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Original Article

MDCT (multi-detector CT) evaluation in ILD (interstitial lung disease): Comparison of MinIP and volumetric HRCT (high resolution CT) images

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ABSTRACT

The aim of the study: Is to compare the role of minimum intensity projection (MinIP) images with that of volumetric high resolution computed tomography (HRCT) images in the diagnosis of interstitial lung diseases (ILD).
Patients and methods: 180 patients (149 females and 31 males) were included in this prospective study that took place over a duration of two and half years. All patients underwent HRCT and MinIP images. The positive findings were compared recording which technique was better and if MinIP adds a value in reaching an accurate diagnosis.
Results: MinIP images showed better visualization of traction bronchiectasis, ground glass opacities and mosaic attenuation pattern, as well as, the cystic lung changes seen in LAM. While MinIP did not add a significant value in thick-walled cystic changes e.g.: honeycombing.
Conclusion: MinIP is one of the multiplanar techniques of HRCT that proved throughout our study to be an informative complementary tool increasing the observer confidence and agreement regarding some findings as compared with HRCT alone.

1. Introduction

Interstitial lung diseases (ILD) forms a huge group of diffuse parenchymal abnormalities that are presented in more than one hundred different forms. [1,2].

The histopathology of the lung changes varies form granulomatous inflammation to extensive pulmonary fibrotic changes associated with parenchymal (architectural) distortion [1,4,5].

This group of diseases is associated with substantial morbidity and mortality. Thus, a multidisciplinary approach including clinical, pathological and radiological correlation is required to reach an accurate early diagnosis, to plan the proper management and to monitor the disease progress and treatment response [2,4–6].

Over the past two decades, HRCT (high resolution computed tomography) of the chest became accepted as the gold standard imaging modality in the diagnosis of ILD as it provides invaluable information that can be diagnostic or suggest further work up [7].

Nevertheless, reaching an accurate diagnosis in ILD group is still considered a challenge to radiologists since these diseases show a wide variety of HRCT findings, reflecting their complex pathology [3] as a result, searching for additional imaging tools would be of value in reaching an accurate diagnosis.

New MDCT (multi-detector computed tomography) multiplanar volumetric rendering techniques of the chest like MIP (maximum intensity projection), MinIP (minimum intensity projection), SS-VRT (surface shaded volume rendering), and VE (virtual encoscopy) enable better visualization and provide more diagnostic capabilities. They allow more exploration of the fine anatomical details and are now widely available. Still not all radiologists are familiar with such techniques, therefore, they are not fully utilized in daily clinical practice [8–12].

One of these techniques is the MinIP which is by definition, "a data visualization method that enhances the visualization of low-density structures in a certain given volume" [8]. It allows projecting voxels of the lowest attenuation value generating a single bi-dimensional image [13].

The subtle difference in density between the endobronchial air and the lung parenchyma, corresponds to an attenuation difference

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of 50–150 HU, which allows visualization of the bronchi below the subsegmental level [10].

In chest imaging, the bronchial tree being air-filled, and being the least dense structures can be explicitly visualized in a MinIP generated image before administration of contrast medium [12]. This grants enhancing the detection of even subtle areas of low attenuation, or areas of regional heterogeneity in the lung parenchyma as in mosaic attenuation in airway diseases [9–11].

The aim of our work is to compare the role of minimum intensity projection (MinIP) images with that of volumetric high resolution computed tomography images in the diagnosis of interstitial lung diseases.

2. Patients and methods

2.1. Patients

The study was approved by the hospital's ethical committee, and an informed consent was obtained assuring respect of the confidentiality of the medical records.

180 patients (149 females and 31 males) were included in this prospective study that took place over a duration of two and a half years.

All patients were sent to do HRCT of the chest as a part of the diagnostic process to investigate the possibility of ILD or to monitor the treatment response and the disease.

2.2. Methods

HRCT and reconstruction of MinIP images were performed for all patients in the radiology department of Kasr Al Aini hospital-Cairo University.

2.2.1. HRCT technique

The scans were performed using a SOMATOM, Emotion, Siemens, 16-MDCT scanner. Scans were acquired at end inspiration with patients placed in the supine position. No contrast medium administered.

The scout was taken during holding breath in full inspiration using parameters of 120 kV and 25 mA. The scan parameters were as follows: slice thickens 1 mm, interval 0.7 mm, pitch 1.5, gantry tilt 0, FOV depending on the patient's size, kV 120, mAs130, rotation time 0.5 s and total exposure time was 8–10 s. The scan covered the whole thorax.

Following acquisition, the acquired images were transferred to a dedicated post-processing workstation and volumetric measurements were obtained by applying the multiplanar reformation function at slice thickness of 5 mm.

Complementary mediastinal images were taken.

2.2.2. MinIP technique

MinIP coronal images were reconstructed by adjusting the window width and level to be (1000/-70) respectively, then coronal reformatted images were obtained using almost the same kV and mA used in the conventional HRCT with special emphasis on the central airways and the lower lobes.

