# Diagnosis of Chronic Thromboembolic Pulmonary Hypertension using Quantitative Lung Perfusion Parameters Extracted from Dual-Energy Computed Tomography Images

## ABSTRACT

**Purpose:** To evaluate quantified iodine mapping parameters in dual-energy computed tomography (DECT) in normal patients vs those with chronic thromboembolic pulmonary hypertension (CTEPH) with and without pulmonary thromboembolism (PTE).

**Materials and Methods:** Using automatically quantified iodine mapping in DECT, we evaluated lung relative average enhancement, standard deviation (SD), and the SD/lung relative average enhancement ratio. We compared the values for these parameters in normal patients vs those with CTEPH. We also performed a receiver operating characteristic (ROC) curve analysis to determine the diagnostic cutoffs for the parameters.

**Results:** Patients constituted 41 patients (10 male [24.4%] and 31 female [75.6%]; mean age [SD]: 70.0 years [13.3]) with CTEPH and 237 (92 male [38.8%] and 145 female [61.2%]; mean age [SD]: 65.9 years [15.9]) normal patients. We found significant differences in lung relative average enhancement (34.9 ± 6.3 vs 26.9 ± 6.3; $P < 0.0001$), SD (11.6 ± 1.9 vs 14.7 ± 3.3; $P < 0.001$), and the SD/lung relative average enhancement ratio (33.7 ± 5.0 vs 55.7 ± 10.4; $P < 0.001$) between the normal and CTEPH groups, respectively. The ROC analyses demonstrated high discriminatory power (AUC = 0.99) for using the SD/lung relative average enhancement ratio to

differentiate between patients in the normal group and CTEPH group. At a threshold for the area under the curve of 44.2, diagnostic sensitivity, specificity, positive predictive value, and negative predictive value for the ratio were 92.7%, 97.5%, 86.5%, and 98.7%, respectively.

**Conclusions:** Patients with CTEPH were well-discriminated from normal patients using the SD/lung relative average enhancement ratio.

**Key Words:** chronic thromboembolic pulmonary hypertension, dual-energy CT, lung relative average enhancement, standard deviation, sensitivity

## INTRODUCTION

Chronic thromboembolic pulmonary hypertension (CTEPH) is a life-threatening disease with a poor prognosis.[1] CTEPH is characterized by obstruction of the large pulmonary arteries by acute and recurrent pulmonary thromboembolism (PTE).[2] These changes lead to progressively elevated pulmonary arterial pressure and pulmonary vascular resistance (PVR) and, consequently, right-sided heart failure.[3] Therefore, it is important to diagnose CTEPH early and start treatment. Dual-energy computed tomography (DECT) pulmonary angiography has recently become an accepted technique for diagnosing PTE. Post-processing software is used to subtract 80−100 kV from 140-kV images to produce an iodine distribution map. Moreover, lung iodine distribution map, CT, and CT angiography (CTA) images can be obtained in a single acquisition, which permits evaluating pulmonary artery dilation and PTE. The lung iodine distribution map shows the iodine-deficient areas of the lung field, and is useful for diagnosing PTE even if the CTA image cannot identify thromboembolism in a pulmonary artery. However, the iodine distribution map is affected by cardiac function and lung field condition (especially emphysema),[4] and it may overestimate increased and decreased pulmonary perfusion. As a result, it is often difficult to determine whether decreased pulmonary perfusion is due to PTE. Lung iodine distribution map quantification is performed for objective evaluation, and it may reflect parenchymal arterial perfusion in patients with PTE.[5] This

quantitative evaluation automatically displays the average increase (lung relative average enhancement) and standard deviation (SD) in blood flow owing to the contrast medium. Because this quantitative evaluation does not cause discrepancies between observers, it may be possible to accurately evaluate increases, decreases, and variability in blood flow in the lung fields of patients that cannot be evaluated visually. Perfusion of the whole lung field in patients with CTEPH is decreased and uneven compared with that in patients without CTEPH. We hypothesized that the average increase (lung relative average enhancement) reflected the amount of lung perfusion, and that the SD reflected the variability of pulmonary perfusion. SD is generally used as an index to evaluate homogenization.[6] Therefore, the objective of the present study was to examine the clinical significance of lung relative average enhancement and SD for diagnosing patients with CTEPH.

## MATERIALS AND METHODS

### Patient Population

Our institutional review board approved this study and waived the need for written informed consent because the study design was retrospective.

From April 2014 to October 2020, 746 patients underwent DECT pulmonary angiography in our hospital for the first time. Among them, 41 patients (10 male

[24.4%] and 31 female [75.6%]; mean age [SD]: 70.0 years [13.3]) were diagnosed as having CTEPH (CTEPH group). All patients were diagnosed as having CTEPH using standard criteria.[7] Pulmonary hypertension was confirmed by right heart catheterization (mean pulmonary arterial pressure ≥ 25 mm Hg and pulmonary arterial wedge pressure ≤ 15 mm Hg at rest). Mismatch on ventilation/perfusion scintigraphy (usually ventilation-perfusion (V/Q) single-photon emission CT) was defined as at least one large perfusion defect in one segment or in two subsegments, or evidence of pulmonary vascular lesions on CT and pulmonary angiography. These findings were obtained after at least 3 months of effective anticoagulation. In the CTEPH group, 14 patients (6 male [42.9%] and 8 female [57.1%]; mean age [SD]: 73.4 years [12.7]) had no PTE (no PTE group), while 27 patients (4 male [14.8%] and 23 female [85.2%]; mean age [SD]: 68.3 years [13.3]) had PTE (PTE group). The diagnosis of PTE was according to the detection of a pulmonary thrombus on pulmonary CTA images. The remaining 705 patients were not eligible to participate in this study if they had pleural effusion, pneumonia, emphysema, or a history of lung surgery or PTE. Finally, a total of 237 patients (92 male [38.8%] and 145 female [61.2%]; mean age [SD]: 65.9 years [15.9]) were included in the normal group (Fig. 1). Two experienced radiologists with more than 10 years of experience in cardiothoracic CT independently analyzed the CT images. If their diagnoses differed, they reviewed the data to reach a consensus.

