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Original Article

Radiology Section

Utility of Maximum Intensity Projections in Volumetric High Resolution Computed Tomography Lung in the Evaluation of Diffuse Lung Diseases- A Retrospective Analysis

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ABSTRACT

Introduction: Though volumetric High Resolution Computed Tomography (HRCT) has increased the sensitivity of diagnosing diffuse lung diseases, there are some drawbacks related with lesion detection. Post processing techniques like Maximum Intensity Projection (MIP) can help in increasing the sensitivity of HRCT further.

Aim: To study various possible utilities of MIP in HRCT lung.

Materials and Methods: A retrospective cross-sectional study was done in a tertiary care hospital, including all Computed Tomography (CT) scans performed in July 2020 to August 2020, with multiple lung findings and diffuse involvement of lungs. Two radiologists reviewed the base mean axial images of 1 mm and MIP images in sliding scale from 2 to 10 mm in lung window. They recorded the findings in every scan based on widely accepted basic pattern of interpretation of HRCT thorax. The slice/slab thickness that best depicted each finding was noted. Inter reader agreement was calculated for each finding.

Results: Fifty nine CT cases, which included scans of 34 males and 25 female patients with a mean age of 37.4±12.5 years were reviewed. There was near perfect to substantial agreement between the two radiologists on various findings (kappa >0.75). MIP images of 6-10 mm slab thickness were best suited to detect smaller nodules, assess vessel size in areas of mosaic attenuation and detect dense lesions in images with poor breath hold. The MIP images of 2-5 mm thickness were useful in detecting the location in relation to secondary pulmonary lobule, reticular densities and crazy-paving densities.

Conclusion: The MIP being an easy to use and readily available post processing technique, when used with volumetric HRCT dataset of thorax enhanced the value of HRCT in detecting various lesions.

Keywords: Mosaic attenuation, Nodules, Reticular densities

INTRODUCTION

With the advent of Multi Detector Helical Computed Tomography (MDCT), high resolution images of thickness less than 1 mm can be reconstructed which are helpful in evaluating suspected focal and diffuse lung diseases [1,2]. They help in identifying the distribution pattern of lesions in the lungs, which help in arriving at a diagnosis, sometimes obviating the need for a tissue diagnosis [3-6]. However, with such thin images, it is often difficult to differentiate tiny abnormal densities from the density of normal vessels in the lung [7-9]. Though volumetric High Resolution CT (HRCT) has increased the overall sensitivity in detecting pathologies [10], there are studies which highlight the limitations of HRCT and the radiologists themselves, in interpreting the scans. Inconsistencies and inaccuracies have been found among radiologists in reporting HRCT thorax [3,7,11]. Few studies have been done to find if post processing techniques like Volume Rendering Technique (VRT), MIP guide us in detecting smaller nodules better [7-9]. A few more possible utilities of MIP images in diffuse lung pathologies have been observed, which potentially can enhance the sensitivity of the HRCT images. This study was done to find and verify the various possible advantages of MIP images in evaluating volumetric HRCT thorax.

MATERIALS AND METHODS

A retrospective cross-sectional study was undertaken in November 2020 including CT scans from July 2020 to August 2020, in Department of Radiodiagnosis of a Tertiary care hospital. Institutional Ethical Committee clearance was taken for the study.

Inclusion and Exclusion criteria: All CT thorax cases, performed in July 2020 to August 2020 in the Department and reported as diffuse involvement of the lungs, were selected for the study. Even CT scans reported as 'suboptimal due to poor breath hold' were included. CT scans with solitary parenchymal pathologies and unilateral involvement were excluded from the study.