2.3. Image evaluation and data analysis

Conventional HRCT images and MinIP Images were interpreted together and the results of HRCT and MinIP images were compared with HRCT considered as the study reference in our work since it is the well-established technique in the diagnosis of ILD in literature and in most institutes.

Other parenchymal or mediastinal findings were recorded to help in the diagnostic process.

The main items that were compared in both techniques are:

- Ground-glass opacities
- Mosaic attenuation of the lung parenchyma
- Fibrotic changes causing traction on surrounding airway structures
- Thickened interstitium
- Reticular opacities
- Honeycombing
- Cysts (their lucency and wall thickness)

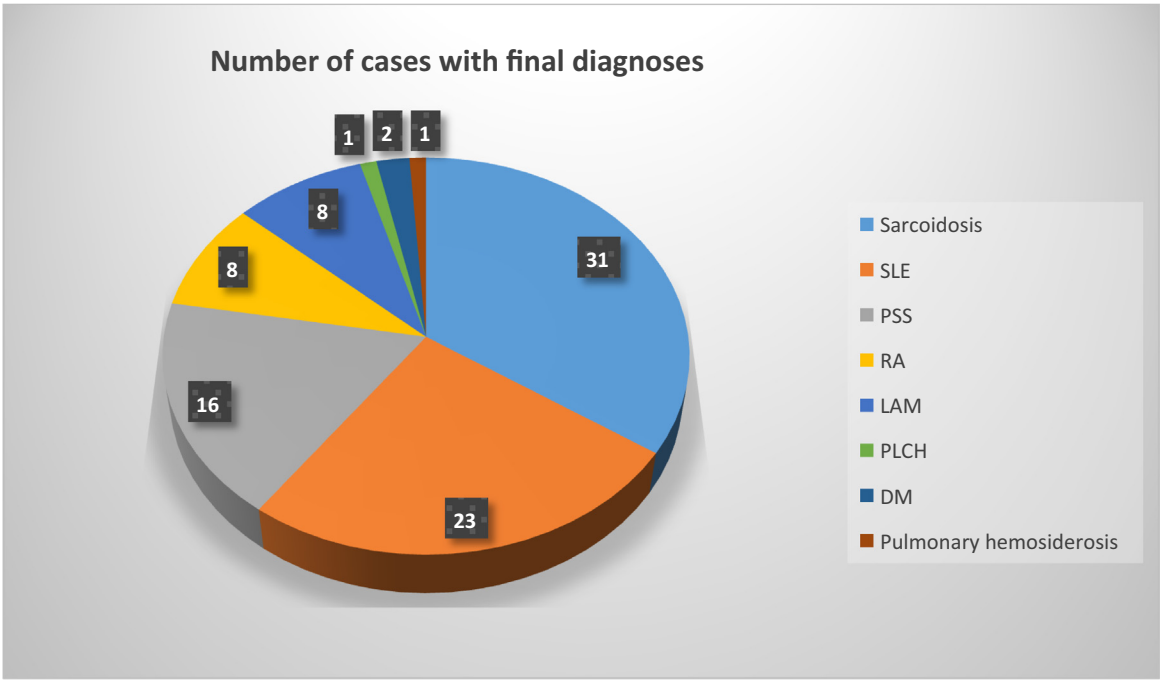

Chart 1. Showing the number of cases with final diagnoses in the study. **SLE:** Systemic lupus erythematosus, **PSS:** Progressive systemic scleroderma, **RA:** Rheumatoid arthritis, **LAM:** Lymphangiomyelomatosis, **PLCH:** Pulmonary Langerhans 'cell histiocytosis, **DM:** Dermatomyositis.

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Table 1
Comparison of findings between conventional HRCT images and MinIP images.

CT Finding		More obvious in MinIP than HRCT images	Equally obvious in MinIP and HRCT images	Less obvious in MinIP than HRCT images
Diffuse ground-glass opacification		+		
Patchy ground-glass opacification		+		
Patchy ground-glass opacification with areas of air trapping (mosaic attenuation)		+		
Fibrotic changes (traction on surrounding airway structures)		+		
Reticulations (prominent inter or intra-lobular interstitium)				+
Honeycombing				+
Cysts	Wall			+
	Lucency	+		
Cavitating nodules			+	
Patches of airspace consolidation			+	

(+) signifies that the lesion is more obvious.

Table 2
The number of cases and their percentage regarding each finding in HRCT and in MinIP images (n = %).

Item	More evident in MinIP images	Equally seen in MinIP & HRCT images	More evident in HRCT images	Total number of cases
Ground-glass opacities (GGO)	94 (80.3%)	23 (19.6%)		117
Mosaic attenuation	16 (66.6%)	8 (33.3%)		24
Traction on airway structures by fibrosis	78 (100%)			78
Thick interstitium		8 (50%)	8 (50%)	16
Reticulations		8 (20.5%)	31 (79.4%)	39
Honeycombing (HC)		8 (33.3%)	16 (66.6%)	24
Cyst wall			16 (100%)	16
Cyst lucency	23 (58.9%)	8 (20.5%)	8 (20.5%)	39
Cavitating nodules		8 (100%)		8
Consolidation		31 (57.4%)	23 (42.5%)	54

GGO: ground-glass opacity, HC: honeycombing.

