reconstruction of blood flow patterns and pressures and is used in cardiac imaging. It may also have a role in the measurement of pulmonary blood flow. Infiltrative pulmonary diseases and pulmonary edema increase proton density in the lung, allowing better definition by MRI of honeycombing in pulmonary fibrosis and pulmonary edema in acute respiratory distress syndrome (ARDS). The use of inhaled hyperpolarized inert gases such as helium 3 or xenon 129 offers the ability to quantify peripheral airspace size, measure gas flow in lobar and segmental bronchi, and detect regional differences in ventilation. It has promising applications in the evaluation of emphysema and asthma and after lung transplantation, including assessment of bronchodilator responsiveness.

Pulmonary Angiography

Pulmonary angiography entails placement of a catheter in the pulmonary artery, followed by rapid injection of a contrast agent. In the past, this was "gold standard" for diagnosis of pulmonary thromboembolic disease. Pulmonary angiography still can be useful for detection of congenital abnormalities of the pulmonary vascular tree, but CT and MRI have largely supplanted it.

Positron Emission Tomography

Positron emission tomography (PET) detects metabolically active masses greater than 0.8 cm in diameter. It is helpful in assessing whether a pulmonary nodule is benign or malignant. However, it does not distinguish between inflammation and malignancy. Therefore, assessment of multiple pulmonary nodules by PET is limited because of false-positive findings due to active granulomatous disease such as tuberculosis, sarcoidosis, or fungal infections.

Dual-modality integrated PET-CT combines morphologic and functional imaging. The combination of PET and CT is helpful for localizing solitary metastatic lymph nodes in the hilum, allowing better staging of lung cancer. In addition, PET-CT is helpful in planning radiation therapy for patients who have lung cancer associated with atelectasis.

Bronchoscopy

Fiberoptic bronchoscopy is used for diagnostic or therapeutic indications. It is most commonly performed to directly visualize the nasopharynx, larynx, vocal cords, and proximal tracheobronchial tree for diagnostic purposes. The procedure is performed by sedating the patient and providing local anesthesia with inhaled and bronchoscopically instilled lidocaine. The bronchial mucosa is assessed for endobronchial masses, mucosal integrity, extrinsic compression, dynamic compression, and hemorrhage. The bronchoscope is equipped with a channel for passage of biopsy forceps, bronchial brushes, or needles for aspiration and tissue biopsy. Saline also can be instilled through the channel for bronchial washings or bronchoalveolar lavage. Bronchial washings can be analyzed for cytology, culture, and special stains. A bronchial brush is used to scrape the bronchial mucosa and harvest cells for cytology. Bronchoscopes can also be adapted to provide ultrasound images of the airways and neighboring tissues. Endobronchial ultrasound (EBUS) uses high acoustic frequencies, in the range of 20 MHz, to provide high-resolution images of proximal tissue. EBUS can provide guidance for needle aspiration of mediastinal lymph nodes.

Common therapeutic indications for bronchoscopy include retrieval of foreign bodies, suctioning of secretions, reexpansion of atelectatic lung, treatment of hemoptysis, and assistance with difficult endotracheal intubations. In special centers, bronchoscopy is used to perform yttrium aluminum garnet (YAG) laser therapy for endobronchial lesions, guide placement of catheters for brachytherapy in lung cancer, or guide placement of stents. Lasers produce a beam of light that can induce tissue vaporization, coagulation, and necrosis. Cryotherapy probes induce tissue necrosis through hypothermic cellular crystallization and microthrombosis. Cryotherapy and electrocautery have been used to treat and relieve airway obstruction caused by benign tracheal bronchial tumors, polyps, and granulation tissue. The goal of endobronchial brachytherapy is to relieve airway obstruction from central tumors. This is typically used as an adjunct to conventional external-beam irradiation. Tracheobronchial stenting can be performed to manage airway compression associated with malignant tumors, tracheoesophageal fistulas, or tracheobronchomalacia. Bronchoscopy is generally a safe procedure; major complications, including significant bleeding, pneumothorax, and respiratory failure, occurring in 0.1% to 1.7% of patients.

PROSPECTUS FOR THE FUTURE

Continued refinement and evolution of techniques and methods currently used to assess pulmonary structure and function will enhance the ability to diagnose and treat individuals with lung disease. Although pulmonary function testing has been performed for decades, advances in equipment design and better standardization of methods will improve accuracy and reproducibility. Further development of noninvasive techniques used to measure changes in lung volume from body surface displacements may allow for assessment of pulmonary function in settings outside the pulmonary function laboratory. Analysis of exhaled gas for biomarkers has tremendous potential for early diagnosis of many lung diseases, especially cancer.

Great strides in assessing lung structure will evolve from advances in CT, PET, and MRI technology. CT volume-rendering techniques will provide images of the central airways, enabling "virtual bronchoscopy." This technique will be useful to guide biopsy site selection in conventional bronchoscopy and to allow visualization of airways distal to an endobronchial obstruction. Volumetric measurements of pulmonary nodules using CT segmentation techniques will allow more accurate calculation of nodule volume and better assessment of tumor doubling times. This, in concert with PET-CT, may provide more accurate means of determining the malignant potential of a solitary pulmonary nodule.

MRI may evolve into the preferred method for evaluating pulmonary emboli, mediastinal disease, and regional ventilation-perfusion matching. Velocity-encoded MRI is a promising modality for assessment of pulmonary vascular blood flow and pressures and may prove to be more accurate than current noninvasive methods. Lymph node–specific magnetic resonance contrast agents and the development of PET molecular tracers targeting tumor proteins and receptors may better differentiate enlarged lymph nodes caused by hyperplasia from those due to