**DECT Acquisition Protocol**

All patients in this study were suspected of having venous thrombosis of the lower extremities and thromboembolism of the pulmonary artery. They were examined with a SOMATOM® Definition Flash dual-source CT scanner (Siemens Healthcare, Forchheim, Germany) in the dual-energy mode. Studies were performed after administering high-concentration iodine-based contrast medium (Omnipaque 350; Daiichi-Sankyo, Tokyo) at 4.0 mL/s (total volume, 1.35 mL/kg) through a power injector into a 20-G venous access catheter in an antecubital vein, with a 20-mL saline chaser at 4 mL/s.

CT scanning began 17 s from the start of the injection. To avoid streak artefacts because of highly-concentrated contrast material in the subclavian vein or superior vena cava, scans were acquired in the caudocranial direction so that the chaser bolus was being injected by the time the scan reached the upper chest.

Other scan parameters were as follows: tube voltage, 140- and 100 kVp at 260 effective mAs; attenuation-based tube-current modulation; rotation time, 0.28 s; pitch, 0.7; and collimation, 128 × 0.6 mm. Coverage was from the lung apex to the lung base. CT angiography images were reconstructed with a specific medium-soft convolution

kernel (D30), without edge modification, at a 2.0-mm slice thickness and 2.0-mm increments.

**Analysis of Dual-Energy Data**

Iodine distribution maps of the lungs were generated according to three-material (soft tissue, air, and iodine) decomposition using a syngo Multimodality Workstation (Siemens Healthcare GmbH, Erlangen, Germany) with specific dual-energy post-processing software. CT values were automatically calculated in Hounsfield units (HU) for several image patterns, namely the whole lung, right or left lung, and three right or left regions (upper, middle, and lower). In this study, we evaluated whole-lung relative average enhancement, SD, and SD/lung relative average enhancement ratio. The SD summarizes the amount by which every value within a dataset varies from the lung relative average enhancement; 68% of values are less than the SD away from the lung relative average enhancement, 95% of values are less than 2 SD away from the lung relative average enhancement, and 99% of values are less than 3 SD away from the lung relative average enhancement.

**Assessment of CTA Images**

CTA images were retrospectively assessed by the same two radiologists who

evaluated the CT images. The radiologists were blinded to the patients' clinical conditions and worked independently. They viewed axial CTA images (soft tissue window setting) and multiplanar reformatted (coronal) images, both of which had a slice thickness of 2.0 mm and a 2.0-mm slice interval. The radiologists evaluated the CT findings for chronic PTE, including the presence of complete filling defects at the level of stenosed pulmonary arteries, eccentric thromboembolism, or web.[8] When different findings were obtained, the radiologists reviewed the dataset to reach a consensus.

**Statistical Analysis**

We used the D'Agostino–Pearson test to assess the normality of the data, and we presented non-normally distributed variables as the median (range). Quantitative results were expressed as the mean ± SD or median (range). (The range provided in the tables is the min–max range.)

Lung relative average enhancement, SD, and SD/lung relative average enhancement ratio were analyzed using the paired t-test or the Wilcoxon signed-rank test, as appropriate. Results were expressed as sensitivity, specificity, and overall accuracy, with 95% confidence intervals (CI) calculated with the normal approximation method.[9]

We created receiver operating characteristic (ROC) curves and determined the threshold that led to the optimal values of probabilities in the presence or absence of CTEPH. This optimal threshold was defined as the intersection of the ROC curve with the bisecting line at which sensitivity equaled specificity.

For all tests, a two-sided *P*-value was used, and differences with a *P*-value of < 0.05 were considered statistically significant. Prism for Windows, version 8.3.0 (GraphPad, San Diego, CA) was used for all statistical analyses.

## RESULTS

### World Health Organization (WHO) Classification

In the CTEPH group, patients had a WHO functional class of II (n = 7), III (n = 5), or IV (n = 2) in the no PTE group and II (n = 11), III (n = 14), or IV (n = 2) in the PTE group (Table 1).

### Lung Relative Average Enhancement in Patients in the Normal Group, with CTEPH no PTE Group, and with CTEPH PTE Group

Lung relative average enhancement was 34.9 ± 6.3 in the normal group and 26.9 ± 6.3 in the CTEPH group, with a significant difference between the groups (*P* < 0.0001). SD, showing the variation in lung relative average enhancement, was 11.6 ±

1.9 in the normal group and 14.7 ± 3.3 in the CTEPH group, with a significant difference between the two groups ($P < 0.0001$). The SD/lung relative average enhancement ratio was 33.7 ± 5.0 in the normal group and 55.7 ± 10.4 in the CTEPH group, with a significant difference between the two groups ($P < 0.0001$) (Table 2) (Fig 2).

In comparison, lung relative average enhancement was 26.9 ± 8.6 in the CTEPH no PTE group and 26.9 ± 4.6 in the CTEPH PTE group, with no significant difference between the two groups ($P = 0.9582$). SD, showing the variation of lung relative average enhancement, was 15.0 ± 3.8 in the CTEPH no PTE group and 14.6 ± 3.0 in the CTEPH PTE group, with no significant difference between the two groups ($P = 0.6668$). The SD/lung relative average enhancement ratio was 57.6 ± 10.7 in the normal group and 54.7 ± 10.1 in the CTEPH group, with no significant difference between the two groups ($P = 0.4012$) (Table 3) (Fig. 3).