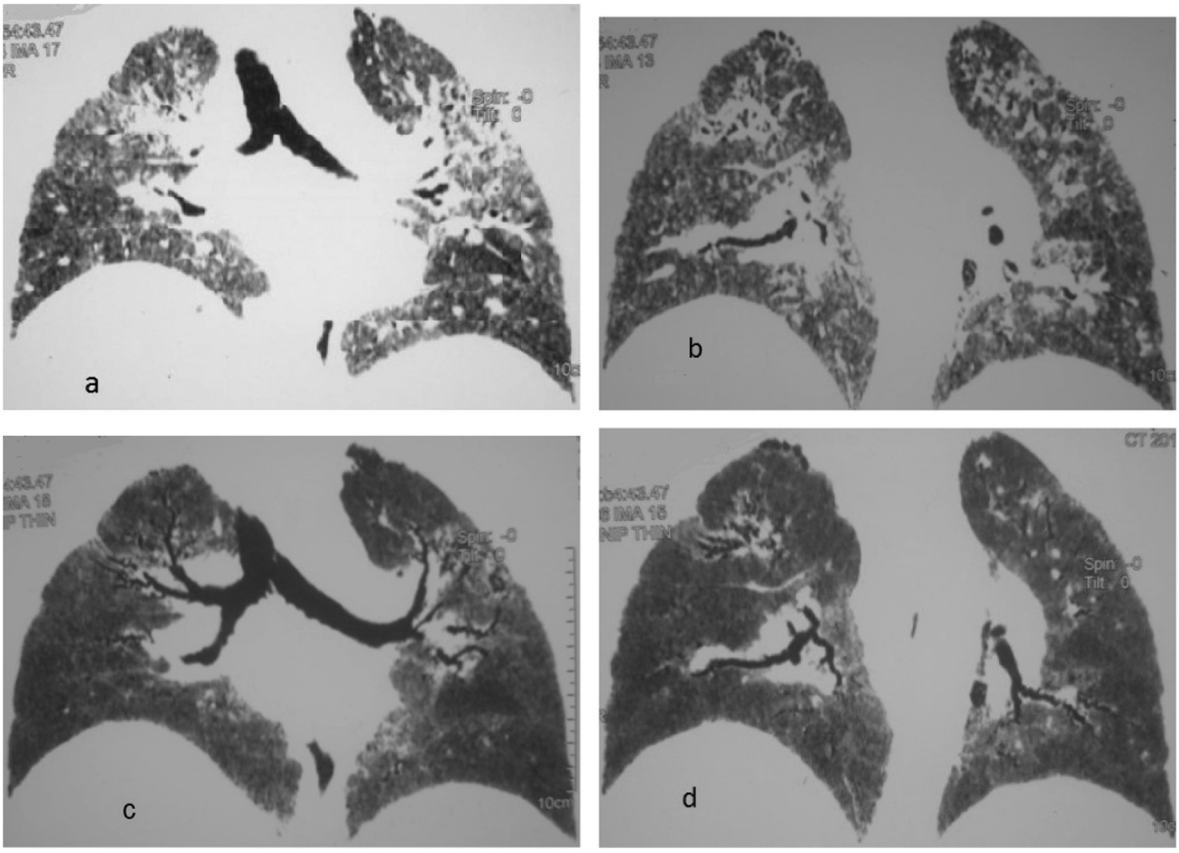

Fig. 1. (a–d): A 20-year-old male patient diagnosed with sarcoidosis was sent to undergo HRCT to monitor the disease progress. Coronal HRCT images (a, b) showing bronchocentric irregular opacities of fibrosis. Traction bronchiectasis and bronchiolectasis detected in the MinIP images (c, d) confirm the fibrotic nature of the lesion.

