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Color-coded Narrow Lung Window Setting for Identification of Air Trapping in Small Airways Diseases

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Abstract

Introduction: Small airway obstruction is measured through assessment of air trapping which is may be the only sign of an early stage small airway disease in an otherwise normal lung.

Aim: the purpose of this study is to assess the ability of color-coded narrow lung window setting in the identification of air trapping in small airways diseases.

Subjects and Methods: We investigated 38 patients with clinically suspected small airways disease. Patients were referred to the radiology department in the period from July 2016 to June 2017.The MDCT examinations were done on Philips Brilliance 64-slice CT. Paired inspiratory and expiratory scans were obtained. The scans were reviewed on OsiriX-MD $^{v.8.5}$ DICOM viewer. Inspiratory images were displayed in the routine lung window setting and narrow lung window setting (WL$^{-800\ HU}$ & WW^{300}). Color-coded mapping was applied to the displayed routine lung window images and narrow lung window images using the rainbow spectrum in the CLUT, in which the blue color was edited for the regions ranging between (-860 to -950 HU) to improve the visualization of the air trapping areas. Scans were assessed for the presence or absence of air trapping.

Results: The expiratory CT detected the air trapping in all 38 patients, while routine lung window showed the corresponding low attenuation areas in (84.2%) patients in the form of mosaic attenuation pattern. The narrow lung window alone identified the low attenuation areas in 34 (89.5%) patients, however it couldn't discriminate between the air trapping regions and the emphysematous areas in the 4 COPD cases. The mosaic attenuation pattern was highlighted in 29 (76.3%) patients by the use of the color-coded mapping alone. The use of combined narrow lung window (WL^{-800} and WW ^{300}) and color-coded mapping was able to identify the air trapping areas in all patients almost like expiratory CT.

Conclusion: This study concluded that, the use of color-coded mapping of the narrow lung window setting may be sufficient for identification of air trapping and could be a reasonable alternative to expiratory CT.

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Introduction

Small airways disease is a broad term including numerous diseases that cause bronchiolar inflammation or fibrosis [1]. Bronchiolar changes can be too small to be visible directly but can cause indirect signs that suggest small airways involvement [2].

Air trapping is the indirect sign that reflects airway obstruction at the bronchiolar level and indicating the retention of excess gas in all or part of the lung [3]. According to Fleischner Society glossary [4],"air trapping is seen on end-expiration CT scans as parenchymal lung areas with less than normal increase in attenuation and lack of volume reduction".

The density differences that characterize the mosaic attenuation pattern on either inspiratory or expiratory CT images may be very subtle and close to the limit of visual detection, which might effects the detection of air trapping [5].

In this work, we supposed that if a narrow lung window setting, which increases the contrast difference between the low attenuation areas and the normal lung, combined with color-coded mapping in the inspiratory images; might have a synergistic effect in identification of air trapping in patients with small airways diseases.

Subjects and Methods

This study was approved by the board of medical ethics committee in our faculty. All patients were aware of the examination and informed consent was obtained.

The study included 38 patients (21 males and 17 females) with an age range from 18 to 62 years and a mean of 41.2 years. Patients with clinically suspected small airway diseases were referred to the MDCT unit in the Radiology department at Alexandria Main University Hospitals, in the period from July 2016 to June 2017.

All patients were subjected to full history taking, thorough clinical examination, conventional chest X-ray study and MDCT imaging. Laboratory tests were considered according to the case. Pulmonary function tests were done for all patients. The final diagnosis in this study was a consensus of clinical, laboratory, radiological findings and histopathological confirmation when feasible.

The MDCT examinations were done on Philips Brilliance 64-slice CT. Intravenous non-ionic contrast (ULTRAVIST Iopromide-Bayer imaging) was given for 20 patients based on the indication of the CT study.

Scanning parameters were as follows: volumetric high-spatial-frequency algorithm; slice thickness: 1mm; table speed for volumetric

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HRCT to enable the least cycles of breath-holds as possible; tube rotation: 0.6-0.9 s (0.75 s); detector collimation: 1 mm; KVp and mA per slice: 120 kVp and 200-300 mA.

Inspiratory CT scans were typically obtained at the end of full inspiration. Complimentary expiratory CT scans were performed; the expiratory maneuver was coached to the patients before the scan. Modulation of radiation dose burden in expiratory scans had been considered by reducing the tube current according to the case.

