The Role of Multislice CT in Imaging of Different Tracheal Lesions


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Abstract

Background: The advent of multi-detector CT has revolutionized imaging of the airways and other thoracic structures. In comparison to single-detector helical CT scanners, multidetector scanners not only provide faster speed, greater coverage, and improved spatial resolution, but also have the unique ability to create images of thick and thin collimation from the same data set. One of the greatest benefits of this new technology is the improved quality of two-dimensional (2D) multi-planar and three-dimensional (3D) reconstruction images. These images break away from the confines of the traditional axial imaging plane and have the potential to facilitate the assessment of a variety of airway disorders. With regard to the assessment of airway stenoses, multi-planar volume reformation methods aid in the detection of mild stenoses, improve the accuracy of determining the length of stenoses, and aid in the identification of horizontal webs. Review of multi-planar volume-reformatted images has been shown to aid in the planning of stent placement or surgery.

Multiple tracheal lesions can be assessed as tracheal stricture, Relapsing polychondritis, Amyloidosis, Tracheomalacia, Tracheopathia osteochondroplastica as well as saber-sheath trachea deformity.

Aim of the Work: The aim of our review study is to distinguish the features of different tracheal lesions using multi-detector CT.

Patients and Methods: This study included 20 patients; 15 males and 5 females, age range 8-83 (average of 46.67 years). Cases were referred from the ENT, Chest and Oncology Departments to Radiology Department in Kasr Al-Aini Hospital for MSCT Chest. The study was performed from March 2012 till March 2013. They were all subjected to Thorough clinical examination with history taking, general and chest examination, MSCT was done to all patients.

Results: In this study, we provide evidence that multislice computed tomography (MSCT) is able to diagnose different tracheal lesions either in symptomatizing patients or incidental in cases presenting with known or chronic illness or other clinical suspicion.

Key Words: Multislice computed tomography – Tracheal lesions.

Introduction

THE advent of multi-detector CT has revolutionized imaging of the airways and other thoracic structures. In comparison to single-detector helical CT scanners, multidetector scanners not only provide faster speed, greater coverage, and improved spatial resolution, but also have the unique ability to create images of thick and thin collimation from the same data set [1,2].

One of the greatest benefits of this new technology is the improved quality of two-dimensional (2D) multi-planar and three-dimensional (3D) reconstruction images. These images break away from the confines of the traditional axial imaging plane and have the potential to facilitate the assessment of a variety of airway disorders.

With regard to the assessment of airway stenoses, multi-planar volume reformation methods aid in the detection of mild stenoses, improve the accuracy of determining the length of stenoses, and aid in the identification of horizontal webs. Review of multi-planar volume-reformatted images has been shown to aid in the planning of stent placement or surgery.

Airway imaging is routinely performed at end-inspiration during a single breath-hold. State-of-the-art helical scanners allow the entire central airways to be imaged in less than 5sec. The speed of the examination is particularly important when imaging patients with airway disorders because many of these patients cannot tolerate the significantly longer breath-hold time required by single-detector CT scanners. Short scanning time is also an advantage for imaging during dynamic breathing.
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or at end expiration in patients with suspected tracheomalacia a condition characterized by excessive collapse of the airway during expiration.

Tracheal stricture caused by damage from cuffed endotracheal tube, tracheostomy or trauma to the neck. Cuff pressure in these devices may exceed the capillary pressure leading to ischemic necrosis and subsequent fibrosis. Assessment of such localized tracheal abnormality can be achieved with contiguous 1.5-5.0mm collimation scans obtained through the area during a single breath hold [3,4].

Relapsing polychondritis is a systemic disease in which the tracheal cartilage is affected by recurrent episodes of inflammation. On CT images, fixed narrowing of the tracheal lumen with associated thickening of the wall is noted [3,4].

Amyloidosis is a condition in which a fibrillar protein is deposited in the trachea. Tracheal involvement takes the form of diffuse or multifocal submucosal infiltrates. On CT scan, narrowing of the lumen, wall thickening and calcification is noted [3,4].

Tracheomalacia is a clinical disorder associated with softening of the cartilage and loss of structural integrity of the trachea. Both primary and secondary etiologies are recognized. In pediatric patients, prematurity or prolonged mechanical ventilation is often implicated. In adults, many cases are posttraumatic or post-inflammatory with or without complicating infections [3,4].

