Value of chest radiography in phenotyping chronic obstructive pulmonary disease

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ABSTRACT

The objectives of our study were to reappraise chest radiography in the diagnosis of emphysema using computed tomography (CT) as the reference standard, and to establish whether chest radiography is useful in phenotyping chronic obstructive pulmonary disease (COPD).

We studied 154 patients who had postero-anterior and lateral chest radiographs and CT for diagnostic purposes. CT were scored for emphysema using the picture-grading method. Chest radiographs were examined independently by five raters using four criteria for emphysema validated against lung pathology. Next, we applied these criteria to assess the prevalence of emphysema in 458 COPD patients. Patients with and without evidence of emphysema were compared as regards age, gender, pack-years of smoking, BMI, FEV₁, DLCO, and health status.

Chest radiography yielded 90% sensitivity and 98% specificity for emphysema. Of 458 COPD patients, 245 had radiologic evidence of emphysema. Emphysemic patients had significantly lower BMI, FEV₁, and DLCO, greater restriction of physical activity, and worse quality of life than non-emphysemic ones. There was no difference across the two groups as to age, gender, or pack-years of smoking.

Chest radiography is a simple means for diagnosing moderate to severe emphysema. It is useful in phenotyping COPD, and may aid physicians in their choice of treatment.

Key words: Chronic obstructive pulmonary disease, Chest radiography, Computed tomography, Emphysema.
INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a major cause of morbidity, mortality, and disability in the western world [1]. Chronic airflow limitation is thought to result from the combination of two mechanisms: increased airway resistance due to narrowing of the small airways, and loss of lung elastic recoil due to emphysema. In clinical practice, spirometry has a key role in the diagnosis of COPD, and in assessing disease severity and progression [2]. However, it provides no information as to the presence or absence of emphysema. Since emphysema is defined as a structural pulmonary abnormality [3], its recognition is based on tests that reflect lung structure rather than function.

Computed tomography (CT) is currently the most accurate imaging technique for diagnosing emphysema in vivo [4]. Extensive use of this technique seems, however, unwarranted due to the high cost and substantial radiation burden. On the other hand, chest radiography is almost invariably obtained in patients with COPD, but its accuracy in diagnosing emphysema is controversial [5].

The aim of the present study was two-fold: 1) to reappraise chest radiography in the diagnosis or exclusion of emphysema using CT as the reference diagnostic standard; 2) to establish whether chest radiography, as a simple means to detect emphysema, may prove useful in phenotyping COPD.

MATERIAL AND METHODS

I. Chest radiography versus CT in the diagnosis of emphysema

Sample
The study sample comprised 154 patients who were evaluated at the Institute of Clinical Physiology (Pisa, Italy) between January 1, 2003 and December 31, 2004. In these patients, CT of the thorax and postero-anterior and lateral chest radiographs were obtained for diagnostic purposes within a week of each other. Patients (124 males, and 30 females) had a median age of 62 years (interquartile range [IQR], 56 to 69). One-hundred-thirty-five (88%) were either current or
former smokers with a median smoking history of 44 pack-years (IQR, 30 to 57). One-hundred-seven (69%) met the criteria of chronic airflow obstruction (forced expiratory volume in one second over forced vital capacity [FEV₁/FVC] <70%). Fifty patients were evaluated for suspected lung cancer, 19 for suspected bronchiectasis, 11 for asbestos-related pleural thickening, and 1 for suspected bronchiolitis obliterans. Of the 73 other patients, 48 were screened as candidates to lung volume reduction surgery for emphysema, 20 as candidates to liver transplantation, and 5 for lung transplantation because of severe pre-capillary pulmonary hypertension.

Computed tomography
CT was performed on a Siemens Volume Zoom scanner (120 KVP, 200 mAs, scanning time 1 second) without infusion of contrast medium. The lungs were scanned from the apex through the base at 1 cm intervals with the patient supine breath holding at full inspiration, using 1 mm collimation and a high-frequency-spatial reconstruction algorithm. Scans were viewed using a window level of –600 and a width of 1500 Hounsfield Units, and were independently examined by two chest radiologists for the presence of areas of low attenuation and vascular disruption. The severity of emphysema was scored on a nonparametric scale from 0 (no emphysema) to 100 using the picture-grading method of Thurlbeck et al [6] adapted for CT [7]. According to this method, a score of 5 or less is consistent with trace emphysema, a score of 10 to 30 indicates mild emphysema, a score >30 to 50 moderate emphysema, and a score >50 to 100 severe emphysema. Neither radiologist was aware of the patients’ clinical data. The average of two independent ratings was used for comparison with chest radiography.