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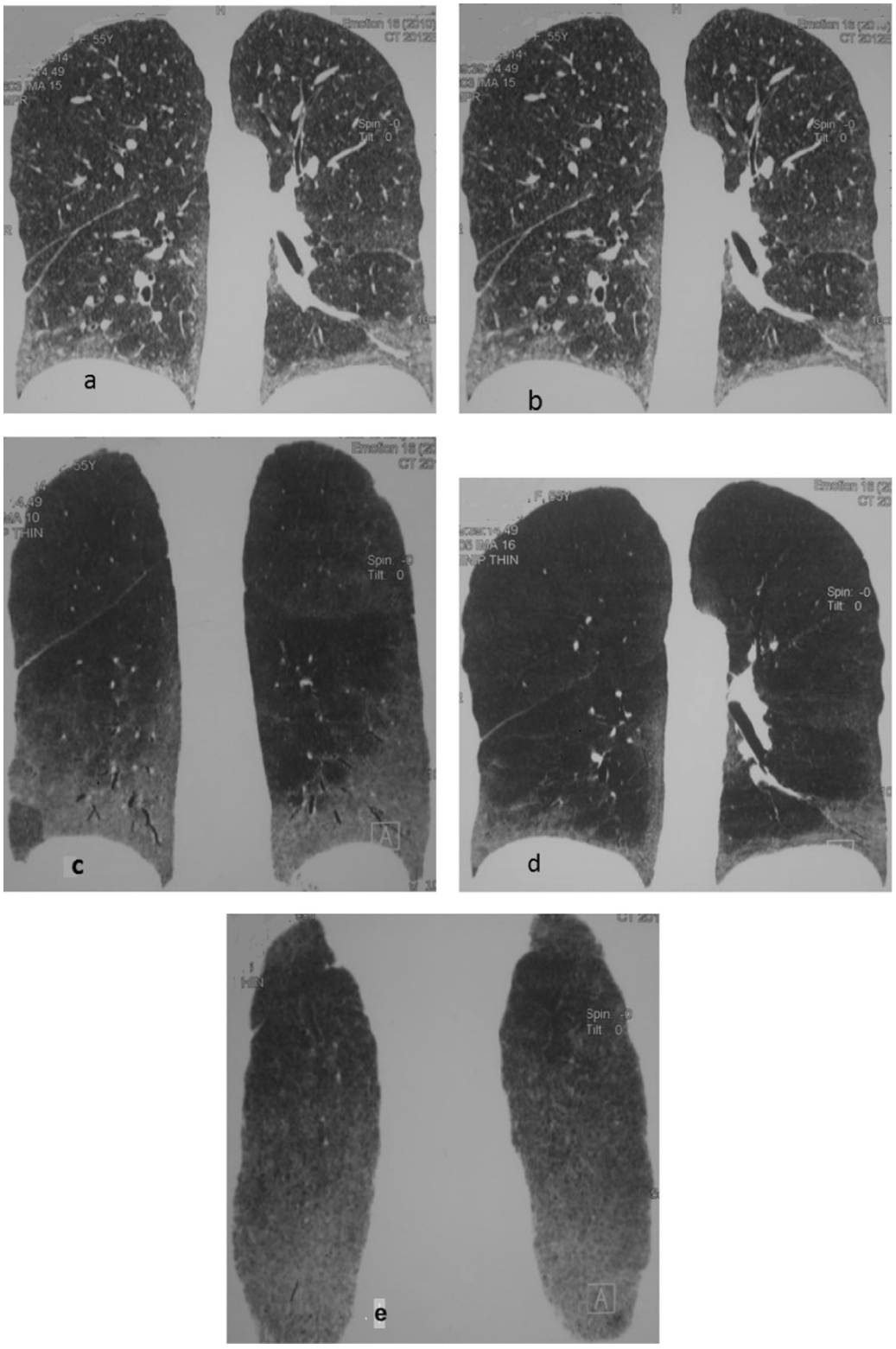

Fig. 2. (a–e): A 55-year-old female patient with IP. Coronal HRCT images (a, b) show bilateral predominantly basal ground glass opacities and bronchial wall thickening. MinIP images (c, d, e) show better visualization of the ground glass opacities, as well as mild traction bronchiectasis within denoting fibrosis.

- Nodules
- Consolidation

The scans were evaluated and compared by three radiologists with different experience duration of 28, 15 and 1.5 years.

3. Results

This study included 180 patients, 149 females and 31 males. Their age ranging between 13 and 56 years (average 24.081 years).

All patients had progressive dyspnea and dry cough.

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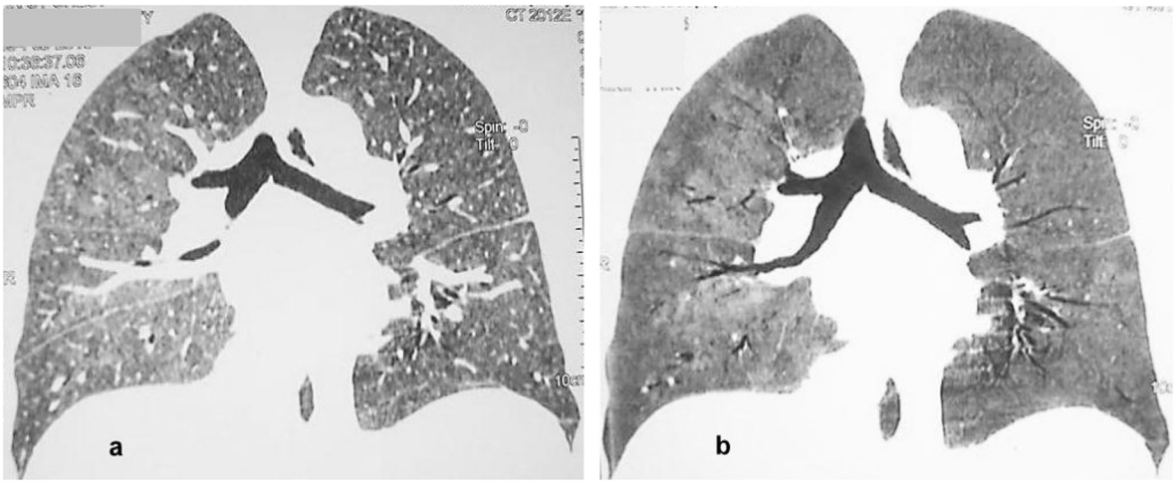

Fig. 3. (a, b): A 27-year-old female patient with recurrent hemoptysis and severe anemia. HRCT coronal image (a) show bilateral diffuse ground glass opacification which are more conspicuous in the coronal MinIP image (b). The case was biopsied and proved pathologically to be haemosiderosis.