Tracheopathia osteochondroplastica is a rare idiopathic and usually asymptomatic disorder of older men; this disorder is characterized by multiple osteo-cartilaginous masses adjacent to the tracheal rings of the inner anterolateral wall of the trachea. Radiologically, focal tracheal thickening, calcification of the tracheal rings, multiple calcified tracheal nodules, and long-segment tracheal narrowing are typically seen.

Saber-sheath trachea deformity is a pathognomonic finding in patients with chronic obstructive pulmonary disease. The saber-sheath appearance is found when mechanical forces of hyperinflated lungs cause the coronal diameter of the intra-thoracic trachea to narrow and the sagittal diameter to elongate so that the sagittal-to-coronal diameter ratio exceeds 2:1. The extra-thoracic trachea remains normal in configuration. CT may also reveal mild intra-thoracic tracheal wall thickening, frequently with ossification of the tracheal rings.

Aim of the work:
The aim of our review study is to distinguish the features of different tracheal lesions using multi-detector CT.

Patients and Methods
This study involved 20 patients; 15 males and 5 females, age range 8-83 (average of 46.67 years). Cases were referred from the ENT, Chest and Oncology Departments to Radiology department in Kasr Al-Aini Hospital for MSCT Chest. The study was performed from March 2012 till March 2013. They were all subjected to Thorough clinical examination with history taking, general and chest examination, MSCT was done to all patients.

Patients were subjected to:
- Thorough clinical examination with history taking, general and chest examination.
- Routine laboratory tests mostly complete blood picture, the other tests were considered according to case e.g. Sputum culture..etc.
- Conventional endoscopy to trachea and bronchi were attempted in 8 cases.
- Pulmonary function tests (PFT) done to 6 patients with obstructive manifestations.
- Transbronchial lung biopsy done in 5 patients.
- MSCT: GE Light Speed Plus MSCT 4 channels set present in the Radiology Department Kasr Al-Aini was used for all cases. 12 cases underwent routine CT chest [with (8 cases) or without IV contrast (4 cases)], virtual bronchoscopy was requested in 7 cases (see Table (1) for technique used) and HRCT was done in one case with bronchiectasis (see Table (2) for technique used).

Results
This study included 20 patients; 15 males and 5 females, age range 8-83 (average of 46.67 years). Table (3) summarizes the different MSCT findings in our 20 cases.

The other findings referred to in the table represent a case showing normal trachea and focal bronchomalacia in a case suspected clinically to have tracheomalacia. Table (4) summarizes the MSCT findings in the cases showing tracheal narrowing; Table (5) presents cases with tracheal masses while Table (6) presents cases with calcification.
IV contrast: None needed.

CT scanning: CT scan examinations were performed using GE Light Speed Multislice 4 channels present in the radiology department at Kasr Al- Aini hospital. The examination is done in supine position. A scout is taken with Kv 120 and mA 120, then helical scanning is done in caudo-cranial direction to minimize respiration artifacts, using detector row 4, helical thickness 1.25, pitch 1.5:1, speed (mm/rot) 7.5. Detector configuration 4x1.25, beam collimation 5.00mm, interval 1.00, gantry tilt 0.0, FOV depends on the patients' body built, but is about 35cm. K 120-140, mA 120-160, total exposure time 16-20sec during breath hold in inspiration. The images acquired are then sent to a separate workstation to be processed, manipulated and reconstructed by resident in the cardiothoracic imaging unit in the radiology department.

Reconstruction techniques: Reconstruction of the images are done using different reconstruction softwares available at the workstation. Several reconstruction techniques are done each aiming for a certain diagnostic achievement as follows:

1- 3D Internal surface rendering: Also termed virtual bronchoscopy (VB), where images simulate those of true bronchoscopy. The cursor of the virtual camera was guided manually by the resident to cover all regions from trachea till segmental bronchi taking pertinent images and naming each.

2- 3D Volume rendering: Images show the outer features of the bronchial tree and lungs where any external deformity could bedetected.

3- 2D Minimum intensity processing (minIP): Images only detect the lowest housefield attenuation values available thus only detecting air column within the bronchial tree, this technique enhances the detection of internal deformities or caliber changes and shows distal air beyond an obstructed area.