**ROC Analysis in Patients in the Normal Group and CTEPH Group**

ROC analyses demonstrated moderate discriminatory power (area under the ROC curve (AUC) = 0.82) for using lung relative average enhancement to differentiate between patients in the normal group and CTEPH group. When an cut off value < 31.5 was used as the threshold for diagnosis, the sensitivity, specificity, positive predictive value, and negative predictive value were 80.5%, 68.4%, 30.5%, and 95.3%,

respectively. ROC analyses demonstrated moderate discriminatory power (AUC = 0.79) for using SD to differentiate between patients in the normal group and CTEPH group. When an cut off value < 12.5 was used as the threshold for diagnosis, the sensitivity, specificity, positive predictive value, and negative predictive value were 68.3%, 75.1%, 32.1%, and 93.2%, respectively. ROC analyses demonstrated high discriminatory power (AUC = 0.99) for using the SD/lung relative average enhancement ratio to differentiate between patients in the normal group and CTEPH group. When an cut off value < 44.2 was used as the threshold for diagnosis, the sensitivity, specificity, positive predictive value, and negative predictive value were 92.7%, 97.5%, 86.5%, and 98.7%, respectively (Fig. 4).

Figure 5 shows lung iodine distribution map image in patient without CTEPH. Lung iodine distribution map image shows slight iodine-deficient areas in the lung field. However, SD/lung relative average enhancement ratio was 32.3, which was below the cut off value of 44.2.

In comparison, Figure 6 shows lung iodine distribution map image in patient with CTEPH and no PTE. Lung iodine distribution map image also shows iodine-deficient areas in the lung field, but it is difficult to determine whether pulmonary perfusion is decreased owing to PTE because this cannot be detected in CTA. However, SD/lung relative average enhancement ratio was 73.9, which was higher than the cut off value of 44.2.

## DISCUSSION

CTEPH is caused by obstruction of the pulmonary vascular bed by repeated PTE with organization. If treatment is delayed, increased vascular resistance with progressive pulmonary hypertension can lead to right-sided heart failure and a poor prognosis.[10] Therefore, early diagnosis of CTEPH is important. However, the main symptoms of CTEPH are non-specific, namely shortness of breath, lethargy, easy fatiguability, and cough. It is difficult to distinguish these symptoms from those caused by asthma and chronic bronchitis in the early stage, and they are easily overlooked.[11–14] Catheter pulmonary angiography is still considered the gold standard for diagnosing CTEPH, but this examination is invasive and is usually not performed unless the patient is suspected of having CTEPH. Symptomatic patients usually undergo CT or contrast-enhanced CT (CECT) for the first examination. CTA has good potential to detect thromboembolic changes at the lobar (97%–100% and 95%–100%, respectively) and segmental (86–100% and 93–99%, respectively) levels.[15–17] If PTE is detected by CECT, we can suspect pulmonary thrombosis, including CTEPH. However, if thromboembolic lesions are located only in the distal pulmonary arteries, PTE may not be identified by CECT. In such cases, it is difficult to suspect CTEPH. In contrast, lung iodine distribution mapping by DECT may be more sensitive regarding pulmonary blood flow.[18] However, this imaging is affected by cardiac function and lung field condition.[4] As a result, it is often difficult to

determine if pulmonary perfusion is decreased owing to PTE. For assessing quantitative parameters from iodine maps, there was a significant difference in whole-lung relative average enhancement between acute PTE and control groups in previous study.[19] There was also a significant difference in whole-lung relative average enhancement between COPD and control groups in previous study.[20] DECT has a high sensitivity for perfusion deficits in patients with CTEPH.[21] However, there was no study about CTEPH for assessing quantitative parameters from iodine maps.

In this study, we found a significant difference in lung relative average enhancement and SD between the patients in the normal group and CTEPH (no PTE and PTE) group. Moreover, ROC analyses demonstrated moderate discriminatory power for using lung relative average enhancement and SD to differentiate between patients in the normal group and CTEPH (no PTE and PTE) group. Lung relative average enhancement in the CTEPH group was lower than that of the normal group, and SD in the CTEPH group was higher than that of the normal group. We speculate that lung relative average enhancement represents a greater decrease in whole-lung perfusion, and that SD represents greater variability in lung perfusion in the CTEPH group compared with the normal group. However, when lung relative average enhancement and SD were used to distinguish between the normal group and CTEPH (no PTE and PTE) group, many patients in the normal group and CTEPH group overlapped and were difficult to

distinguish. In contrast, ROC analyses demonstrated high discriminatory power for using SD/lung relative average enhancement to differentiate between patients in the normal group and CTEPH (no PTE and PTE) group. SD/lung relative average enhancement may reflect both decreased perfusion and variability in whole-lung perfusion in patients with CTEPH. As a result, patients in the normal group and CTEPH group do not overlap and are easily distinguished. Additionally, automated quantification is rapid and simple to use. In this DECT technique, lung iodine distribution map, quantitative evaluation (lung relative average enhancement and SD), CT, and CTA images can be obtained in a single CECT. This method is less invasive than catheter pulmonary angiography. We can evaluate the anatomy in CT images with thinner slices more precisely than in SPECT images and detect PTE in CTA images.

The results of this study should be clinically useful. Using this quantitative evaluation (lung relative average enhancement and SD), we may be able to detect patients with CTEPH in normal CTA image findings; CTA cannot detect PTE.

There was no significant difference in lung relative average enhancement, SD, and SD/lung relative average enhancement ratio between the CTEPH with no PTE and CTEPH with PTE groups. We consider that the cause of this lack of difference was that whole-lung perfusion was similarly reduced and varied in patients with CTEPH with or without PTE regardless of whether PTE could be identified by DECT.

## Limitations

The present study had several limitations. First, this study included a low number of CTEPH patients and lacked an external validation cohort. Second, most patients in the CTEPH group in this study had a WHO functional class of II or III (n = 37) because they were referred to our hospital to undergo balloon pulmonary angioplasty and other cardiac procedures. Third, many patients in this study underwent DECT because of suspected PTE and were excluded owing to pleural effusion, pneumonia, emphysema, or a history of lung surgery and PTE. Therefore, the results cannot be generalized to the entire population because of this specially-selected population subset. Fourth, the lung parenchymal changes and extent of pulmonary arterial stenosis were not considered in this study. Therefore, this may have changed lung relative average enhancement. Finally, some patients with CTEPH in this study were already being treated with anticoagulant therapy with edoxaban or warfarin when they underwent DECT in our hospital. Therefore, pulmonary perfusion could have been influenced by anticoagulation.

