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MULTIDETECTOR COMPUTED TOMOGRAPHY BASED THREE-DIMENSIONAL IMAGING OF AIRWAY: CAN WE REDUCE THE NEED OF CONVENTIONAL BRONCHOSCOPY IN PEDIATRIC POPULATION?

Radiodiagnosis

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ABSTRACT

Objective: To detect, localize and characterize intrinsic and extrinsic lesions of airway in the pediatric population using multi-detector computed tomography (MDCT) and to compare these findings with fiberoptic bronchoscopy (FB).

Material and methods: MDCT images were acquired in 35 children (aged 6 months to 16 years) with clinically suspected airway diseases. Computer generated multi-planar reformats (MPRs); minimum intensity projections (MinIPs) and virtual bronchoscopy images were reconstructed. The children subsequently underwent fiberoptic bronchoscopy. The findings were categorized into intraluminal obstruction, extra-luminal compression and dynamic airway compromise.

Result: A total of 29 lesions were detected in 28 children, whereas 7 children had normal airway. MDCT detected 18 intraluminal obstructive and 8 extra-luminal compressive lesions with a sensitivity and specificity of 100%. Additional synechiae was detected on MDCT distal to airway occlusion, which was not visualized on fiberoptic bronchoscopy. Out of the 3 dynamic airway lesions only one was detected on MDCT. The combined sensitivity, specificity, positive and negative predictive value of MDCT in detecting airway diseases were 93%, 100%, 100% and 77.8% respectively.

Conclusion: MDCT including virtual bronchoscopy is a rapid, accurate, non-invasive and reproducible method for evaluation and characterization of pediatric airway lesions. MDCT also visualizes distal lesions of airway, which can be easily missed on fiberoptic bronchoscopy due to a proximal occlusion. However, fiberoptic evaluation of airway is required to accurately detect dynamic airway lesions.

KEYWORDS

tracheobronchial tree, pediatric airway, virtual bronchoscopy, bronchoscopy, 3-D airway imaging

INTRODUCTION

Tracheobronchial tree is a musculo-cartilagenous framework which acts as a conduit to aerate the lungs and consequently the entire body. A large spectrum of pathological conditions can involve the pediatric airway ranging from infections, post-intubation airway injuries, foreign body aspiration and extraluminal vascular compression.[1]

Fiberoptic bronchoscopy remains the gold standard for evaluation and surveillance of endoluminal and mucosal lesions of the airway. It permits direct visualization of tracheobronchial tree. However, it is an invasive procedure and also cannot view structures outside the bronchial wall.[2]

The introduction of multi-detector computed tomography (MDCT) technology over the past decade has revolutionized imaging of the airway.[3] MDCT scanners markedly increase the speed of data collection compared to the conventional and single-detector helical scanners by using multiple arrays of detectors that register multiple channels of information simultaneously with each gantry rotation. This technology, combined with decreased gantry rotation time and increased craniocaudal volume coverage, has enabled modern MDCT scanners to acquire thin-section, high spatial resolution images of the entire airway.[4,5] One of the greatest benefits of this new technology is the improved quality of two-dimensional (2D) and three-dimensional (3D) reconstruction images of the bronchial tree. [6] The developed computer software generates 3D view of the airway which provides clinically acceptable real time visualization of the entire tracheobronchial airway.[7]

Two basic methods of 3D imaging currently employed in airway reconstruction include external rendering and internal rendering. The external rendering of the airway (or CT tracheobronchography) depicts the external surface of an airway and its relationship to adjacent structures. Internal rendering (or virtual bronchoscopy (VB)) combines the CT data with virtual reality computing techniques to allow the viewer to navigate through the internal lumen of the airways in a fashion similar to conventional bronchoscopy.[8,9] The natural contrast between the soft tissue of the airway wall and air within the tracheobronchial tree establishes a plane for generating the virtual airway.[10]The virtual airway generated by CT virtual bronchoscopy can be manipulated in space and evaluated from multiple angles, thereby facilitating the analysis of airway distal to high grade stenosis beyond the limits of fiberoptic bronchoscopy.[11]

Although virtual bronchoscopy is a promising non-invasive imaging tool, this technique is not currently used as a routine diagnostic tool in clinical practice as an alternative to fiberoptic bronchoscopy. Therefore it seems valuable to review its potential in evaluating various clinical conditions that affect the airway.

