State-of-the-art airway imaging with CT: Part 3

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Abstract: A significant advance in CT imaging is the use of 3-dimensional (3D) reconstruction techniques. A 3D reconstruction, for example, permits a volumetric evaluation of the contours of the airways and displays areas of stricture, or narrowing, more effectively than do routine axial images. External 3D rendering, also called CT bronchography, helps reveal complex airway abnormalities and improves the detection of subtle airway stenoses. Although it is primarily an investigational tool, internal 3D rendering (virtual bronchoscopy) has several potential applications, including assessing airway stenoses, guiding transbronchial biopsy procedures, and screening for lung cancer. Multiplanar reformation imaging methods can aid in the assessment of airway stenoses, airway stents, tracheomalacia, and extrinsic airway compression. A review of multiplanar images can also aid in the planning of stent placement or surgery. (J Respir Dis. 2006;27(8):348-352)

In the May and June 2006 issues of The Journal of Respiratory Diseases, we reviewed current CT technology for assessment of the airways. We now discuss applications of 3-dimensional (3D) reconstruction and multiplanar reformation imaging.

3D RECONSTRUCTION
There are 2 basic types of 3D CT reconstruction imaging techniques. The first, external rendering (also called CT bronchography), depicts the external surface of the airways and its relationship to adjacent structures. The second, internal rendering, combines helical CT data and virtual reality computing techniques, allowing the viewer to navigate the internal lumen of the airways. This method has been referred to as "virtual bronchoscopy" because it produces images that closely correlate with conventional bronchoscopic images.

External 3D rendering
The technique of external 3D rendering has been shown to help illustrate complex airway abnormalities and improve the detection of subtle airway stenoses. In a study by Remy-Jardin and associates, axial and 3D rendered images were obtained in 47 patients with benign tracheobronchial stenoses. The 3D images provided important supplemental information in one third of cases by enabling a more precise evaluation of the shape, length, and degree of airway stenoses. In some of these cases, 3D rendering enabled the confident recognition of mild stenoses that were not clearly depicted on axial images. The same study assessed the role of 3D external rendering of the airways in 15 patients who had a variety of complex tracheobronchial abnormalities. The 3D images provided relevant supplemental information in more than half of the cases, and they led to correction of interpretive errors of axial images in about 10% of the cases. 3D external renderings are therefore recommended for patients referred for imaging evaluation in whom tracheobronchial stenoses or complex central airway abnormalities are suspected.

3D reconstructions permit a volumetric evaluation of the upper airway contours (Figure 1), and they display areas of stricture, or narrowing, more effectively than do routine axial images. Such images are particularly helpful in assessing patients with sleep apnea. They also aid surgical planning by providing an anatomic display of the airways and of the adjacent bone and soft tissue landmarks.

Internal 3D rendering
At present, internal 3D rendering (virtual bronchoscopy) is still primarily an investigational tool. Potential applications include the assessment of airway stenoses, guidance for transbronchial biopsy procedures, and assistance in lung cancer screening. One of the most promising applications of virtual bronchoscopy relates to its ability to evaluate the airways distal to a high-grade stenosis, beyond which a conventional bronchoscope cannot pass. For example, Fleiter and colleagues assessed virtual and conventional bronchoscopy in 20 cancer patients with high-grade airway stenosis (beyond which a conventional bronchoscope could not pass). They found that virtual bronchoscopy offered the advantage of viewing the airways beyond the site of stenosis in 5 (25%) of the patients. Virtual bronchoscopy also offers the potential benefit of viewing a stenosis or obstructing endobronchial lesion from a distal perspective. Conventional bronchoscopy allows visualization of
such a lesion only from a proximal perspective, with a view of only "the tip of the iceberg" in some cases. In contrast, virtual bronchoscopy can provide a more global perspective.

One of the earliest applications of virtual bronchoscopy was the guidance for transbronchial needle aspiration procedures for lymph nodes. McAdams and associates\(^5\) demonstrated that virtual guidance improved the yield and reduced the time of this procedure. However, this potential application has already been largely supplanted by the advent of CT fluoroscopy, which has the advantage of providing "real-time" rather than "virtual" guidance.\(^6\,\,8\)

When CT fluoroscopy is not available, virtual bronchoscopy may be useful in providing a "road map" for the pulmonologist. Since future technologic advances will allow for interactive, real-time virtual reality guidance for airway procedures such as bronchoscopy and surgery,\(^9\) it is likely that virtual bronchoscopy will play a larger role in these settings in the future.

Another potential application for virtual bronchoscopy that is theoretically appealing is screening for lung cancer in the central airways. Although low-dose screening of the lungs with helical CT has been shown to be highly sensitive in the detection of early lung cancer, this method has a bias for detecting adenocarcinoma (the cell type of 93% of lesions in a large screening study).\(^10\) Adding a complementary method of screening for central lung cancers would be helpful in detecting squamous cell carcinomas,\(^11\) which are the most common subtype of lung cancer to present as an endobronchial lesion.

Since both virtual bronchoscopy and imaging of the lung parenchyma can be performed using the same CT dataset, they are—in theory—an appealing complement of tests for lung cancer screening. However, virtual bronchoscopy for lung cancer screening is currently limited by the difficulty of detecting and characterizing small lesions typical of early lung cancer; the inability to distinguish mucosal from submucosal lesions; a relatively high false-positive rate, given that retained secretions can be problematic; its relatively high labor-intensive nature as a screening tool; and the lack of general experience of most radiologists with this technique.\(^11\,\,13\) Further advances are therefore required before this method can be used as an effective mass screening tool.

Clinical and experimental studies have shown that virtual bronchoscopic imaging of the upper airways can be as diagnostically effective as standard endoscopic techniques (Figure 2).\(^14\) In a large study by Burke and colleagues,\(^14\) patients with a range of upper airway pathologies were imaged with both standard upper airway and virtual endoscopy. The pathologic conditions included tumors, webs, vascular compression, and laryngomalacia. There was excellent correlation with conventional endoscopy for evaluation of stenoses and airway tumors (Figures 3, 4, and 5). Although evaluation of laryngomalacia was limited in this study, it would have been improved by the use of dynamic imaging.

Other studies have shown similar excellent correlation between standard and virtual endoscopic techniques in a pediatric population that included patients with congenital and acquired stenoses, subglottic angiomas, and vascular rings.\(^15\) Multiplanar reformation imaging methods help depict mild airway stenoses, determine the length of stenoses, and identify horizontal webs.\(^3\,\,16\,\,18\) A review of multiplanar images has been shown to aid the preprocedural planning of stent placement or surgery.\(^18\) In addition, these images provide an accurate measure for patient follow-up after airway procedures.\(^18\)

The continuous display of stents provided by multiplanar reformation images aids in the identification of complications, such as stent migration and fracture.\(^19\,\,20\)

When assessing tracheomalacia, paired end-inspiratory and end-expiratory sagittal 2-dimensional images along the axis of the trachea help display the craniocaudal extent of excessive tracheal collapse during expiration (Figure 6).\(^19\,\,21\) The future of CT imaging

In the near future, advances in CT technology, data processing, and image display, as well as increased clinical experience with advanced imaging reconstruction methods, will likely further expand the role of multiplanar and 3D reconstruction images in the assessment of a wide range of disorders of the central airways (Table).

References: REFERENCES


20. Boiselle PM, Reynolds KF, Ernst A. Multiplanar and three-dimensional imaging of the central airways with multidetector CT. AJR. 2002;179:301-308.

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