Study Procedure

Two radiologists with seven years experience each in chest imaging and blinded to the CT reports were asked to review the cases. The radiologists were provided with 1 mm thin contiguous mean high resolution axial images of the chest acquired on a 16 slice CT scanner (Toshiba, Activion). A 21.5 inch iMAC system with screen resolution of 1920×1080, 3.06 GHz Intel Core2 duo processor and NVIDIA Geforce 9400 256MB graphics was provided for viewing the images on an Osirix application (OS×10.8.5). The reviewers evaluated the given set of mean images first and then used the MIP application with slab thickness from 2 to 10 mm (sliding scale) in lung window (window level: -500 HU, window width: 1500) to detect the possibility of each of the finding enumerated in [Table/Fig-1].

The list of findings were designed based on the widely accepted basic pattern of interpretation of HRCT thorax [12,13]. Accordingly a nodule refers to a well-defined dense lesion of less than 3 cm. Reticular densities refer to net-like abnormalities. Areas of increased attenuation include ground glass densities within which vascular markings, can be seen and consolidations, in which vascular markings though present, cannot be delineated separately. Decreased attenuation areas are cysts (with discrete walls) and areas of emphysema (no distinct walls). Nodules are further described based on their location in relation to a secondary pulmonary lobule.

Basic pattern	Finding
Dominant pattern	Nodular densities
	Reticular densities
	Increased attenuation areas (Ground glass opacities, consolidation)
	Decreased attenuation areas (Cysts, emphysema)
	Mosaic attenuation
	Crazy paving
Location in relation to secondary pulmonary lobule	Centrilobular/perilymphatic/random
Location within the lungs	Upper versus lower or central versus peripheral predominance

[Table/Fig-1]: List of findings based on the widely accepted basic pattern of interpretation of HRCT thorax.

The secondary pulmonary lobules are the peripheral most areas which are bound by interlobular septae on all sides. If the nodules are located within the lobule, they represent centrilobular nodules. Nodules located in the septae are perilymphatic and nodules randomly arranged without any specific distribution are said to be randomly arranged. Mosaic attenuation refers to interspersed areas of increased and reduced densities. Crazy paving densities are ground glass densities with thickened interlobular septae within [12,14].

The reviewers recorded the slice/slab thickness that best depicted the finding. In case, no advantage of MIP images was found over the base images in detecting such findings, base images were deemed to be the best. This process was repeated for each finding and every case. The best found image slice/slab thickness was classified into three sets for tabulation purposes. The first set was the original 1 mm mean base images, the second set was MIP images of 2 to 5 mm thickness and the third was MIP images of 6 to10 mm thickness.

STATISTICAL ANALYSIS

The data was entered in Statistical Package For The Social Sciences (SPSS) software (version 25) and inter-reader reliability (kappa coefficient) was calculated for each finding.

RESULTS

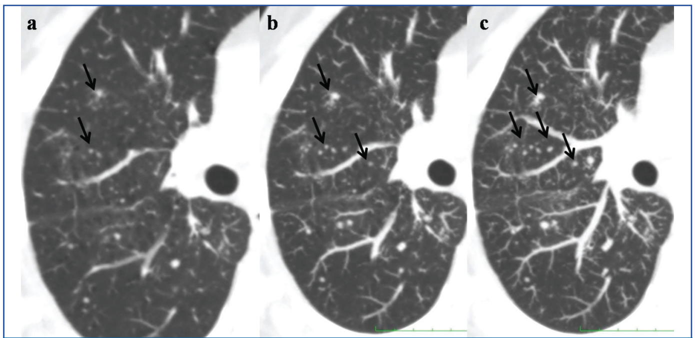
A total of 59 HRCT thorax cases were reviewed and included 34 males and 25 females. The mean age of the patients was 37.4±12.5 years with a minimum age of 16 years and maximum of 65 years. Among the cases that were included in this study were diagnosed cases of interstitial pneumonias (27), miliary tuberculosis (9), hypersensitivity pneumonitis (7), bronchiolitis (8), metastases (5), vasculitis (3). All included cases had multiple lung lesions of varying types. The observations of both reviewers on the best image set for each finding is depicted in [Table/Fig-2].