Final diagnoses were known in some of the patient population after clinical, radiological, laboratory and in few cases, pathological correlation (Chart 1).

Biopsies were done in few cases and pathology were provided in three cases of LAM (Lymphangiomyelomatosis), two cases of atypical sarcoidosis, a case of PLCH (Pulmonary Langerhans 'cell histiocytosis) and a case of pulmonary hemosiderosis.

The total time of the examination and the reconstruction process took 10–15 min.

The items to be compared are illustrated in Tables 1 and 2.

Traction fibrotic bronchiectatic and bronchiolectatic changes mainly perihilar and upper lobar in location that were seen in most of the thirty-one cases of sarcoidosis included in our work were more evident in the MinIP images (seen in 100% of cases) than in those of conventional HRCT images (Fig. 1). The same was noted regarding the different fibrotic changes seen in the IIPs (idiopathic interstitial pneumonia) cases where MinIP images also showed subpleural ground-glass opacities and thickened interstitium.

Mosaic attenuation and ground-glass opacities (Figs. 2 and 3) were better visualized in MinIP images being seen in 66.6% and 80.3% respectively of the cases.

Regarding the cystic lung changes reported in our study; it was noted that MinIP was ahead of HRCT in visualizing the lucency of the cysts only but not their walls.

- LAM (Lymphangioleiomyomatosis) cases showed dispersed variable sized cysts were seen within normal lung parenchyma having imperceptible walls. The cyst lucencies were more conspicuous in the MinIP images, even the smaller cysts that were not seen in conventional HRCT images (Fig. 4).
- The pathologically proved PLCH (pulmonary Langerhans' cell histiocytosis) case showed bizarre shaped variable sized cysts at both upper lobes totally replacing lung parenchyma. Such lesions were hardly detected in the MinIP images as the cyst walls were inconspicuous (Fig. 5).
- Honeycombing on the contrary was better seen in conventional HRCT images as their walls were also not clearly visualized in MinIP images (Fig. 6).

4. Discussion

HRCT of the chest is now worldwide recognized as the main imaging tool in the diagnosis of ILD due to its highest sensitivity and specificity in this field [14].

ILD is a huge category whose patients share common non-specific clinical complaints [15].

Knowledge of the basic HRCT anatomy of the lung parenchyma and its different techniques is required to ensure appropriate interpretation of HRCT images [6,17] also, correlation with clinical and laboratory findings and referring to available previous imaging scans increase the possibility of reaching an accurate histospecific diagnosis [16].

The value of MinIP in diagnosis of ILD is hardly mentioned in literature. Very limited studies like Beigelman-Aubry et al. used it in research but did not implement it in the diagnostic process [10].

Our work included 180 patients over a duration of two and a half years who underwent HRCT to evaluate a known ILD, or for investigating the probability of the presence of ILD.

In our work, we integrated MinIP images in each HRCT exam as an additional complementary tool, to help reach an accurate diagnosis in the evaluation of different types of ILD owing to its value in delineating the difference in attenuation of the lung parenchyma and in better visualization of air-filled structures, mainly the bronchial tree, especially those affected by fibrosis leading to traction bronchiectasis and bronchiolectasis as reported by Perandini et al. [12].

We compared the positive findings in the HRCT and in the MinIP images.

Minimum intensity projection is the postprocessing technique of choice for the detection and characterization of most patterns of diffuse lung disease [10].

Throughout our study, MinIP proved to be an excellent tool in visualization of traction bronchiectasis and bronchiolectasis resulting from fibrotic changes mainly in the sarcoidosis cases. The dilated airway structures were more delineated in the MinIP images compared to the HRCT ones and those at the periphery were easily detected in MinIP images.

MinIP images showed better facility in evaluation of lung diseases presenting with low attenuation [21]. Cases showing areas of low attenuation in our work included ground-glass opacities and mosaic attenuation pattern of the lung parenchyma were better visualized in the MinIP images being seen in 80.3% and 66.6% of the cases respectively. This agrees with studies by Kauczor, Gotway et al. and Beigelman-Aubry et al. and others that reported that MinIP was of value in detection of the presence, distribution, extent and characterization of areas of ground-glass attenuation and mosaic perfusion [10,18–20].