## Conclusion

The SD/lung relative average enhancement ratio reflects the decrease and variability in pulmonary perfusion in patients with CTEPH, and is useful to make a clearer

distinction between CTEPH and the normal group compared with using lung relative average enhancement or SD alone. We found no difference in lung relative average enhancement, SD, and SD/lung relative average enhancement ratio between CTEPH patients with and without PTE.

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**Figure captions**

**FIGURE 1.** Flowchart showing the patient selection.

**FIGURE 2.** Individual data.

(a) Individual data for lung relative average enhancement in the normal group and chronic thromboembolic pulmonary hypertension (CTEPH) group ($P < 0.0001$).

(b) Individual data for standard deviation (SD) in the normal group and CTEPH group ($P$ < 0.0001).

(c) Individual data for SD/lung relative average enhancement ratio in the normal group and CTEPH group ($P$ < 0.0001).

**Figure 3.** Individual data.

(a) Individual data for lung relative average enhancement in the chronic thromboembolic pulmonary hypertension (CTEPH) no pulmonary thromboembolism (PTE) group and the CTEPH PTE group ($P$ = 0.9582).

(b) Individual data for SD in the CTEPH no PTE group and the CTEPH PTE group ($P$ = 0.6668).

(c) Individual data for standard deviation (SD)/lung relative average enhancement ratio in the CTEPH no PTE group and CTEPH PTE group ($P$ = 0.4012).

**FIGURE 4.** Receiver operating characteristic (ROC) analysis.

(a) ROC analyses demonstrated moderate discriminatory power for using lung relative average enhancement to differentiate between patients in the normal group and chronic thromboembolic pulmonary hypertension (CTEPH) group. When an area under the curve (AUC) value of < 31.5 was used as the threshold for diagnosis, the sensitivity, specificity,

positive predictive value, and negative predictive value were 80.5%, 68.4%, 30.5%, and 95.3%, respectively.

(b) ROC analyses demonstrated moderate discriminatory power for using standard deviation (SD) to differentiate between patients in the normal group and CTEPH group. When an AUC value < 12.5 was used as the threshold for diagnosis, the sensitivity, specificity, positive predictive value, and negative predictive value were 68.3%, 75.1%, 32.1%, and 93.2%, respectively.

(c) ROC analyses demonstrated high discriminatory power for using the SD/lung relative average enhancement ratio to differentiate between patients in the normal group and CTEPH group. When an AUC value < 44.2 was used as the threshold for diagnosis, the sensitivity, specificity, positive predictive value, and negative predictive value were 92.7%, 97.5%, 86.5%, and 98.7%, respectively.

**FIGURE 5.** Images for a 56-year-old woman without chronic thromboembolic pulmonary hypertension (CTEPH).

(a) Fusion image in computed tomography (CT) angiography and a color-coded map shows a slight iodine-deficient area in the lung field (arrows).

(b) Lung relative average enhancement and SD were calculated automatically (surrounded). Lung relative average enhancement was 31, SD was 10, and SD/lung relative average enhancement ratio was 32.3.

**FIGURE 6.** Images for a 78-year-old woman with CTEPH and no pulmonary thromboembolism (PTE).

(a) Fusion image in CT angiography and a color-coded map shows an iodine-deficient area in the lung field (arrows).

(b) Lung relative average enhancement and SD were calculated automatically (surrounded). Lung relative average enhancement was 23, SD was 17, and SD/lung relative average enhancement ratio was 73.9.

**Table 1.** Patients' Demographic and Clinical Characteristics

| **Variable** | **Normal (n=237)** | **CTEPH no PTE (n=14)** | **CTEPH PTE (n=27)** |
|---|---|---|---|
| Age, years | 65.9±15.9 | 73.4±12.7 | 68.3±13.3 |
| Male, n | 92 | 6 | 4 |
| WHO functional class | | | |
| II | | 7 | 11 |
| III | | 5 | 14 |
| IV | | 2 | 2 |
| History of cancer, n | 80 | 0 | 2 |
| Previously treated with anticoagulation therapy with edoxaban or warfarin, n | 0 | 9 | 13 |
| Previously treated with PEA or BPA, n | 0 | 0 | 0 |

Data expressed as n or mean ± standard deviation (range). CTEPH indicates chronic thromboembolic pulmonary hypertension; PTE, pulmonary

thromboembolism; WHO, World Health Organization; PEA, pulmonary endarterectomy; BPA, balloon pulmonary angioplasty.

**Table 2.** Lung Relative Average Enhancement, SD, and SD/Lung Relative Average Enhancement Ratio in the Normal Group and CTEPH Group

| **Variable** | **Normal (n=237)** | **CTEPH (n=41)** | **p** |
|---|---|---|---|
| Lung relative average enhancement (HU) | 34.9±6.3 | 26.9±6.3 | <0.0001 |
| SD (HU) | 11.6±1.9 | 14.7±3.3 | <0.0001 |
| SD/lung relative average enhancement × 100 (%) | 33.7±5.0 | 55.7±10.4 | <0.0001 |

Data expressed as n or mean ± standard deviation (range). CTEPH indicates chronic thromboembolic pulmonary hypertension; PTE, pulmonary thromboembolism; SD, standard deviation.