MIP images of 6-10 mm thickness were found more suitable to detect smaller nodules [Table/Fig-3] and to assess the vessel calibre in mosaic attenuation areas [Table/Fig-4] which is critical in arriving at a diagnosis. The MIP images of 2-6 mm were found helpful to detect reticular densities [Table/Fig-5] and subtle areas of crazy paving [Table/Fig-6]. MIP images of different slab thicknesses fared better than the 1 mm base images in all our cases in identifying the location of the small nodules in relation to the secondary pulmonary lobule [Table/Fig-7]. MIP images offered no distinct advantage in visualising areas of increased or decreased attenuation, over the mean images. Additionally, both the reviewers found that MIP images of 6-10 mm help to assess images with poor breath hold in detecting nodules and increased density areas within [Table/Fig-8].

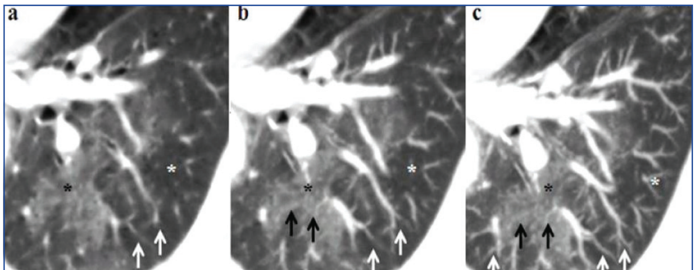
Overall the reviewers opined that in cases with multiple closely arranged densities, 2-5 mm MIP slabs were beneficial and thicker slabs of 6-10 mm were advantageous in a setting of sparsely distributed lesions.

Findings	Number of cases	Reviewer 1			Reviewer 2			Kappa coefficient for inter-reader agreement
		1 mm mean images (set 1)	2-5 mm MIP images (set 2)	6-10 mm MIP images (set 3)	1 mm mean images (set 1)	2-5 mm MIP images (set 2)	6-10 mm MIP images (set 3)	
Nodular	41	-	1	40	-	-	41	0.95
Reticular	22	2	20	-	7	15	-	0.78
Increased attenuation	16	16	-	-	14	-	2	0.92
Decreased attenuation	8	8	-	-	8	-	-	1
Location in relation to secondary lobule	41 (nodules only)	-	16	25	-	10	31	0.80
Location within the lung	59 (all findings)	59	-	-	59	-	-	1
Mosaic attenuation	8 (for size of vessels)	-	-	8	-	-	8	1
Crazy-paving	8	3	5	-	3	5	-	1
Evaluation of images with poor breathhold (for nodules and increased attenuation only)	7	-	-	7	-	2	5	0.79

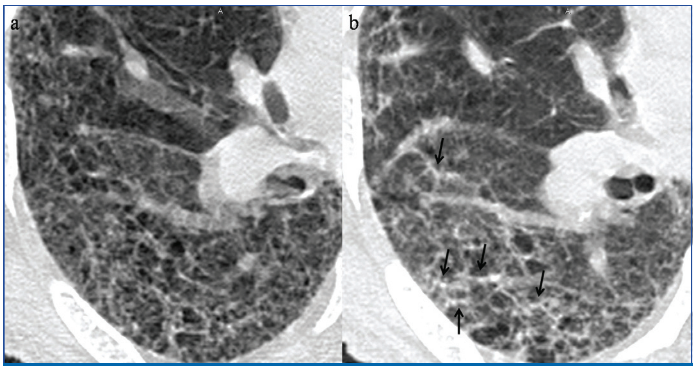
[Table/Fig-2]: Consolidated findings of the two reviewers with inter-reader agreement for each finding.