The purpose of this study was to detect, localize and characterize various intrinsic and extrinsic lesions of tracheobronchial tree in the pediatric population using multi-detector computed tomography and compare the findings with fiberoptic bronchoscopy.

MATERIALS AND METHODS

We conducted a cross-sectional study in 35 children (aged 6 months to 16 years) with clinically suspected airway diseases. The procedure was explained to the guardians and informed consent in vernacular language was obtained in every case. The institutional ethical review board at our institution approved all aspects of this study.

The patients included in our study met the following inclusion criteria: children with clinical indication for bronchoscopy with suspected airway disease i.e. patients presenting with stridor, chronic cough, persistent or recurrent pulmonary infections, suspicion of foreign body aspiration etc or with abnormal findings at physical examination like wheeze, localized atelectasis, evidence of intra- and extra luminal airway obstruction etc. Patients with severe respiratory distress where imaging study could not be conducted before bronchoscopy were excluded from the study.

All the 35 patients underwent chest radiograph, followed by MDCT of the thorax. Fiberoptic bronchoscopy was performed within 24 hours of performing the CT scan.

1. MDCT Virtual Bronchoscopy

Examination Technique

All patients were imaged on a multidetector CT scanner-128 slice MDCT Siemens Somatom Definition AS+ (Erlangen, Germany). Thin slice axial images were acquired in a single breath hold. The imaging protocol used for children was: 0.5second gantry rotation speed, 80 kV tube voltage, 110 mA tube current, 0.6 mm × 128 slices, 1.5 helical pitch and 512 × 512 matrix size.The scans which required the use of contrast were acquired after the initiation of peripheral intravenous injection of nonionic iodinated contrast medium (300–350 mg of iodine per ml) at an approximate dose of 1.5 ml/kg for children less than 12 years of age and at a dose of 1ml/kg for children more than 12 years.The contrast was injected manually into peripheral venous access at a rate of 3-4 ml/sec. To minimize motion artefacts in very young children, minimal sedation (intravenous midazolam) was used with constant respiratory monitoring. Images were obtained in a cranio-caudal direction from the level of laryngeal inlet to the dome of diaphragm.

Image Reconstruction

The cross-sectional images thus acquired were transferred to a separate graphic computer (Syngo Multimodality Workplace). Reconstruction was done using standard visualization software. The acquired volumetric data sets were used to generate multiplanar reformation (MPR), minimum intensity projection (MinIP) and volume rendered images for 3D reconstruction.

The acquired overlapping thin section data sets were also used to generate an endoluminal view of the airways using the "fly through" virtual endoscopy CT software. The workstation screen was divided into quadrants containing an endoluminal view, a transaxial view, MPR coronal and sagittal view and a navigator. Navigation through the endoluminal images was performed using the cursor movement to fly through the virtual bronchoscopic view. The cursor position on the endoscopic view was correlated with its 3-D coordinates on the MPR views in real time as the cursor moved. VB associated with the MPRs determined the exact position of a referenced anatomical structure such as carina or bronchial orifices. As measurements were not possible on the VB image, MPR and VRT images were used to demonstrate the length of any pathology.

Interpretation

Axial CT images and MPRs were viewed using standard lung window (centre:-600 HU; width: 1200 HU) and soft tissue window (centre: 40 HU; width:400 HU) settings to evaluate airway, lung fields and the mediastinal structures which could affect the airways. MinIP and VRT images were used to look for airway column narrowing or diverticula. The anatomic location and dimension of the detected lesions were also noted. This was followed by interpretation of VB images. The presence or absence of intraluminal obstruction, extraluminal compression or dynamic airway wall abnormality were recorded. The length of narrowing was assessed by measuring the maximal projectional length on the MPR or VRT images. All detected abnormalities in the tracheobronchial tree were recorded in the datasheet.

2. Fiberoptic Bronchoscopy

Flexible bronchoscopy was considered the reference test from which we determined the presence or absence of airway lesions. It was performed by the pulmonologist using a fiberoptic bronchoscope under electrocardiographic and oxygen saturation monitoring. Systemic anesthetics were also used to achieve better compliance In children. Intravenous midazolam and pentazocine were used in appropriate doses to achieve conscious analgesia along with topical anesthetics. After the anesthetic had taken effect, the scope was introduced through the nose. The scope was then passed across the vocal cords and the tracheobronchial tree was explored systematically (trachea, carina, mainstem bronchi, lobar bronchi and segmental bronchi). Based on the clinical indication diagnostic or therapeutic procedures were performed. Therapeutic retrieval of foreign body was done in one of our cases.

