Abstract: Advances in CT technology afford the ability to create 3-dimensional (3-D) reconstructions of the airways in only a few minutes. The 2 basic types of 3-D reconstruction imaging methods are CT bronchography, which depicts the external surface of the airways and its relationship to adjacent structures, and virtual bronchoscopy, which allows the viewer to navigate the internal lumen of the airways by a means similar to conventional bronchoscopy. Although axial images are routinely used to evaluate the upper airways, multiplanar reformations in the coronal and sagittal planes also help evaluate upper airway pathology. Coronal multiplanar reformation images are useful in defining the anatomy of the larynx; sagittal images provide excellent delineation of the epiglottis, vallecula, and piriform sinuses. Axial images are the reference standard for assessing tracheal wall thickening and, therefore, may be particularly helpful in the differential diagnosis of tracheal stenosis. (J Respir Dis. 2006;27(6):266-273)

In the May 2006 issue of The Journal of Respiratory Diseases, we reviewed advances in CT technology for noninvasive assessment of the airways, particularly multi-detector row CT scanning and multiplanar and 3-dimensional (3-D) reconstruction imaging. In this article, we examine reconstruction and reformation methods in relation to normal airway imaging anatomy. In a subsequent article, we will consider applications of 3-D reconstruction and reformation imaging.

3-D RECONSTRUCTION
Advances in CT technology have enabled 3-D CT reconstructions of the airways to be created in just a few minutes, contributing to a more accurate assessment of various disorders of the central airways. 3-D CT reconstructions require the transfer of data to a separate workstation, which allows the interactive display of 3-D images in real time. Fortunately, such workstations are becoming increasingly commonplace in inpatient and outpatient radiology department settings. Most commercially available workstations provide a menu of options consisting of preset reconstruction algorithms, including dedicated airway techniques. The use of clip-editing planes (also known as trimming or extraction functions) precludes the need to trace regions of interest and significantly enhances the efficiency with which one can obtain 3-D images. Using clip-editing planes, a trained technologist or radiologist can complete a series of reconstructions in less than 10 minutes. There are 2 basic types of CT 3-D reconstruction imaging methods:

- **External rendering** depicts the external surface of the airways and its relationship to adjacent structures (Figure 1). This technique is also called CT bronchography because of the similarity of the images it produces to conventional bronchographic images.
- **Internal rendering** combines helical CT data and virtual reality computing techniques, allowing the viewer to navigate the internal lumen of the airways by a means similar to conventional bronchoscopy. This method is also called virtual bronchoscopy because it produces images that closely correlate with conventional bronchoscopic images (Figures 2 and 3).

2-D MULTIPLANAR REFORMATION
Two-dimensional (2-D) reformation methods include multiplanar reformations and multiplanar volume reformations. Images are easy to generate using these methods, which can be interactively performed in real time at the CT console or at a dedicated workstation. Multiplanar reformation images are sections of single-voxel thickness that may be displayed in coronal and sagittal planes or in a curved fashion along the axis of the airways. By comparison, multiplanar volume reformations comprise a thick slab of adjacent, thin slices and represent a block of contiguous images. The thickness of such blocks (or slabs) varies but usually ranges from 5 to 10 mm. Multiplanar volume reformation images therefore combine the spatial resolution of multiplanar reformation images with the anatomic display of thick slices.

Multiplanar volume reformation images can also be reconstructed using a rotational (or "paddlewheel") method, along the axis of the carina, to enhance the continuous display of the central airways (Figure 4).

NORMAL AIRWAY ANATOMY

**Upper airways**
In the evaluation of the upper airways, a review of the standard axial landmarks of the airways is...
valuable. The most important anatomic landmark is the epiglottis, which forms the superior border of the larynx. On axial slices, it first appears as a horizontally oriented elliptical soft tissue density (Figure 5A). Inferiorly, it forms the border between the laryngeal airway and the vallecula, which are paired ovoid structures anterior to the epiglottis. The valleculae are separated by a thin band of tissue known as the glossoepiglottic fold (Figure 5B).