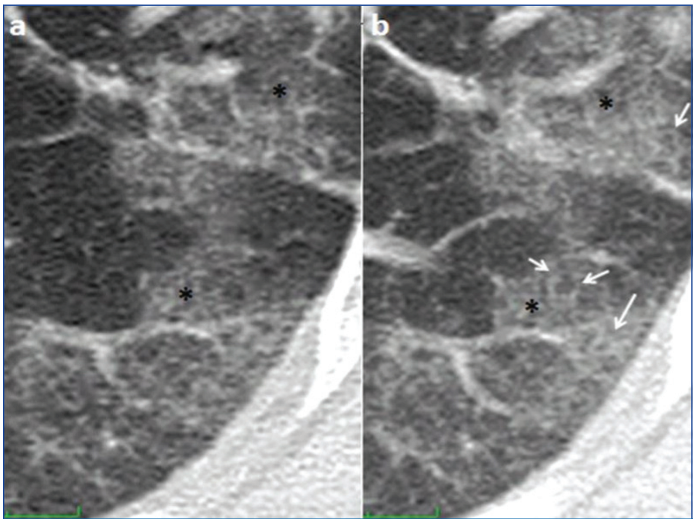
[Table/Fig-3]: Depicting conspicuity of small lung nodules (black arrows) in: (a) 1 mm mean image; (b) 4 mm thick MIP image; and (c) 9 mm thick MIP image. MIP images detect more number of small nodules as distinct from vessels.



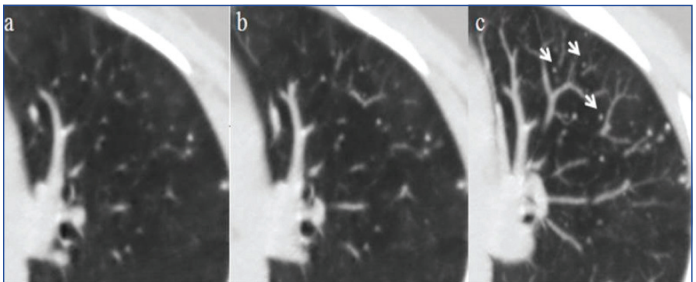
[Table/Fig-4]: Depicting mosaic attenuation. Dense areas (black asterisk) are interspersed amidst less dense areas (white asterisk): (a) 1 mm mean image; (b) 4 mm thick MIP image; and (c) 8 mm thick MIP image showing comparison of calibre of normal pulmonary vessels (white arrows) and smaller calibre vessels (black arrows). Smaller calibre vessels are seen in denser areas suggesting that denser areas are abnormal.



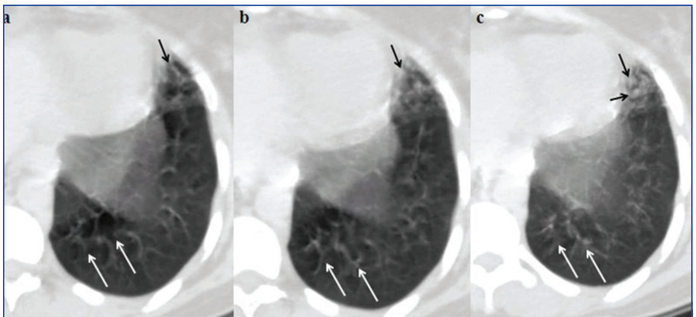
[Table/Fig-5]: Depicting interlobular septal thickening/reticular a) 1 mm mean image; b) 4 mm thick MIP image (black arrows depicting more obvious densities).



[Table/Fig-6]: Depicting ground glass opacities (black asterisk) in both: (a) 1 mm mean image; and (b) 3 mm thick MIP image. However, interlobular septal thickening (white arrows) within these ground glass opacities are more distinctly seen in MIP image.



[Table/Fig-7]: Depicting small lung nodules (white arrows) in: (a) 1 mm mean image; (b) 4 mm thick MIP image; and (c) 10 mm thick MIP image. 10 mm MIP image is showing distinctly the location of nodules between the septae (centrilobular nodules).