4- 2D Multiplanar images reconstruction (MPR): Images are reconstructed in axial and coronal planes showing the air-way, the surrounding lesion(s), their extent, effects and relations. It also could clarify other possible lesions as pleural effusions, mediastinal extension and lymph adenopathy, pericardial changes, etc.

5- High resolution CT images of the lungs are done as a supplementary study to evaluate the lungs for possible lymphangitis carcinomatous, this is not a part of the virtual bronchographic study but we found it helpful in patient's staging and management without significant extra effort.

| Table (2): HRCI technique used in Kasr Al-Aini. | Table (4): MSCT findings in the cases showing tracheal narrowing. |
| Scout Holdin g breath | Causes of narrowing | No. of cases | Focal/ diffuse |
| Scout | K v120 | mA 20 | Holding breath in full inspiration |
| HRCT protocol: | Helical full 0.5sec | Vascular | 1 | Thoracic trachea |
| Scan type | 4 | Saber-sheath trachea | 1 | Thoracic trachea |
| Detector Row | Helical Thickness 1.25 | Extrinsic compression | 4 | Thoracic trachea |
| Helical Thickness 1.25 | Pitch 1.5:1 | Extrinsic compression | 1 | Focal |
| Speed (mm/rot) 7.5 | Detector configuration 4x1.25 | Chemical inhalation | 1 | Focal |
| Beam collimation 5.0 | Interval mm 1.0 | Tracheobronchopathia osteochondroplastica | 1 | Focal |
| Ga ntry tilt 0.0 | FOV Depends on patients’ size | Tracheobronchopathia extrinsic with tracheal infiltration | 1 | Bronchogenic carcinoma |
| Total exposure time 16-20 | Kv 120-140 | Intrinsic | 1 | Sarcoi d |
| Holding breath in full inspiration | mA 120-160 | Table (5): MSCT findings in the cases with tracheal masses. |
| Reconstruction type | STD (standard) | Site of lesion | No. of cases | Pathological diagnosis |
| Mediastinal window images are also taken | Table (6): Presents cases with tracheal calcification. |
| Table (3): Different MSCT findings of the trachea. | Cause of calcification | No. of cases |
| Narrowing | 10 | Aging | 3 |
| Focal filling defect | 1 | Trauma | 1 |
| Widening | 1 | Tracheobronchopathia osteochondroplastica | 1 |
| Tracheal diverticulum | 1 | Amyloidosis | 1 |
| Calcification | 5 | Other findings | 1 |
Case (1): Axial CT chest (lung window) in a 23 year-old male patient showing right tracheal bronchus.

Case (2): Virtual bronchoscopy and reconstructed coronal image (lung window) in a 53 year-old female patient showing right tracheal bronchus.

Case (3): Axial CT chest images (mediastinal and lung windows) in a 83 year-old female patient showing right tracheal diverticulum.

Case (4): Male 48 years old with known esophageal carcinoma and suspected trachea-esophageal fistula Axial CT chest images (mediastinal window) showing tracheoesophageal fistula at the thoracic inlet.
Case (5): Male child 10 years old with history of penetrated neck trauma by sharp object that penetrated the anterior aspect of the trachea with severe surgical emphysema. Axial CT chest images (lung window) showing marked surgical emphysema with residual anterior mid-line tract along the path of the original penetrating object.

Case (6): Female patient 34 years old with history of sarcoidosis coming for follow-up CT. Axial CT chest images (mediastinal window) showing intrinsic sessile small left mass lesion protruding into the tracheal lumen.

Case (7): Male patient 65 years old with known left central Bronchogenic carcinoma coming for virtual bronchoscopy. Virtual bronchoscopy (scout, VB, reconstructed coronal images in MinIP), and coronal mediastinal window images) in a case of left central Bronchogenic carcinoma with upper lobar collapse, showing extrinsic compression of the trachea with displacement to the right but no evidence of tracheal infiltration.
Case (8): Male patient 45 years old with known right central Bronchogenic carcinoma coming for virtual bronchoscopy. Virtual bronchoscopy (scout, VB, axial mediastinal window, MinIP coronal images) and axial mediastinal window images) in case of right central Bronchogenic carcinoma, showing marked extrinsic compression of the trachea with displacement to the left and evident tracheal infiltration.

