HRCT Versus Volume Rendering (Three Colors, Three Densities Lung Images) in Diagnosis of Small Airway Disease: A Comparative Study

SAHAR M. EL-MASHAD, M.D.*; YOUSSRIAH Y. SABRI, M.D.*; HEBA H. ASSAL, M.D.** and MAI B.I. GHONEIMY, M.Sc.*

The Departments of Radiology* and Chest**, Faculty of Medicine, Cairo University

Abstract

High-resolution computed tomography plays a key role in the detection and classification of small airways diseases. The functional imaging may allow us to detect lung disease early before structural abnormalities develop.

In this study, we describe the variety of HRCT findings in small airways diseases, and comparing finding of Min IP images to VR 3D 3 colors images.

Key Words: High Resolution Computed Tomography (HRCT) – Multi-Detector Computed Tomography (MDCT) – Small airways diseases.

Introduction

HIGH-RESOLUTION CT (HRCT) scanning of the chest often proves to be the most important diagnostic tool, because different subtypes of bronchiolar disorders may present with characteristic image findings [1]. Which plays a key role in the detection and classification of small airways disease, when combined with relevant clinical and pathologic findings, leads to a more accurate diagnosis [2].

The imaging manifestations of small airways disease on high-resolution computed tomography include centrilobular nodules and branching nodular (tree-in-bud) opacities, or the demonstration of mosaic attenuation that is typically exaggerated on expiratory computed tomography [3].

Visual detection of signs like air trapping and mosaic perfusion is facilitated by post-processing methods such as minimum Intensity Projection (minIP) [4].

The density of the lung parenchyma, measured on CT scans in Hounsfield Units (HU), results from the X-Ray attenuation by intralobular structures, such as alveolar membranes, interstitium, capillaries, or small conductive airways. Therefore, any change in either of them is able to modify the lung attenuation values, and this provides an indirect tool to assess distal airway remodeling [5].

The functional images may allow us to detect lung disease early before structural abnormalities develop [3].

The ability of CT to measure airway structure/function assessing not only individual lungs but also individual lung segments and even smaller regions, unlike conventional lung function tests, makes these techniques very powerful and useful [3].

In addition, quantitative methods based on lung density measurements are available. These methods are more objective and more reproducible, however, they require specific software [4].

Three-dimensional models of the lungs were reconstructed with analysis software. Threshold limits of –500 to –1,024 HU were applied to exclude soft tissue surrounding the lung and large vessels within the lung [6].

Aim of work:

The aim of this study is to compare the results of HRCT and VR (3D 3 colors lung images) in diagnosis of small airway diseases.

Patients and Methods

This study involved 12 patients; 7 females and 5 males, age range 7-73 years (average of 27.58
years. Cases referred to Radiology Department in Kasr Al-Aini Hospital from Chest and Rheumatology Departments for HRCT, from May 2012 till August 2014.

These cases presented by variety of symptoms, clinical background and history.

<table>
<thead>
<tr>
<th>Presenting symptoms and clinical background</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dyspnea</td>
<td>12</td>
</tr>
<tr>
<td>Cough</td>
<td>3</td>
</tr>
<tr>
<td>Low grade fever</td>
<td>1</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>3</td>
</tr>
<tr>
<td>Scleroderma</td>
<td>1</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>3</td>
</tr>
<tr>
<td>Bronchial asthma</td>
<td>3</td>
</tr>
<tr>
<td>History of bird breading</td>
<td>1</td>
</tr>
<tr>
<td>History of industrial injury</td>
<td>2</td>
</tr>
</tbody>
</table>

All patients were subjected to:

1- Thorough clinical examination with history taking, general and chest examination.

2- Laboratory tests mostly complete blood picture, the other tests were considered according to case e.g. sputum analysis, sputum culture, tuberculin test, etc.

3- MDCT of the chest:

HRCT chest techniques were done in the Radiology Department Kasr Al-Aini Hospital using Toshiba Aquilion MSCT 64 channels set.

HRCT was done with min IP reconstruction and VR (3 colors, 3D lung images).

Reconstruction of the images done using different reconstruction software available at the workstation.

Several reconstruction techniques done each aiming for a certain diagnostic achievement as follows:

- 2D minimum Intensity Processing (min IP):
  The use of this technique, which highlights low-attenuation voxels, enhances detection of low-attenuation foci of lung attenuation. It thus enhances the visibility of airways within lung parenchyma and shows areas of air trapping without need for an expiratory study.

- VR (3 colors, 3D volume rendering lung images):
  - Images sent to work station to be processed using software, three-dimensional models of the lungs were reconstructed. Threshold limits of 500 to 1,024 HU were applied to exclude soft tissue surrounding the lung and large vessels within the lung.
  - Selecting lung density analysis preset, the lungs are automatically segmented from chest wall, mediastinum, airways and vessels.
  - Segmentation is image analysis, it is often essential to distinguish the object of interest from the rest of the image, usually referred to as the background.
  - This software automatically analyses the density distribution of the lungs into different colors by using color mask tool, by entering the density range, selecting the desired color, which indicates the area that the HU ranges occupy in the image.
  - Selecting the red color (or any other color) for voxels with a density lower than –900/–950 HU (emphysematous lung) and the blue color (or any other color) for voxels with a density between –500 to –750/800 HU (normally aerated lung) and the yellow color (or any other color) for voxels with a density between –750/–800 to –900/–950 HU (pre emphysematous changes denoting small air way disease) Fig. (1).
  - We can measure the attenuation of each voxel.

Results

This study involved 12 patients; 7 females and 5 males.

Range of age was from 7-73 years (average of 27.58 years).