**Table 3.** Lung Relative Average Enhancement, SD, and SD/Lung Relative Average Enhancement Ratio in the CTEPH no PTE group and CTEPH PTE group

| **Variable** | **CTEPH no PTE (n=14)** | **CTEPH PTE (n=27)** | **p** |
|---|---|---|---|
| Lung relative average enhancement (HU) | 26.9±8.6 | 26.9±4.6 | 0.9582 |
| SD (HU) | 15.0±3.8 | 14.6±3.0 | 0.6668 |
| SD/lung relative average enhancement × 100 (%) | 57.6±10.7 | 54.7±10.1 | 0.4012 |

Data expressed as n or mean ± standard deviation (range). CTEPH indicates chronic thromboembolic pulmonary hypertension; PTE, pulmonary thromboembolism; SD, standard deviation.

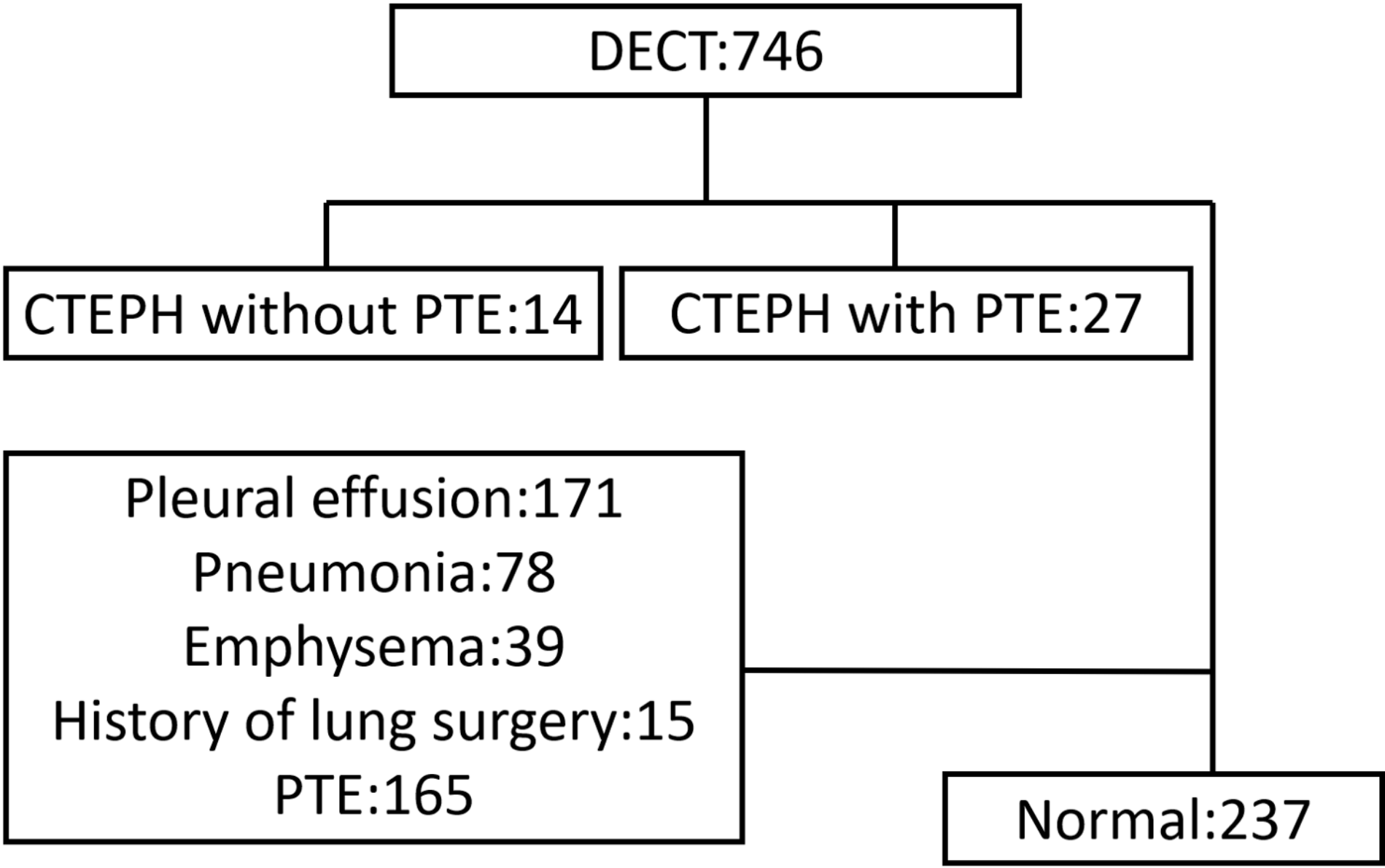

DECT:746
CTEPH without PTE:14
CTEPH with PTE:27
Pleural effusion:171
Pneumonia:78
Emphysema:39
History of lung surgery:15
PTE:165
Normal:237