[Table/Fig-8]: Depicting images acquired with poor breathhold: (a) 1 mm mean image; (b) 3 mm thick MIP image; and (c) 9 mm thick MIP image. 9 mm MIP image is depicting the vascular markings sharper (white arrows) than other images. Also, note nodular densities which are more distinct in 9 mm MIP image (black arrows).

DISCUSSION

Identifying the pattern of lung involvement is the basic role of HRCT thorax. Together with clinical input, such pattern detection narrows the differentials, sometimes pin pointing to the most plausible diagnosis [3-6]. Though such images have high sensitivity, there are still some lacunae. It is difficult and laborious to distinguish small 2-4 mm nodules and reticular opacities from normal vessels leading to false negatives [7-9]. In this context, MIP images have been used to increase the accuracy of small nodule detection. MIP is a post processing technique which forms an image by selecting only the highest density voxels in the lines that are projected through the volume data [13].

The present study, found MIP slab thickness of 6-10 mm to be more sensitive which is in agreement with Kawel N et al., who found that MIP slab thickness of 8 mm was superior to VRT for lung nodule detection [7]. Coakley FV et al., used 15 mm MIP images to improve odds of nodule detection [8]. In the present study, slab thickness of more than 10 mm was not used as it led to crowding and overlapping of pulmonary vessels and nodules, potentially obscuring the nodules. Studies on other possible applications of MIP in CT thorax have not been done earlier.

MIP slabs better delineated secondary pulmonary lobule, which is the epicenter for several pathologies. Identifying if the nodules are within the lobule or in its wall is an important prerequisite to come at a particular set of differentials. Centrilobular nodules are seen in conditions like bacterial infections, hypersensitivity pneumonia, bronchoalveolar carcinoma whereas perilymphatic nodules are prevalent in sarcoidosis and lymphangitic carcinomatosis etc. Random distribution is seen in miliary tuberculosis and metastases [12].

The MIP images proved more helpful in identifying the abnormal areas in mosaic attenuation by identifying vessel calibre in the areas. The smaller vessel calibre indicates pathology and the area of normal vessel calibre represent normal lung. This distinction is critical in differentiating vascular versus peripheral airway disease which is entirely different set of pathologies [15]. In the present study, thin (2-5 mm) MIP slabs also scored over the regular mean 1 mm images in detecting reticular densities and areas of crazy paving appearance.

In some cases adequate breathhold may not be possible due to the urgency/criticality of the patient condition. Such images tend to be blurred due to motion artefacts which can obscure the underlying subtle pathologies and create artefacts like false ground glass densities, pseudo bronchiectesis, double fissures etc., [16,17]. MIP images proved to be helpful in such cases by making the images sharper and accentuate dense lesions like nodules, consolidations, reticulations etc.

The MIP did not add any additional information in case of hypoattenuating lesions like cysts, honeycombing, emphysema. Infact, The MIP tends to obscure them. MIP did not prove to be advantageous in recognising consolidations and ground glass opacities, other than in cases with inadequate breathhold.

Considering the results of this study and with increasing use of volumetric HRCT, MIP images may prove to be advantageous in interpreting the findings better. MIP images can be reconstructed from the volumetric data hence no additional exposure to radiation is needed. As post processing techniques are readily available by default, in the present MDCT consoles, it has no additional financial implications. MIP is easy to use and there is no requirement of additional formal training for the same.

Limitation(s)

In the present study, MIP was not compared to other post processing techniques like VRT. The MIP requires volumetric dataset which can be acquired in multislice scanners. Our findings cannot be applied to HRCT images of single slice scanners.

CONCLUSION(S)

The MIP is an easy to use post processing technique which, when applied to volumetric HRCT dataset, enhances the capability of assessing smaller nodules, reticular opacities and areas of crazy paving. MIP images are also superior in evaluating areas of mosaic attenuation and images with poor breathhold.

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