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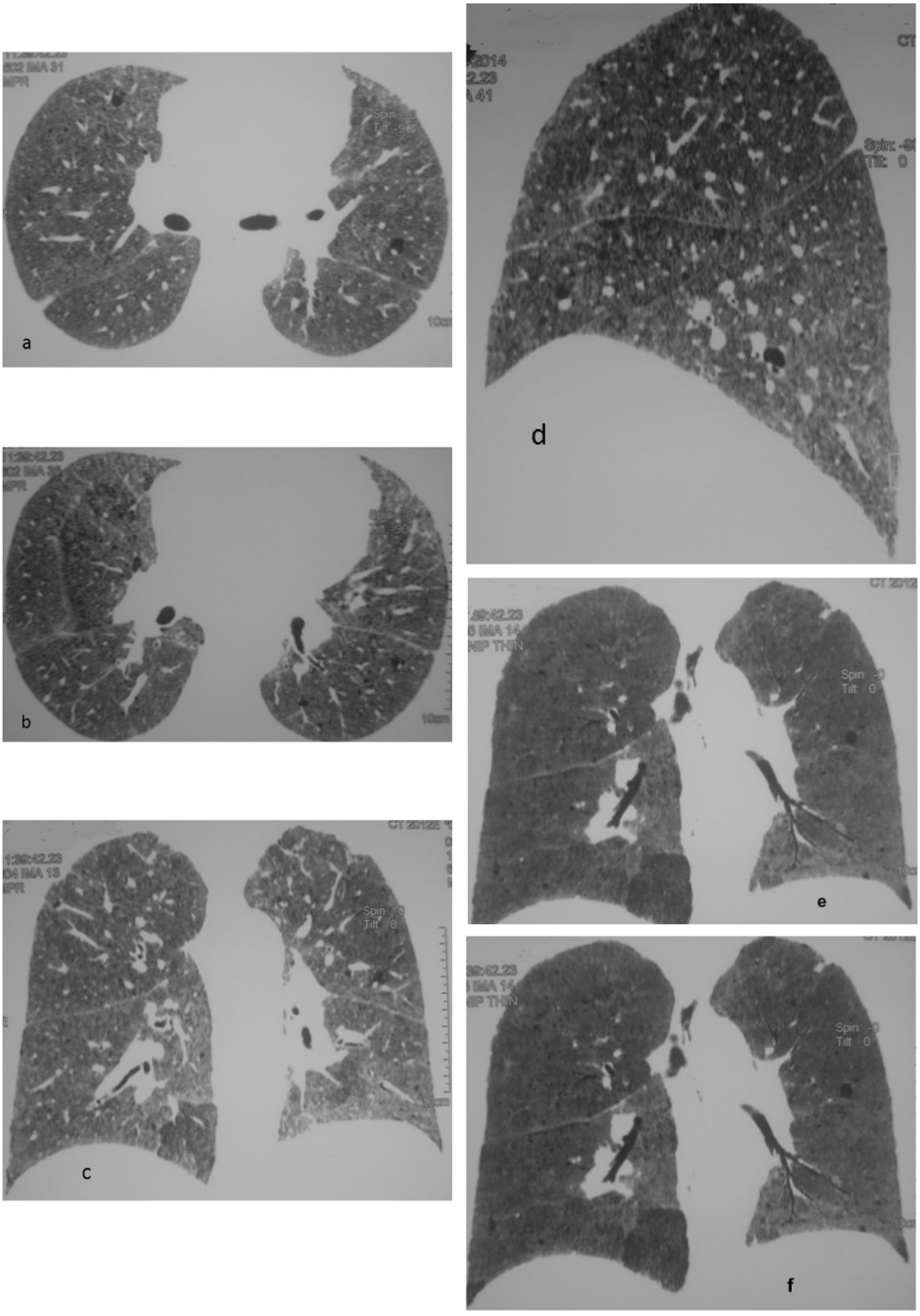

Fig. 4. (a–f): A 46-year-old female diagnosed with pulmonary LAM (Lymphangiomyelomatosis). HRCT axial (a, b) and coronal (c), sag (d) images show bilateral multiple variable sized cysts having imperceptible walls within the otherwise normal lung parenchyma. MinIP coronal image (e, f) show the bilateral numerous cysts even the smaller ones that were not seen in the HRCT images.

The cases in our study that showed cystic changes of the lungs included LAM and PLCH patients and cases showing honeycombing in the context of lung fibrosis.

Cases diagnosed with LAM disease (Lymphangioleiomyomatosis) in our work showed the typical appearance of LAM; multiple variable sized cysts having imperceptible walls against the normal lung parenchyma [22]. These characteristic findings were better detected in the MinIP images compared to HRCT. Furthermore, MinIP could detect smaller cysts that were not seen in the HRCT. This is in conformity with recent publication in 2016

