventional Pulmonology as well as national associations dedicated to the dissemination of B-IP continue to provide guidance and training in B-IP procedures, and this activity will continue and expand.

Summary

It is likely that the importance of B-IP will increase in the future. The caveat that accompanies this statement is that a multitude of factors will increase or decrease the need for and the importance of B-IP procedures in the future. It is essential to concurrently recognize that the newer nonpulmonary tests and procedures do not compete with B-IP procedures but are complimentary. As the number of indications increase and newer instruments and techniques become available, more and more training becomes imperative. Even now, in some major medical centers with a large number of specialists in B-IP, not every procedure can be performed by each and every B-IP specialist. Subgroups of specialists have dedicated themselves to the practice of certain B-IP procedures.

Further reflections on the history of B-IP and current practice and trend provide ample evidence to state with confidence that the field of bronchoscopy and interventional pulmonology will remain dynamic.

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