For adequate multi-planar reconstruction, scans were performed to cover the root of the neck down to the level of the adrenal glands. Images were studied on OsiriX-MD $^{v.8.5}$ DICOM viewer by at least two qualified radiologists with minimum five years of experience in HRCT chest reporting.

Several reconstruction methods were done, including: MPR, MIP, MinIP and VR, each aiming for a certain diagnostic achievement. Inspiratory Images were reviewed in the routine lung window setting and narrow lung window setting (WL^{-800} HU & WW^{300}). Color-coded mapping was applied for the routine lung window and the narrow lung window images using the rainbow spectrum in the color look up table (CLUT), with editing the blue color for the regions ranging between (-860 to -950 HU) to improve the visualization of the air trapping areas.

Scans were assessed for the presence or absence of air trapping. The presence of air trapping in each lobe was documented on a confidence scale of 0 to 3. The overall mean confidence for each observer was compared. Consensus diagnosis was used as the gold standard for the assessment of the diagnostic accuracy of each observer. A confidence score of 2 or more was considered diagnostic for presence of air trapping.

Results

The patients in this study presented by variety of symptoms, clinical background and history. The most common presenting symptoms were cough (36 of 38, 94.7%) followed by dyspnea (34 of 38, 89.5%). (Table 1).

The pulmonary function tests showed obstructive pattern in 25 patients (65.8%), mixed obstructive and restrictive pattern in 12 (31.6%) patients and restrictive pattern in 1 (2.6%) patient.

The underlying diseases were constrictive bronchiolitis 7 (18.4%) patients, asthma 5 (13.2%) patients, subacute hypersensitivity pneumonitis 5 (13.2%) patients, COPD 4 (10.5%) patients, chronic hypersensitivity pneumonitis 3 (7.9%) patients, mineral dust airway disease in 3 (7.9%) patients, atypical respiratory infections 3 (7.9%) patients, connective tissue diseases 2 (5.3%) patients, respiratory bronchiolitis interstitial lung disease 2 (5.3%) patients, bronchiolitis obliterans syndrome after hematopoietic stem cell transplantation 2 (5.3%) patients, diffuse panbronchiolitis 1 (2.6%) patient and primary ciliary dyskinesia 1 (2.6%) patient.

Clinical Presentation	No	%
Cough	36	94.7
Dyspnea	34	89.5
Wheeze	8	2101
Fever	4	10.5

Table 1: Distribution of the studied cases according to clinical presentation (n=38)

The HRCT findings in this study were air trapping (100%), mosaic attenuation pattern (84.2%), bronchial wall thickening (78.9%), centrilobular nodules (21.1%), ground glass centrilobular nodules (18.4%), centrilobular emphysema (18.4%), bronchiectasis (15.8%), consolidation or patchy ground glass opacities (15.8%) and interstitial fibrosis (7.9%).

The expiratory CT detected air trapping in all 38 patients, while the routine lung window showed mosaic attenuation pattern with the corresponding low attenuation areas in 32 (84.2%) patients.

The narrow lung window setting of the inspiratory images identified the low attenuation areas in 34 (89.5%) patients, however it couldn't discriminate between the air trapping regions and the emphysematous areas in the 4 COPD cases.

The use of the color-coded mapping for the routine lung window images highlighted the mosaic attenuation pattern in 29 (76.3%) patients.

The use of color-coded mapping of the narrow lung window (WL^{-800} and WW^{300}) images was able to identify the air trapping areas in all 38 patients almost like expiratory CT. (Figure 1-3).

Moreover, the expiratory CT was not able to distinguish between air trapping regions and the emphysematous areas in the 4 cases of COPD, while the use of colorcoded mapping of the narrow lung window (WL^{-800} and WW^{300}) could identify both areas clearly. (Figure 4).

Discussion

According to several researchers [1,6-8] the expiratory CT has an important role in the detection of air trapping by increasing the difference of lung attenuation between normal lung and air trapping region, because air trapping may be imperceptible on inspiratory images. However, it delivers extra radiation to the patient and obtaining expiratory CT images is not always straightforward as the patients may be unable to perform the technique.