The lesions affecting the airway were grouped under intraluminal obstruction, extraluminal compression and dynamic airway lesions. The findings obtained on FB were correlated with those of MDCT-virtual bronchoscopy.

RESULTS

A total of 35 patients with clinical suspicion of tracheobronchial pathology were included in the study. MDCT-Virtual bronchoscopy (VB) and fiberoptic bronchoscopy (FB) was performed in all the cases. FB detected 29 lesions in 28 patients of which one patient had two lesions, whereas MDCT identified 27 lesions. In the remaining 7 patients no airway lesions were detected on either MDCT or FB.

FB detected 18 intraluminal obstructive lesions, 8 extra luminal compressive lesions and 3 dynamic airway lesions. MDCT detected 18 intraluminal obstructive lesions, 8 extra luminal compressive lesions and one dynamic airway lesion

1. Intraluminal obstructive lesions

A total of 18 intraluminal obstructive lesions were detected in our study. FB and VB detected all the lesions. Post intubation tracheal complications were the most commonly obstructive lesions seen in 14 cases. Prolonged tracheal intubation can cause ischemic/pressure injury to the tracheal mucosa with or without associated injury to cartilage rings. Depending on type of injury the appearance of the tracheal luminal narrowing was divided into circumferential stenosis (n=11 lesions) (fig. 1), intraluminal membrane (n=2 lesions) (fig. 2) and intraluminal synechiae (n=1 lesion). 4 cases of foreign body aspiration were seen lodged in left and right main bronchus in two patients each (fig. 3). In 7 of our patients no abnormality was found either on MDCT or FB. The sensitivity and specificity was 100 %. The positive and negative predictability value was 100%.

2. Extraluminal compressive lesions

A total of 8 extraluminal compressive lesions were detected in our study on both MDCT and FB. FB showed the extraluminal compressive lesions as a smooth indentation on the airway wall with intact mucosa. The exact etiology could not be ascertained on FB. However, MDCT also clearly delineated the exact cause of extraluminal compression. The vascular causes of compression were due to double aortic arch in two patients, innominate artery compression, left pulmonary artery sling and aberrant left subclavian artery in one patient each. Two patients had paratracheal bronchogenic cyst compressing the airway and one patient had a large subcarinal lymph nodal mass causing compression of left main bronchus. The sensitivity and specificity was 100 %. The positive and negative predictability value was 100%.

3. Dynamic airway lesions

A total of 3 dynamic airway lesions (tracheo-bronchomalacia) were detected in our study on FB whereas, VB also detected only 1 case of bronchomalacia. It failed to recognize the two cases of tracheomalacia. The sensitivity and specificity was 33.3% and100% respectively. The positive and negative predictability value was 77.7% and 100% respectively.

The combined sensitivity and specificity of MDCT-VB in assessing the airway lesions is 93% and 100% respectively. The positive and negative predictive value is 100 and 77.8% respectively.

DISCUSSION

We evaluated the tracheobronchial tree in 35 patients with clinical suspicion of airway diseases using MDCT. Virtual reconstruction of the tracheobronchial tree was done using the same data sets without acquiring any additional scans. Complete evaluation of the tracheobronchial tree was possible in all patients by MDCT. A total of 29 lesions were included in our study.We classified the various lesions affecting the airway as: intraluminal obstructive lesion, extraluminal compressive lesion and dynamic airway compromise.

In our study, MDCT-VB had a high accuracy in diagnosing intraluminal obstructive and extraluminal compressive disease .VB could assess the airway distal to a proximal occlusive lesion and detect extra lesions which could not be evaluated on FB. It could also provide information about the cause of compression. The results are similar to the previous sudies conducted in evaluating the role of MDCT in airway diseases.[12-15] Tracheomalacia was seen in two patients on FB who had tracheostomy tube in situ but was not seen on VB because MDCT failed to detect the dynamic causes of airway compromise as the scans were only obtained in a single respiratory phase in our study. Acquisition of scan in both inspiratory and expiratory phases can help us identify thses dynamic airway lesions as seen in few studies. [16] We however identified a case of bronchomalacia in a young child who had a diffuse narrowing left main bronchus and showed diffuse areas of air trapping in left lung on expiratory scan. We had a prevoius scan of

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the patient which was esentially normal. The overall sensitivity, specificity, positive and negative predictive value of MDCT-VB in detecting airway lesions was observed to be 93%%, 100%, 100% and 77.8%% which corraborated with the studies published earlier.[17,18] The low negative predictive value in our study was due to the inability of MDCT and VB to diagnose cases with dynamic airway compromise (tracheomalacia).