Different HRCT findings suggestive of small airway disease were reported, (Table 1).
Table (1): HRCT findings in small airway disease.

<table>
<thead>
<tr>
<th>HRCT finding</th>
<th>Number</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mosaic perfusion</td>
<td>5</td>
<td>41.7</td>
</tr>
<tr>
<td>Patchy ground glass and mosaic perfusion</td>
<td>1</td>
<td>8.3</td>
</tr>
<tr>
<td>Centrilobular nodules</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>Tree-in-bud pattern</td>
<td>3</td>
<td>25</td>
</tr>
<tr>
<td>Bronchectasis</td>
<td>2</td>
<td>16.7</td>
</tr>
<tr>
<td>Hyperinflation</td>
<td>7</td>
<td>58.3</td>
</tr>
<tr>
<td>Peribronchial thickening and bronchiolectasis</td>
<td>2</td>
<td>16.7</td>
</tr>
<tr>
<td>Beading of the bronchial wall (suggesting follicular bronchiolitis)</td>
<td>1</td>
<td>8.3</td>
</tr>
</tbody>
</table>

VR (3 colors, 3 densities lung images) findings of the small airway diseases:

It allowed visualization of different lung attenuation areas as different colors, varying from blue color for areas of high attenuation varying between –750 to –500 HU, yellow color for areas of medium attenuation varying from –750 to –950 HU and red color for areas of low attenuation varying from –950 to –1024 HU Fig. (2-4).

VR (3 colors, 3 densities lung images) allow better diagnosis of diffuse low attenuation of lung, in diffuse small airway diseases (seen in 3 cases), that could be missed if evaluating HRCT images alone.

In 9 cases, findings of small airway diseases where evident in both VR and min IP images.

Fig. (1): Lung 3D volume rendering preset curve.

Fig. (2): HRCT chest (A: Coronal, B: Min IP and C: 3 color 3D volume rendering lung images) showing mosaic perfusion of both lung fields (sparing left upper lung lobe) with evidence of air-trapping detected in Min IP images that appear as diffuse yellow areas (pre-emphysematous area) in the VR lung images. PFT showed obstructive changes, picture is impressive of BO.
Fig. (3): HRCT chest (A: Coronal, B: Sagittal, C: Min IP and D: 3 color 3D volume rendering lung images) showing mosaic perfusion of both lung fields (more on right side) with evidence of air-trapping detected in MinIP images that appear as yellow area (pre-emphysematous area) and red area (emphysematous area) in the VR lung images. PFT showed obstructive changes, picture is impressive of BO.

Fig. (4): HRCT chest (A: Coronal, B: Sagittal, C: Min IP and D: 3 color 3D volume rendering lung images) showing mosaic perfusion of both lung fields with evidence of air-trapping detected in Min IP images that appear as yellow area (pre-emphysematous area) and red areas (representing emphysematous areas) in the VR lung images. PFT showed obstructive changes, picture is impressive of BO.
Discussion

The prevalence of airway diseases has been increasing in the past two decades [7].

High-Resolution CT (HRCT) scanning of the chest is the most important diagnostic tool to guide diagnosis of small airway disease as bronchiolar disorders may present with characteristic image findings [1].

CT attenuation values may vary significantly between different manufacturers’ CT scanners. This is especially true in the less attenuating structure such as the trachea [8].

Volumes in the range –500 to –750 HU were considered to represent pixels including tissue such as small bronchi, vessels and borders with denser structures [9].

CT emphysema and CT air trapping were calculated; CT emphysema was defined as the percentage of voxels below –950 Hounsfield Unit (HU); CT air trapping was defined as the ratio of expiratory to inspiratory mean lung density [10].

The areas between –750 and –900 HU, designated % high density spectrum (% HDS), representing lung tissue in the denser normal range, thus, we consider that areas with a density of –750 and –900 HU represent lung tissue with minimal interference from emphysema and denser structures and this area can represent a good surrogate for measuring the degree of local inflammation in the lung [9].

In this study, HRCT with VR was done for 12 patients. 3 patients showed diffuse air trapping seen only in VR (3 colors, 3 densities lung images) which could’t be detected in min IP images.

VR lung images showed areas of abnormal low attenuation (emphysematous and pre-emphysematous areas) appearing as red and yellow colored areas respectively, which were corresponding to areas of air trapping appearing in min IP images.

Using min IP images, it is possible to detect air trapping without need for neither additional expiratory images nor special software (like that needed for VR 3 colors 3D lung images). We found similar results in both HRCT and VR findings.

VR (3 colors, 3 densities lung images) and min IP reconstruction allow better diagnosis of diffuse low attenuation of lung, in diffuse small air way diseases (seen in 3 cases), that could be missed if evaluating HRCT images alone.

• VR 3 colors, 3 densities lung images also allow visualization of mild change in attenuation of lung, denoting early small airway disease.
• VR 3 colors 3D lung images allow assessing not only individual lung but also individual lung segments and even smaller regions.
• VR 3 colors 3D lung images together with Min IP images allow diagnosis of air trapping without need of expiratory images.

Summary and Conclusion:

The use of VR (3 colors 3D lung images) allowed better visualization of areas of abnormal low attenuation values, especially in cases of diffuse low attenuation value of the lung (diffuse small air way disease, diffuse air trapping).

VR (3 colors 3D lung images) allow assessing not only individual lung but also individual lung segments and even smaller regions.

HRCT with different post imaging processing is currently the imaging modality of choice in diagnosis and classification of different small airway diseases.

Min IP is promising post processing technique allowing diagnosis of air trapping without need for neither expiratory images nor special software (like that needed for VR 3 colors 3D lung images).

References

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