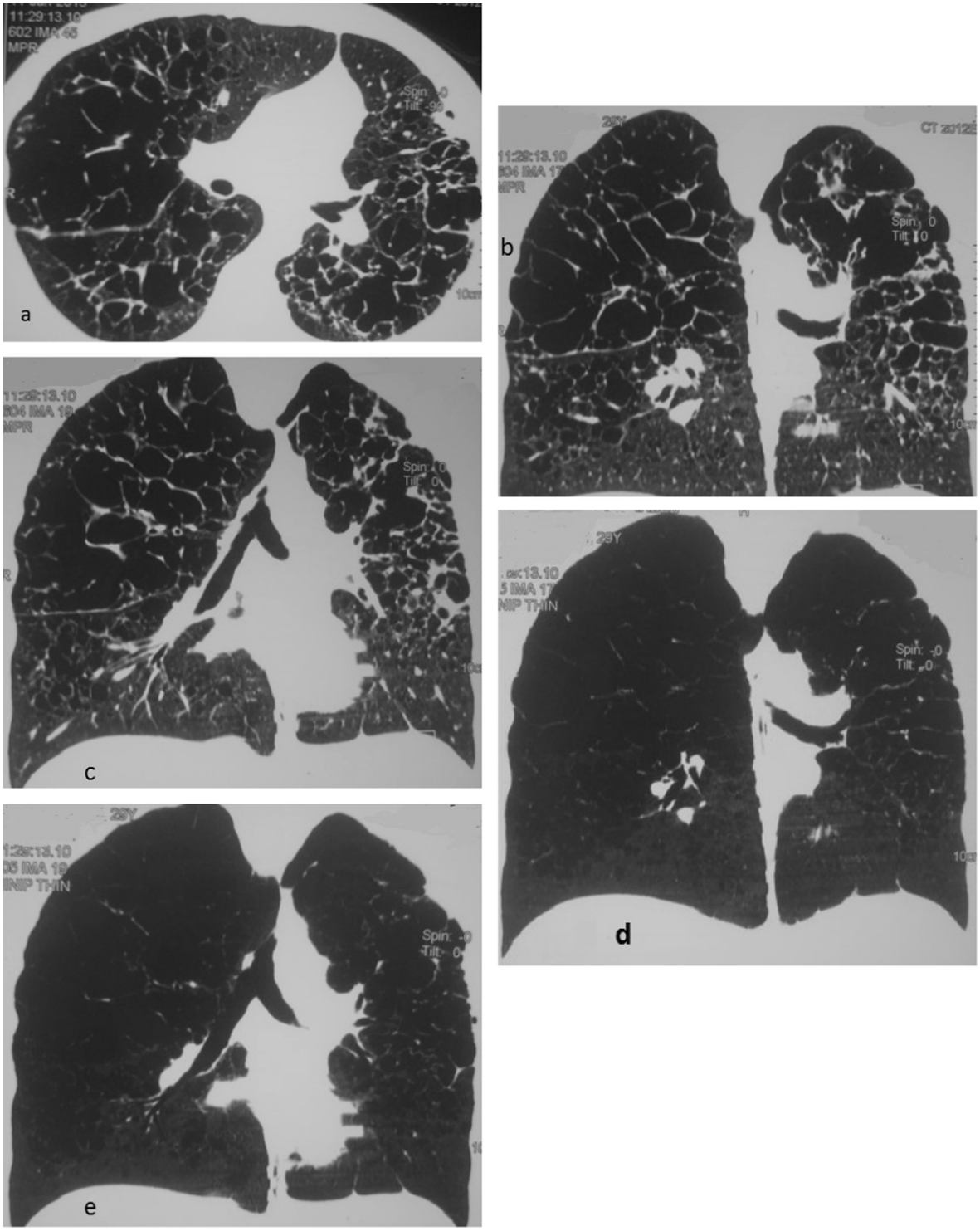

Fig. 5. (a–e): A 29-year-old heavy smoker male, known to have pulmonary Langerhans 'cell histiocytosis (PLCH) (pathologically proven). HRCT axial and coronal images (a–c) showing bilateral predominantly upper lobar bizarre shaped cysts showing thickened walls. Such changes were not clearly visualized in the MinIP coronal images (d, e) as the cysts lucencies were hardly seen and the thickened walls were not visualized.

conveying that MinIP improved the detection of pulmonary cysts [18].

However, MinIP did not add value in some cases presenting with cystic changes e. g.: honeycombing and thick-walled cysts.

Regarding the pathologically proven case of PLCH (pulmonary Langerhans' cell histiocytosis) in our work; it showed the typical bizarre shaped cystic lesions with relatively irregular thickened walls; that was accurately seen in the HRCT images, while MinIP was not informative as the thickened walls were not detected.

Regarding honeycombing which is a pathognomonic finding in UIP (Usual interstitial pneumonia) and can confirm the diagnosis of IPF (Idiopathic interstitial pneumonia) if combined with its clinical features [21,22]; it was accurately visualized in HRCT images in our work in cases showing different forms of lung fibrosis and