Moreover, the human eye has an important limitation on the ability to distinguish different levels of gray, while it can distinguish thousands of colors. A trained eye can distinguish from 50 to 100 tones of different gray levels. Therefore it is impossible for the human eye to be able to interpret correctly the full range gray levels present in a radiological image that potentially contains 65,536 levels of gray [9].

In this study, the inspiratory CT in the routine lung window setting was not able to identify the contrast difference between the low attenuation areas and the normal lung in 6 (15.8%) patients while, the expiratory CT had identified the air trapping areas in all patients.

According to Matsuoka et al. [3] air trapping could be detected as decreased attenuation on expiratory CT as compared with the corresponding inspiratory images. However, in COPD patients the area of decreased attenuation includes not only air trapping but also areas of emphysema. Thus, this method would be influenced by the extent of emphysema.

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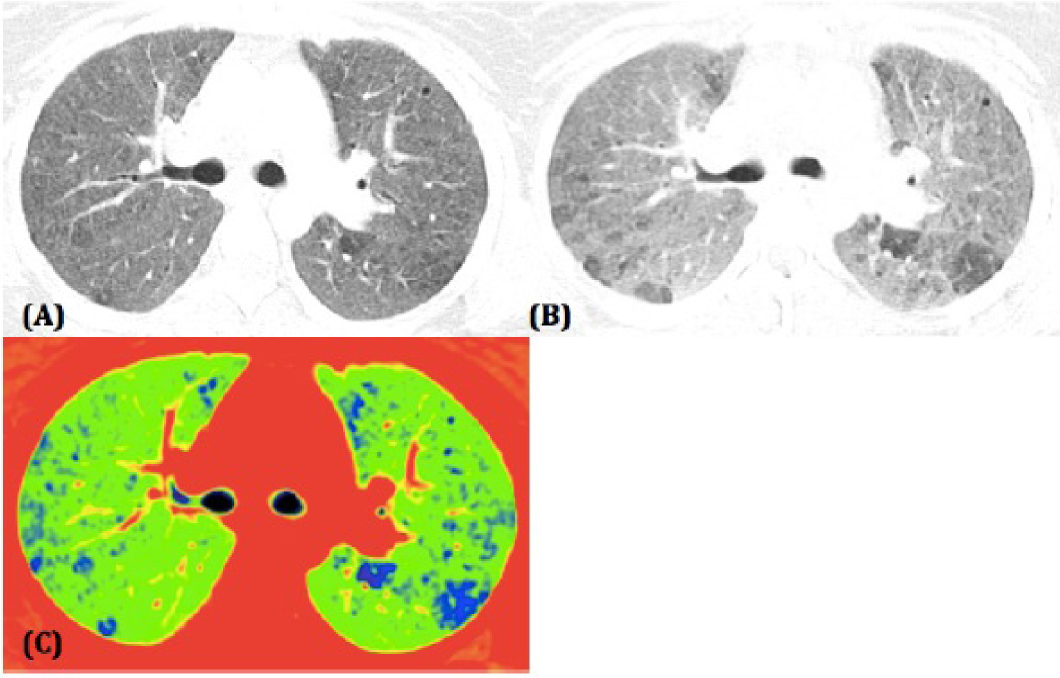

Figure 1: A 42 year-old female patient with rheumatoid arthritis presented by progressive dyspnea. (A) Axial inspiratory CT image showing mosaic attenuation pattern with subtle attenuation difference. (B) Axial expiratory CT image shows multiple bilateral lobular areas of air trapping (B) Corresponding combined narrow window color-coded inspiratory CT image shows the air trapping areas in blue color at the same locations as identified by the expiratory CT.