Figure 1

# Normal vs CTEPH

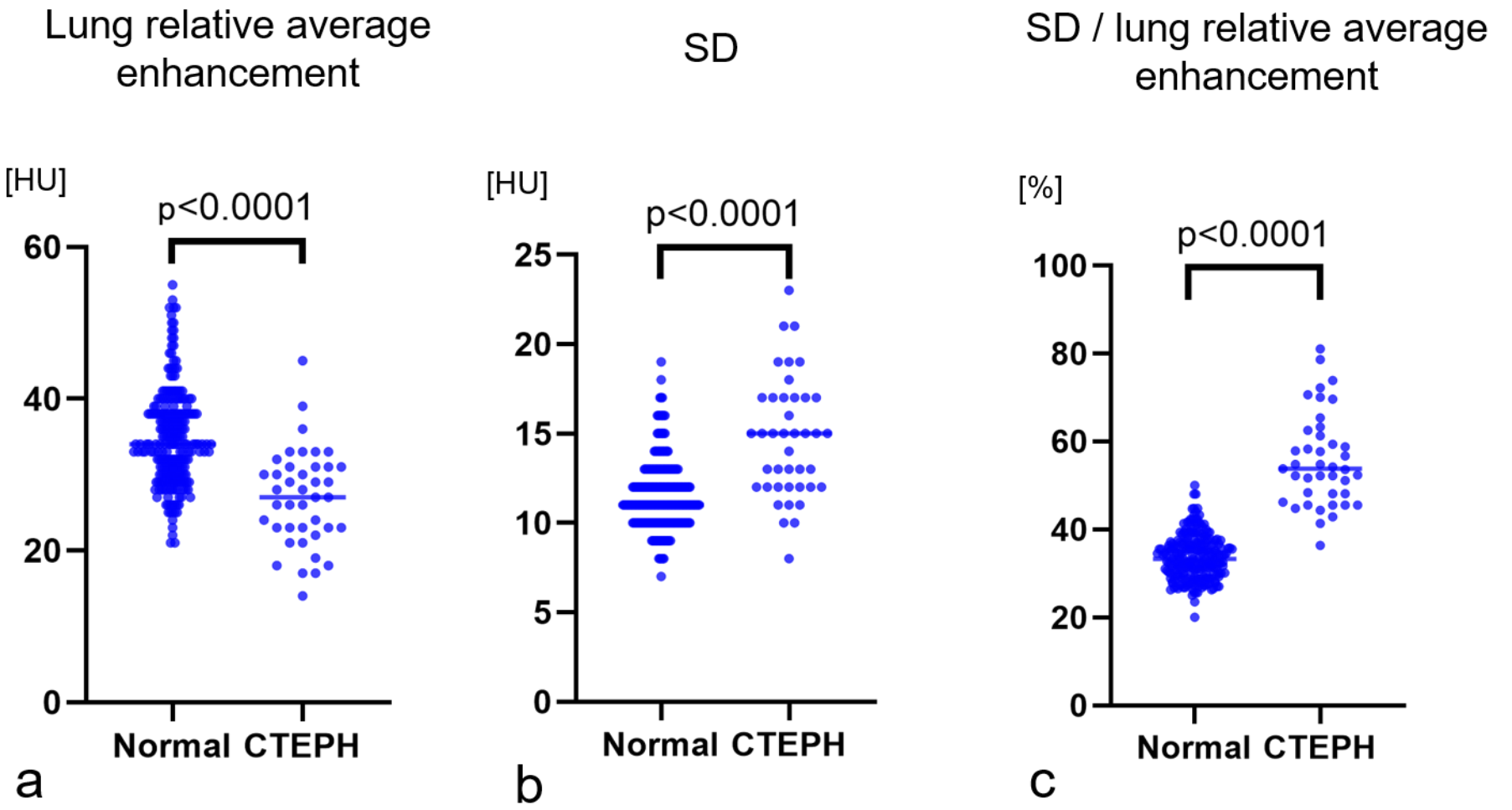



Figure 2

# CTEPH no PTE vs CTEPH PTE