Case (9): Tracheomalacia: Incidental finding during MSCT of the chest in a 76 year-old male patient. Axial CT chest images (lung window) in Inspiratory and expiratory phases showing marked collapse of trachea in expiration and abnormal configuration during inspiration.
Case (10): Male patient 10 years old with suspected tracheomalacia referred for follow virtual bronchoscopy. Axial CT chest images, VB and MinIP images in inspiration and expiration showing no evidence of tracheomalacia but MinIP expiratory images show tight proximal left bronchus with dilated distal bronchus a sign denoting focal bronchomalacia.

Case (11): Female patient 8 years old with clinical signs of pulmonary hypertension referred for CT chest. CT chest images (mediastinal window) showing prominent main pulmonary artery and anomalous origin of left pulmonary artery from right pulmonary artery causing concentric compression of the trachea with marked narrowing and deformity suggesting tracheomalacia.
Case (12): Saber-sheath trachea: Incidental finding during MSCT of the chest. Axial CT chest (lung window) in a 45 year-old male patient, smoker showing increased sagittal to coronal diameter ratio (2:1), finding diagnostic of saber-sheath trachea.

Case (13): Tracheomegaly: Incidental finding during HRCT of the chest done for bronchiectasis in a 53 year-old male patient. Axial HRCT chest images (lung windows) in a 53 year-old male patient showing tracheomegaly (trachea more than 3cm). HRCT shows the classic wall corrugation and right tracheal diverticulum. Basal cuts shows bronchiectasis. Mediastinal image also shows antero-lateral calcification due to aging.

Case (14): Tracheal calcification: Incidental finding during MSCT chest Axial CT chest images (mediastinal window) showing marked tracheal calcification in 50 year-old male patient. The affection of the posterior membranous wall suggests amyloidosis.

Case (15): Female patient 57 years old with stridor of six month duration, chest X-ray showed tracheal calcification while conventional endoscopy showed tracheal narrowing. The diagnosis of tracheopathia osteochondroplastica was considered and virtual bronchoscopy was recommended. Virtual bronchoscopy, MinIP image and coronal and axial mediastinal window images in a 57 year-old female patient showing tracheal narrowing and nodular calcification in a case of tracheopathia osteochondroplastica.
Discussion

Multi-detector CT has become the imaging modality of choice for a wide range of tracheal lesions as it allows direct visualization of the cross-sectional tracheal airway and allows determination of the size, extent, and attenuation value of a lesion. In addition, recent advances in computer technology allowed multiplanar and 3D reconstruction of the acquired axial images, thus facilitating the detailed evaluation of a large variety of tracheal lesions. Also faster imaging times markedly reduced the radiation dose to the patients and more importantly the motion artifacts which could degrade the quality of the examination [8].

Three-dimensional reconstruction of axial CT images permits navigation through the tracheobronchial tree via real-time simulated bronchoscopy known as virtual bronchoscopy (VB). Such technique overcame many of the drawbacks of conventional bronchoscopy as it allowed the visualization of the relationship between a tracheal lesion and the surrounding mediastinal structures as well as airway patency beyond a stenosis, through which a bronchoscope can never pass [6].

The majority, 13 out of 20 (65%), of the tracheal lesions encountered throughout our study were not suspected clinically and were incidentally discovered during scanning for another clinical suspicion. This was consistent with the study conducted by Marom E et al., [7] who stated that a patient with tracheal affection usually does not present with a typical clinical presentation.

In the two patients in which a tracheal bronchus was detected, it was an incidental finding on CT and in both cases it was arising from the right tracheal wall and supplying the apical segment of the right upper lobe. This is consistent with the study done by Masayuki et al., [8], who reported that tracheal bronchi arose from the right lateral wall of the trachea supplying one or more right upper lobe segments and is detected in about 0.31% of the overall patient population.

In the single case of tracheal diverticulum (Case 3) we detected on CT, it was an incidental finding in an 83 year-old female patient. It was arising near the thoracic inlet, along the posterolateral right tracheal wall appearing as an air filled sac communicating with the tracheal lumen in some of the axial cuts and as an isolated paratracheal air cyst in the lower ones. This site and CT appearance typically matches a study done by Goo et al., [9] who reported that most cases of tracheal diverticulum is located at the right posterior-lateral side of the trachea and appears to have one or multiple connections with the trachea. Two types have been reported; congenital and acquired. Congenital tracheal diverticulum is smaller, located approximately 4-5cm below vocal cords or just above the carina. It's more common in males than females.