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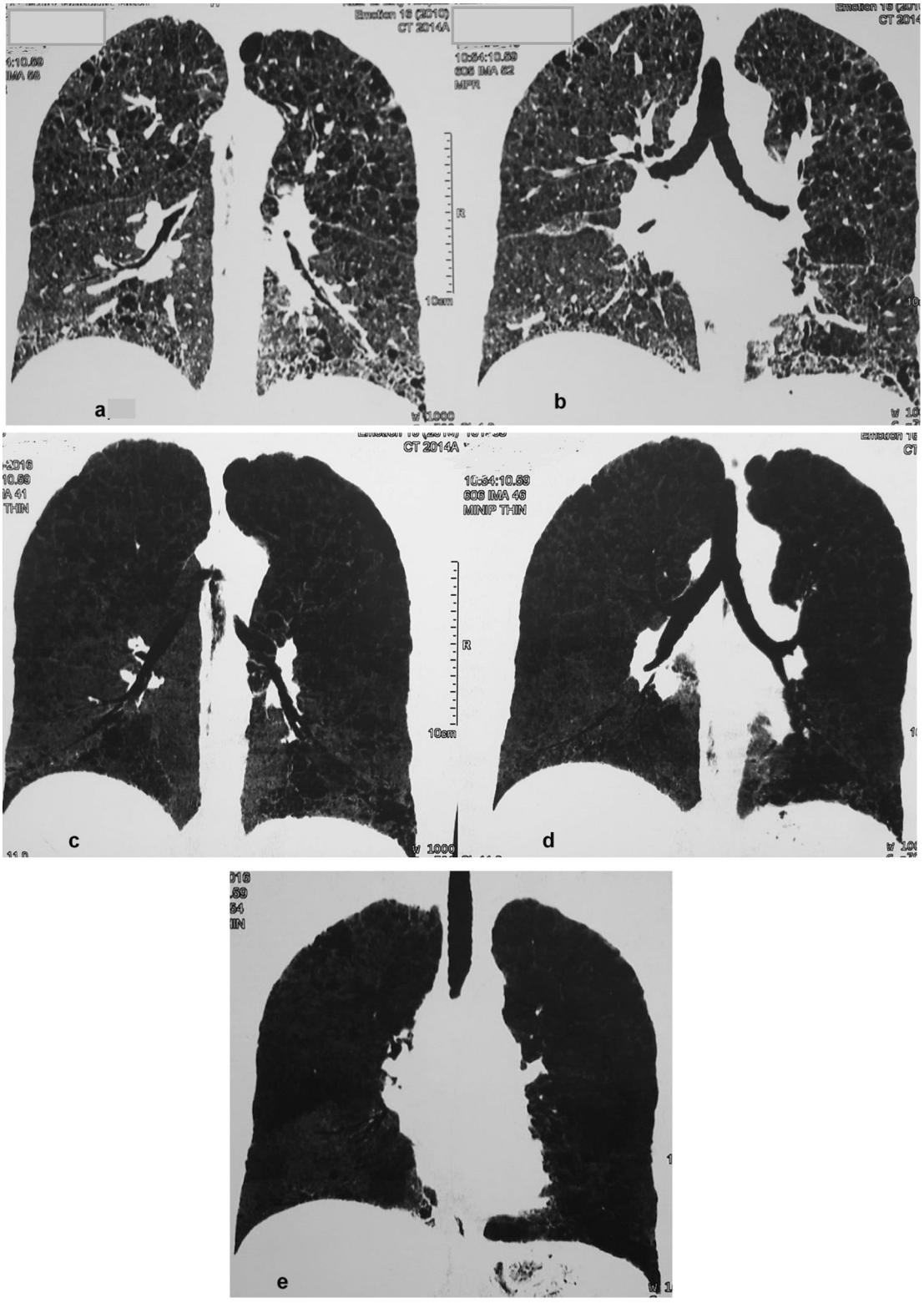

Fig. 6. (a–e): A 48-year-old female patient complaining of dyspnea on mild exertion and diagnosed with ILD was sent to do HRCCT for follow up. Coronal HRCT images (a, b) showed bilateral widespread predominantly basal fibrotic changes and honeycombing while the MinIP images (c–e) were not of value and such changes were hardly noted.

architectural distortion, however, it was hardly detected in MinIP images which was not able to delineate their thickened walls.

Our findings were in agreement with a recent study conducted by Watadani et al. in 2013 whose work that revealed that multiplanar reconstruction techniques were of value in differentiating bronchiectasis from honeycombing [21].

MinIP is one of the techniques that are still under research and in continuous evolution making a significant difference in the diagnostic process of ILD. It is advisable to gain the professional skills of appreciating these techniques and how to integrate each of them into clinical practice [23].

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Processing and reconstruction of new techniques like MinIP might increase the number of operations of each exam increasing its complexity leading to believing that these techniques increase the time of evaluation of the exam. However, the data gained is beneficial and the overall speed of reaching an accurate diagnosis is markedly improved [13,24,25].

We integrated MinIP in our department as a part of the routine HRCT scan. The process of reconstruction of MinIP images is now performed by our second and third-year residents, since it proved to be a rapid (not time consuming), and uncomplicated process. This agrees with what was stated in literature; that MinIP does not require much time or sophisticated skills [26].

However, we agree with Watadani et al. that MinIP cannot be used as a solo technique in the diagnosis of ILD. It is a complementary tool to the conventional HRCT technique helping in narrowing the differential diagnosis by increasing the observer confidence and inter-reader agreement as compared with using HRCT alone [21].

5. Conclusion

HRCT is a very powerful imaging tool in the evaluation process of ILD. Proper utilization of the its technical capabilities ensure accurate interpretation.

MinIP is one of the multiplanar techniques of HRCT that proved throughout our study to be an informative complementary tool increasing the observer confidence and agreement regarding some findings as compared with HRCT alone.

We recommend adding it as a complementary tool in the routine HRCT protocol in the diagnostic process of ILD.

Conflict of interest

The authors declare that there are no conflict of interests.

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