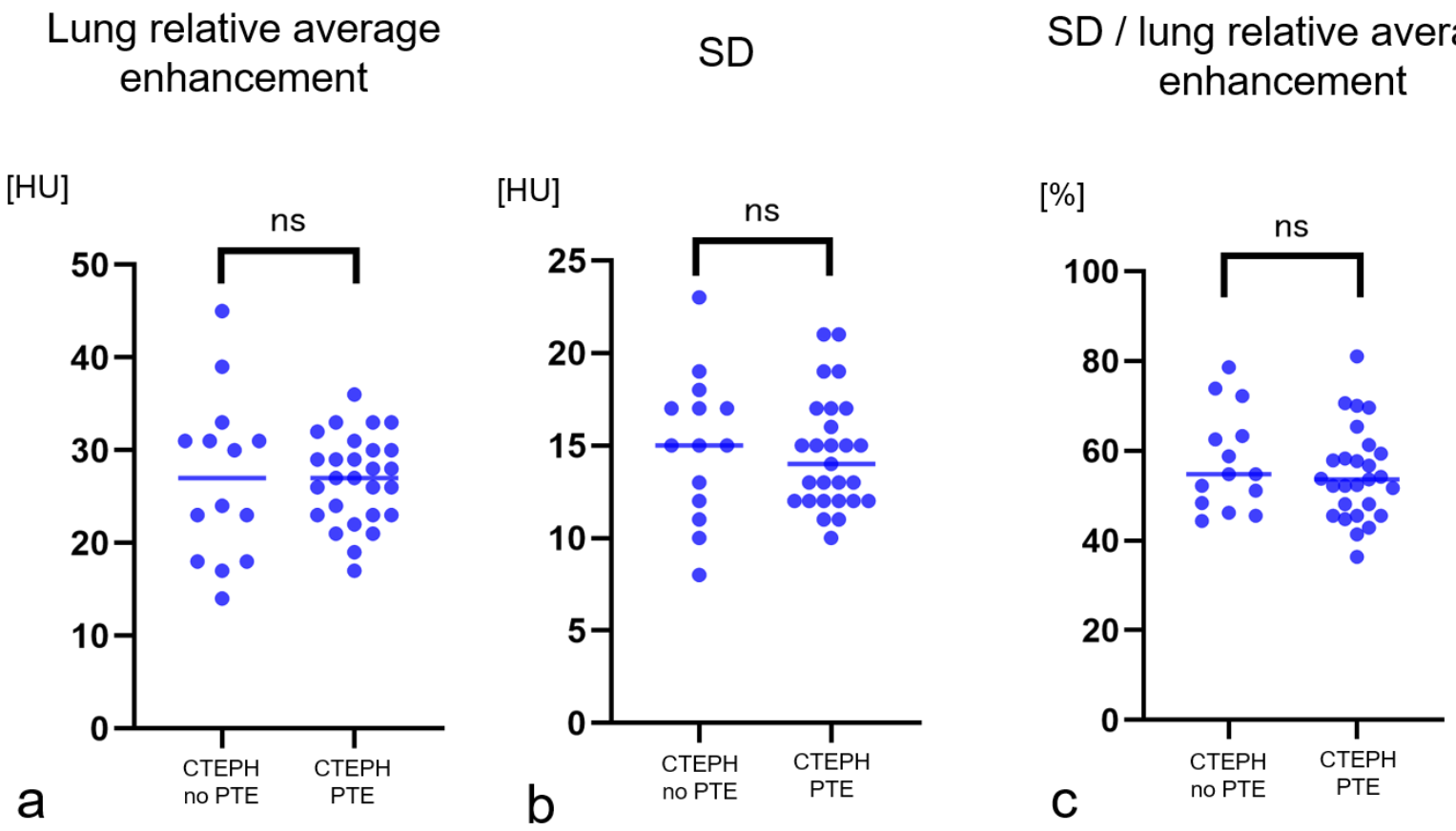



Figure 3

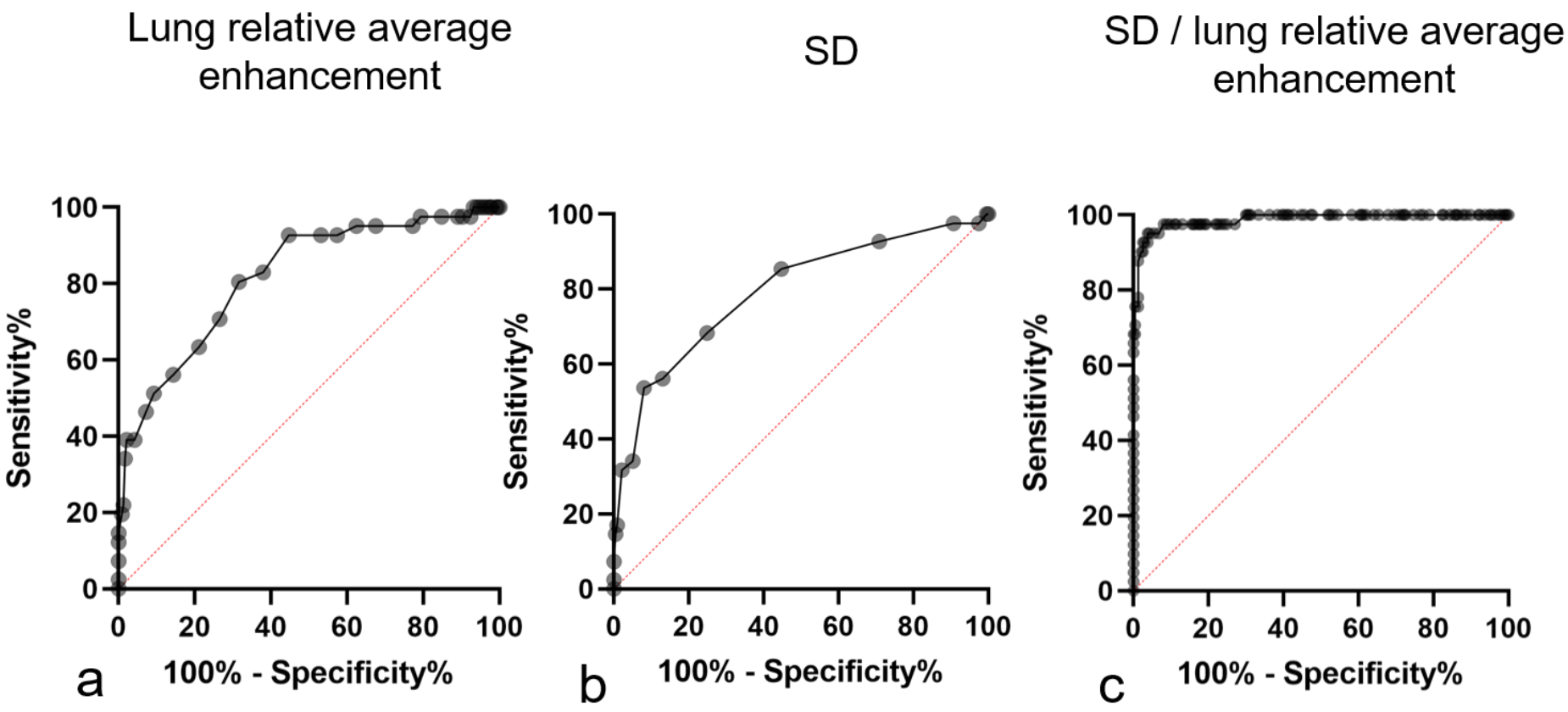
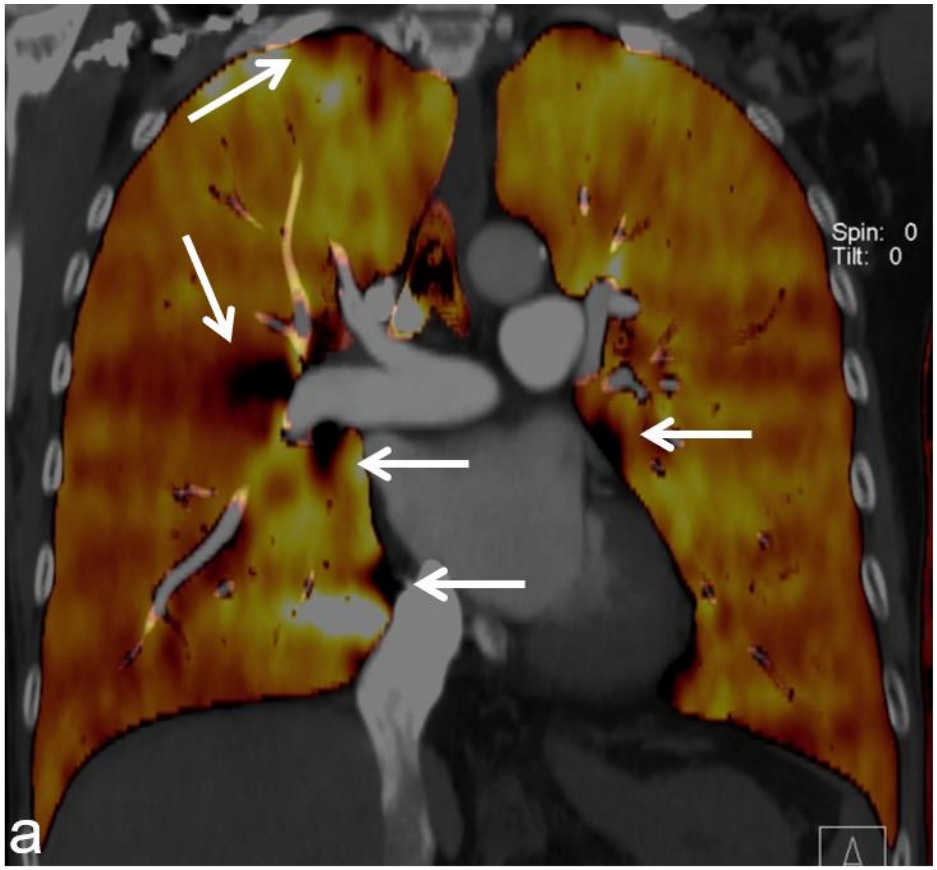