In our case of tracheomegaly (Case 13), the tracheal diameter was more than 3cm with tracheal wall corrugations and basal CT cuts showed bronchiectatic changes. These are consistent with a study done by Hubbard M. et al., [10] which states that dilatation of the trachea and tracheal wall corrugations are characteristic features of tracheomegaly, and that bronchiectasis is a common association as seen in our case.

In our three patients who were diagnosed as tracheomalacia (Case 9,10,11), collapse of the trachea with bowing of the posterior membranous portion anteriorly during expiration was noted in two cases and acquired tracheomalacia secondary to prolonged vascular compression was seen in one case. In a retrospective study done by Heussel and Hafner (May 2001-July 2008) [11], a patient group (n=27) of children with bronchoscopic evidence of tracheomalacia, and a control group (n=320) underwent inspiratory and expiratory CT. The patient group showed significantly greater cross-sectional area change of the trachea (57.2% ± 22.2% vs. 10.6%±11.2%, p<0.001) than the control group.

In our case of saber sheath trachea, it was an incidental finding in a 45 year-old male patient, smoker, in whom MSCT showed increased sagittal to coronal diameter ratio (2:1). This is set to be the diagnostic feature of saber sheath trachea according to the study done by Ochs R. et al., [12] on 176 patients, out of which 124 (70%) displayed an increase in the sagittal to coronal diameter ratio of the trachea.

In the case of tracheoesophageal fistula (case 4), it was in a patient suffering from an esophageal neoplasm which was markedly compressing the trachea causing narrowing of its lumen, the diagnosis of an acquired tracheoesophageal fistula was clinically suspected. On CT, the fistulous communication between the trachea and esophagus was demonstrated. This was consistent with a study done by Yalcin et al., [13] which involved five females and two males who were subjected to tracheal intubation. The presenting symptoms were respiratory difficulty (n=3), coughing (n=2), and dysphagia with coughing (n=2). The site of the fistulae were proximal (n=3) and middle (n=1) trachea, left main bronchus (n=1), and nearly the entire posterior wall of the trachea (n=2).
The CT findings of the trachea in the case of sarcoidosis (Case 6) coming for follow-up were limited to a mural sessile mass lesion protruding into the tracheal lumen with preserved diameter and shape of the trachea. In a study done by Nunes H. et al., [14] on 67 patients with sarcoidosis, out of whom 48 patients (72%) showed diffuse tracheal narrowing associated with calcified nodular masses while 19 patients (28%) showed mural sessile mass lesion as in our case.

In the patient who was clinically suspected tracheopathia osteochondroplastica (Case 15) virtual bronchography, reconstructed volume rendering and MinIP images as well as the mediastinal window images constituted an integrated study that showed tracheal wall thickening with luminal narrowing and nodular calcification of the wall. These are consistent with the study done by Leske et al., [15] that showed the value of virtual bronchography in evaluating wall of trachea on CT, 3D volume rendering and virtual bronchoscopic and delineated the distinct nodular mucosal lesions as well as tracheal stenosis and its extent.

In the case diagnosed as having tracheal amyloidosis showed, CT showed tracheal calcification with evident affection of the posterior membranous wall. These findings are consistent with a study conducted by Marchiori E. et al., [16] that stated that amyloidosis involving the trachea presented irregular nodular narrowing of the tracheal lumen with mural calcification favoring the posterior tracheal wall.

In our three patients with bronchogenic carcinoma (Case 7,8), the axial CT images compression and displacement of the trachea by the mediastinal lesion in all three cases, with infiltration of the tracheal lumen in one of them. This was clearly demonstrated by the aid of volume rendering, coronal MinIP as well as virtual bronchoscopic images. These findings are consistent with the study conducted by Herth F.J. et al., [17] who stated that virtual bronchoscopy has a great role in evaluation of tracheal involvement in mediastinal lesions by allowing non-invasive intra-luminal assessment of the tracheo-bronchial tree and easy detection of endo-luminal invasion of the trachea in such lesions.

**Conclusion:**

Multidetector CT has greatly overcomed the several limitations associated with routine axial CT images suffice for evaluating many airway abnormalities such as limited ability to detect subtle airway stenoses; underestimation of the craniocaudal extent of disease; difficulty displaying complex 3D relationships of the airways; and inadequate representation of the airways that are oriented obliquely to the axial plane.

**References**