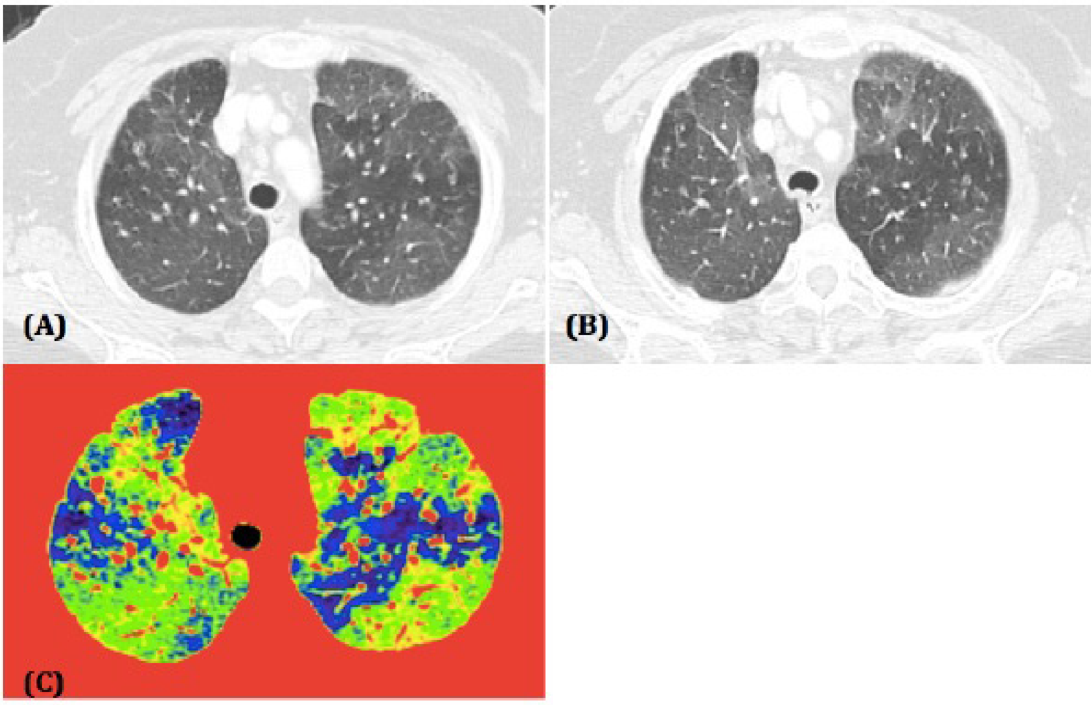

Figure 2. A 45-year-old male patient with constrictive bronchiolitis. (A) Axial inspiratory CT section through the upper lobes demonstrates mosaic attenuation pattern, the density differences in the lung parenchyma are subtle. (B) Expiratory CT image shows accentuation of the geographic low attenuation areas of air trapping, the adjacent areas of higher-attenuation lung represent the expected increase in attenuation at expiratory imaging, bowing of the posterior wall of the trachea (*arrow*) signifies good expiratory effort. (C) Corresponding combined narrow window colorcoded inspiratory CT image clearly identifies the air trapping areas (*blue areas*).

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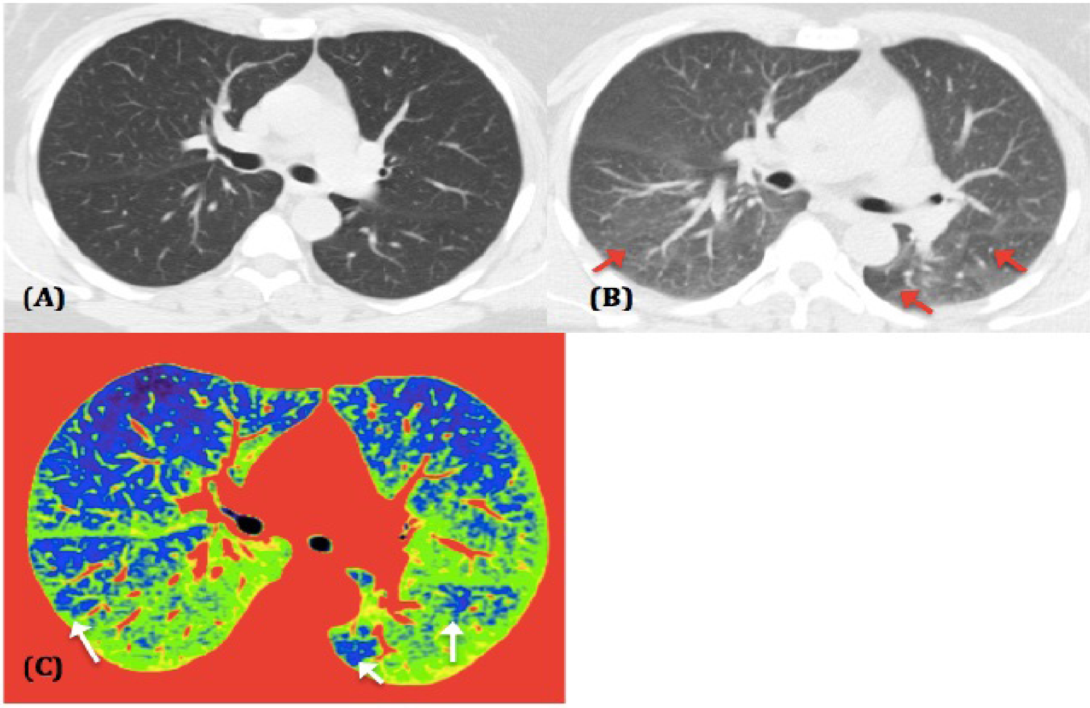