The second most important landmarks are the aryepiglottic folds. These folds appear as triangular structures along the anterolateral aspect of the airway and continue posteriorly to form the border between the laryngeal airway anteriorly and the pyriform sinuses posteriorly. Inferiorly, the glottic airway consists of the true and false cords. At the level of the false cords, the upper airway is visualized as an elliptical structure bounded posteriorly by the base of the aryepiglottic folds, which can be differentiated by the presence of fat in the surrounding soft tissues (Figure 5C).

The airway at the level of the true cords is elliptical, bounded anteriorly by the thyroid cartilage and laterally by the homogeneous soft tissue density of the thyroarytenoid muscle (Figure 5D). The more circular subglottic airway is bordered posteriorly by cricoid cartilage (Figure 5E).

Although axial images are routinely used to evaluate the upper airway, multiplanar reformations in the coronal and sagittal planes also help evaluate upper airway pathology. Coronal multiplanar reformations are particularly helpful in defining the anatomy of the larynx by delineating the aryepiglottic folds, true and false cords, laryngeal ventricles, and subglottic space (Figure 6A). Sagittal multiplanar reformations also enable excellent delineation of upper airway structures, particularly the epiglottis, vallecula, and piriform sinuses (Figure 6B). Sagittal shaded surface displays (Figure 6C) and volume-rendered images (Figure 6D) are effective 3-D reconstruction techniques of the upper airway.  

**Trachea and main-stem bronchi**

The trachea extends from the inferior margin of the cricoid cartilage to the carina, which is the origin of the main-stem bronchi (Figure 7). Although the trachea is generally midline in position, it is often displaced slightly to the right at the level of the aortic arch. The trachea consists of 16 to 22 C-shaped cartilages, which are connected posteriorly by the membranous wall of the trachea and are linked longitudinally by annular ligaments of fibrous and connective tissue. On axial CT images, the tracheal lumen may have an oval, round, or horseshoe shape. This finding is frequently associated with malacia.

On axial CT images, the tracheal lumen may have an oval, round, or horseshoe shape. The term "saber-sheath trachea" refers to a configuration of marked coronal narrowing and accentuation of the sagittal diameter, a finding frequently associated with chronic obstructive lung disease. In contrast, a "lunate trachea" refers to accentuation of the coronal diameter with a relative narrowing of the sagittal diameter. This finding is frequently associated with malacia.

The tracheal wall is usually visible as a 1- to 2-mm soft tissue density stripe, demarcated internally by the air-filled tracheal lumen and externally by the adjacent fat density of the mediastinum (Figure 8). Typically, the posterior wall is thinner than the anterior and lateral walls. Normally, cartilage in the tracheal wall may appear slightly denser than surrounding soft tissue and fat. Calcification of cartilage may be observed in older patients, mainly women. Calcified thickening of the tracheal wall is associated with tracheal pathology, particularly relapsing polychondritis (Figure 9).

Thickening of the airway wall, with or without calcification, is an important sign of tracheal pathology. Axial images are the reference standard for assessing tracheal wall thickening, a finding that may be overlooked when using conventional bronchoscopy or 3-D reconstruction imaging. The distribution of wall thickening can be helpful in limiting the differential diagnosis of tracheal stenosis. For example, disorders of cartilage, such as relapsing polychondritis and tracheobronchopathia osteochondroplastica, spare the posterior membranous wall of the trachea, whereas other disorders generally result in circumferential thickening (Figure 10).

The main-stem bronchi arise from the trachea at the level of the carina and course obliquely to the axial plane. Because of the limitations of axial images for assessing structures that course obliquely, multiplanar and 3-D reconstruction images are particularly helpful in evaluating caliber changes in the main-stem bronchi.

**References:**

1. 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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