Lung relative average enhancement
SD
SD / lung relative average enhancement
Sensitivity%
100% - Specificity%
0
20
40
60
80
100
a
b
c

Figure 4

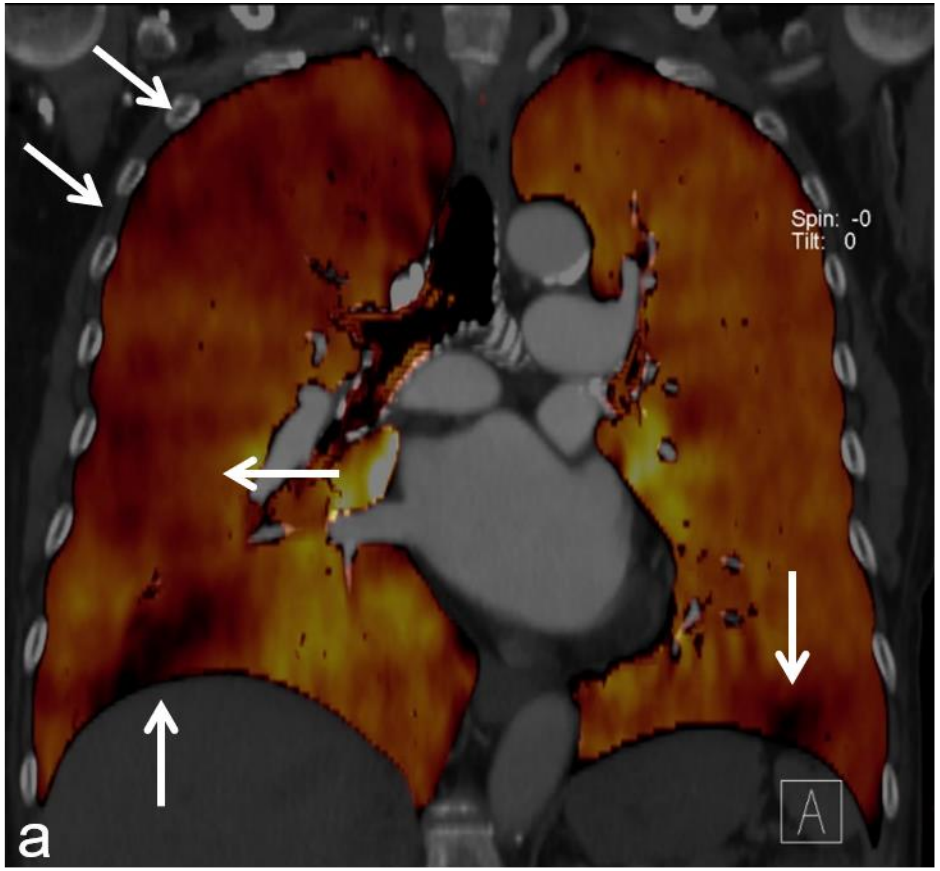



| Analysis Region | Volume [cm³] | Below Min. % of Voxels | Above Max. % of Voxels | Enhancement [HU] | Relative Enh. % |
|---|---|---|---|---|---|
| Total | 3313 | 1 | 4 | 31 ± 10 | 79 |
| Right | 1850 | 1 | 4 | 32 ± 10 | 81 |
| Left | 1464 | 1 | 5 | 30 ± 9 | 77 |
| Right - Lower | 613 | 0 | 4 | 30 ± 8 | 79 |
| Right - Middle | 605 | 1 | 5 | 33 ± 11 | 84 |
| Right - Upper | 632 | 1 | 3 | 32 ± 10 | 82 |
| Left - Lower | 485 | 0 | 6 | 29 ± 12 | 74 |
| Left - Middle | 475 | 1 | 5 | 30 ± 8 | 79 |
| Left - Upper | 503 | 1 | 3 | 30 ± 7 | 77 |

R L

b

Figure 5




b

| Analysis Region | Volume [cm³] | Below Min. % of Voxels | Above Max. % of Voxels | Enhancement [HU] | Relative Enh. % |
|---|---|---|---|---|---|
| Total | 2695 | 0 | 7 | 23 ± 17 | 14 |
| Right | 1642 | 0 | 6 | 19 ± 16 | 12 |
| Left | 1053 | 0 | 10 | 28 ± 18 | 17 |
| Right - Lower | 544 | 0 | 6 | 12 ± 15 | 7 |
| Right - Middle | 540 | 0 | 7 | 19 ± 14 | 12 |
| Right - Upper | 559 | 0 | 4 | 25 ± 17 | 15 |
| Left - Lower | 346 | 0 | 12 | 21 ± 22 | 13 |
| Left - Middle | 344 | 0 | 10 | 29 ± 16 | 18 |
| Left - Upper | 363 | 0 | 7 | 35 ± 9 | 21 |

R L

Figure 6