Figure 3: A 45-year-old female asthmatic patient with recurrent attacks of cough and wheezes. (A) Axial inspiratory CT image is normal. (B) Corresponding expiratory CT image shows lobular areas of air trapping (*red arrows*). (C) Corresponding inspiratory CT image displayed in color-coded narrow window shows clearly posterior lobular areas of air trapping in blue (*white arrows*).

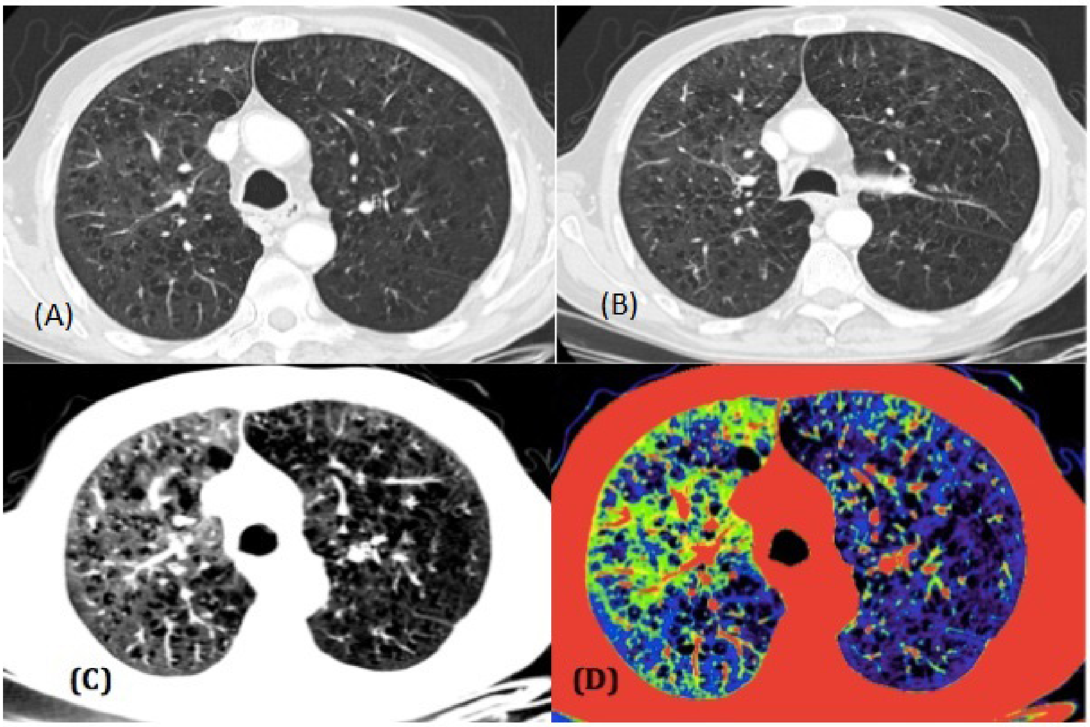

Figure 4. A 52-year-old male, heavy smoker presenting with cough and dyspnea. (A) & (B) Axial inspiratory and expiratory CT images show upper lobar centrilobular emphysema (*yellow arrow = central dot sign*) and diffuse large area of low attenuation, no clear difference between inspiratory and expiratory images could be appreciated. (C) Corresponding inspiratory axial CT image in narrow window accentuates the contrast difference between the normal lung and low attenuation regions. (D) Combined color-coded narrow window inspiratory CT image identifying the air trapping areas (*blue areas*) and shows the normal lung (*green areas*) & clearly distinguishing the emphysematous areas (*black areas*).