MDCT also provided additional information about the airway pathology which had a strong bearing on the surgical management of these patients. It could estimate the grade of stenosis, length of stenosis and distance of stenotic segment from a fixed landmark.

On MDCT we also obtained a comprehensive view of the entire thorax besides the airway. It therefore, gave additional information about the disease process that could not be obtained on FB. It provided information about the mediastinal structures including the status of the thoracic vessels and the lymph nodes which helped us to determine the cause of extra- airway pathology which directly affect the airway.

To conclude MDCT- virtual bronchoscopy is a rapid, accurate and non-invasive investigation modality for evaluation of patients with suspected airway pathology which can be performed without the additional risk of radiation. It is highly accurate in evaluating intraluminal obstruction and extraluminal compressive lesions.. Additionally, VB also allows access to sites beyond a stenosis and can detect lesions which cannot be seen on fiberoptic bronchoscopy due to the inability of bronchoscope to negotiate through a proximal occlusive lesion. MDCT-VB, however, cannot be used to perform diagnostic and therapeutic interventions like biopsy or foreign body retrieval. Also, single respiratory phase MDCT cannot detect dynamic airway lesions. Even with these limitations MDCT-VB has an immense potential to emerge as a non-invasive, rapidly reproducible investigation tool which can provide information about primary airway disease as well as extraluminal pathologies affecting the airway.

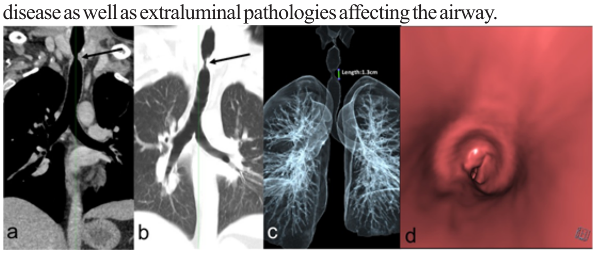

Fig 1: Post intubation tracheal stenosis. (a,b) Coronal MPR in mediastinal and lung window setting shows a focal segmental narrowing of tracheal lumen (arrow). (c) VRT shows the length of narrowing of 1.3 cm (d) corresponding appearance on virtual bronchoscopy.

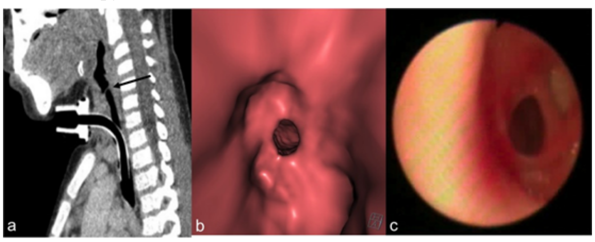

Fig 2:Tracheal membrane. (a) Sagittal image show a circumferential thin membrane in subglottic airway (arrow). Tracheostomy tube seen in situ.(b) Virtual bronchoscopy shows a membrane causing narrowing of airway lumen (c) corresponding apperarence on fiberoptic bronchoscopy .

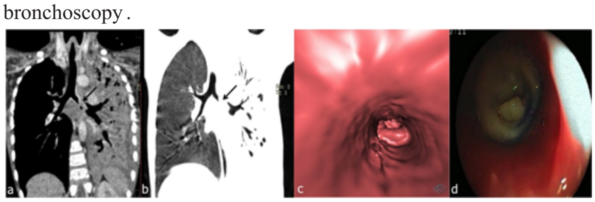

Fig 3:Foreign body aspiration. (a) Oblique coronal MPR image shows a tissue density occluding the left main bronchus (white arrow) with complete consolidation of left lung and bronchiectatic changes. (b) Coronal MinIP image shows attenuation of left main bronchus (arrow) with non-aeration of left lung. (c) Virtual bronchoscopy shows complete obstruction of left main bronchus with smooth lobulated surface that was confirmed to be endobronchial foreign body on fiberoptic bronchoscopy (d).

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