In the current study the use of paired inspiratory and expiratory scans were not able, on the basis of visual assessment, to distinguish clearly the areas of emphysema from air trapping regions because both areas were having low attenuation.

Therefore, to minimize the confounding influence of emphysema in the quantification of air trapping, a range of low attenuation values has been proposed [10]. Schroeder et al. [11] defined emphysema, as the percentage of low-attenuation areas <-950 HU on inspiratory CT, while air trapping, defined as the percentage of lowattenuation areas <-856 HU on expiratory CT.

According to Matsuoka et al. [3] patients with minimal to mild and moderate to severe emphysema, the strongest correlations with the obstructive deficit were found with changes in attenuation values between –860 HU and –950 HU in portions of lung with little emphysema, suggesting a limited influence of emphysema on the indirect assessment of airways changes. Thus, these findings suggest that the exclusion of voxels with attenuation of -950 HU or less from both inspiratory and expiratory CT data sets is desirable for quantifying air trapping [12].

To obviate this problem there are various methods, one of which is to use a windowing transformation, which allows us to tighten the window of visualization in a more appropriate range. Another solution is to apply some CLUTs (Color Look Up Table) so that it is possible to exploit the greatest range of distinguishable colors by the human eye [9].

Sukkasem et al. [13] investigated the ability of a narrow lung window setting from inspiratory HRCT for detecting air trapping in the patients with clinically suspected small airway disease, and found that obtaining HRCT with using an air trapping window (a window width of 300 HU, a window level of -800 HU) may be sufficient for identifying air trapping in the inspiratory scan. They also stated that familiarity with this window setting might obviate the conventional expiratory scan and help to decrease an unnecessary radiation exposure.

Several researchers [14-17] have investigated the ability of the color mapping in detection and quantification of air trapping using different methods that require various software products and complex techniques.

In these studies [14,15,17] they used the benefit of expiratory CT in identification of air trapping with the added value of color mapped images as in parametric response mapping and had shown promising results in functional small airway disease assessment.

Furthermore, El-mashad et al. [16] used only color mapping by three color densities to separate areas of air trapping from normal lung density and emphysematous areas, however they didn't compare 3 color density with expiratory CT and didn't correlate their results with pulmonary function tests.

In our study we used the benefit of narrow lung window setting to identify air trapping so we can overcome the drawbacks of expiratory CT and we combined it with color coded mapping based on certain attenuation values to improve both visual and quantitative assessment of air trapping. To our knowledge no study has used this method before so we couldn't compare it with other studies.

However, Hansell [5] stated that altering window settings may increase the conspicuity of a mosaic pattern but the subjective manipulation of window settings will spuriously affect the apparent extent of abnormal versus normal lung. Accordingly in this study we fixed the narrow window setting at WW: 300 and WL: -800, to avoid the subjective manipulation of the window setting.

Therefore, in this study, we found that combining the narrow window "air trapping window", with color-coded maping "on the basis of measurable attenuation values"; could have a synergistic effect and better ability for air trapping detection than each method alone.

This method was able to identify air trapping areas in all patients with small airways disease of this study and clearly distinguish air trapping from the emphysematous regions in all COPD patients. Furthermore, compared to the expiratory CT, this method showed similar ability to detect air trapping in all patients; including the patients who had normal inspiratory scan.

The expected additional advantages of this method over expiratory CT were avoiding the extra radiation exposure and overcoming the difficulty of performing expiratory CT as well as the possible misregistration of air trapping regions in the paired inspiratory and expiratory scans that could result from changes in the body posture, complex respiratory motions of the lungs, and heart beating.

Conclusion

This study concluded that:

1. The use of combined color-coded mapping and narrow lung window setting may be sufficient for identification of air trapping and could be a reasonable alternative to expiratory CT.
2. Color-coded narrow lung window setting can be used to identify air trapping, especially in the cases where the degree of small airway injury is so diffuse that it can be difficult to distinguish normal parenchymal from air trapping by expiratory CT.
3. The use of combined color-coded mapping and narrow lung window setting has the ability to distinguish the air trapping areas from the emphysematous areas in COPD patients.

We recommend further comparative studies between this method and the expiratory CT in the detection of air trapping on a large number of patients who have clinically suspected small airways disease and a normal inspiratory CT.

Competing Interests

No authors have a conflict of interest or any financial tie to disclose.

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