Chest radiography
Postero-anterior and lateral chest radiographs (99 digital, 55 analog) were obtained at a standard 2-meter focus to detector (film) distance with the patients upright holding their breath at full inspiration. Chest radiographs were evaluated for the presence or absence of emphysema by 5 independent raters who had no access to clinical or CT data. Two of them were pulmonologists with experience in the interpretation of the chest radiograph, and three (two medical students and a
radiology technician) had limited or no experience. In evaluating emphysema, four radiographic criteria were used that were originally introduced by Sutinen and coworkers [8]. The radiographic criteria are described in Table 1. According to Sutinen et al, the diagnosis of emphysema is made when the chest radiographs reveal any two or more of these criteria. In that study, emphysema was correctly identified in ante-mortem chest films of 82% of the patients who had autopsy proven emphysema. This was any amount of emphysematous tissue destruction occupying >2% of total lung volume as measured by the "point counting" technique [9]. By contrast, all of the chest radiographs corresponding to the patients with structurally normal lungs were rated as normal. The overall accuracy of chest radiography in diagnosing or excluding emphysema was 90%.

The three less experienced raters were trained to identify the radiographic criteria of Table 1 using a set of 25 chest radiographs from subjects with normal lungs and from patients with emphysema of varying degree of severity. The training set did not include chest films that were used for comparison with CT.

II. Value of chest radiography in phenotyping COPD

Sample
The study sample included 458 patients with COPD who were part of a larger cohort enrolled in a case-control study that was aimed at assessing genetic susceptibility to the development of COPD [10]. In that study, 1018 COPD patients and 911 nondiseased controls were recruited at six European centres between October 1, 2001 and September 30, 2003. The 458 patients reported here are those in whom postero-anterior and lateral chest radiographs had been obtained within a month before entering the study. Two-hundred patients were recruited at the Institute of Clinical Physiology (Pisa, Italy), 132 at the Respiratory Service, Hospital Clinic (Barcelona, Spain), and 126 at the Department of Pulmonology, Leiden University Medical Centre (Leiden, The Netherlands).

Patient selection criteria
Criteria for patients recruitment were a firm clinical diagnosis of stable COPD; airflow limitation as indicated by FEV₁/FVC <70%, and FEV₁ ≤70% of the
predicted value [11]; reversibility of FEV<sub>1</sub> on bronchodilation <12% or <200 mL; a smoking history ≥20 pack-years.

Patients were excluded from the study if they had an established diagnosis of asthma, established obstructive syndromes other than COPD or lung cancer, history of atopy, known alpha-1-antitrypsin deficiency, or a serum alpha-1-antitrypsin concentration <1.0 g/dL. Patients were also excluded if they had had an acute exacerbation in the 4 weeks preceding the study entry.

Study protocol
Clinical history and physical examination were obtained in all patients. Lung function studies included measurement of FVC and FEV<sub>1</sub> (before and after bronchodilator), and of single breath carbon monoxide lung diffusing capacity (DL<sub>CO</sub>). Actual DL<sub>CO</sub> values were corrected for hemoglobin and carbon monoxide levels and were expressed as percent of the predicted value [12]. Patients were then invited to complete a self-administered questionnaire (St. George’s respiratory questionnaire) which consists of 3 sections: symptoms, activity, and impacts [13]. The symptoms section is concerned with the frequency of cough, mucous hypersecretion, wheezes, and breathlessness. The activity section deals with the physical activities that either cause or are limited by breathlessness. The impacts section covers such factors as disturbance of daily life, expectations for health, employment, or need for medication and its side effects. Each of the three sections is scored separately in the range 0 to 100%. The total score, which utilizes responses to all items, also ranges from 0 to 100%.

The protocol was approved by the local ethics committees. Before entering the study, an informed written consent was obtained from all the patients.

Chest radiography
Chest radiographs (272 digital, 186 analog) were examined independently by the two pulmonologists who were involved in first part of the study. Emphysema was diagnosed if any two or more of the criteria in Table 1 were present. In a subset of 200 cases, the chest radiographs were also used to measure total lung capacity (TLC) according to the planimetric method of Harris and coworkers [14]. Software was developed that provides online computation of TLC from digital chest
radiographs. Radiologic TLC was expressed as percent of the predicted value using appropriate reference equations [15].

**Statistical analysis**

Inter-rater reliability in scoring emphysema on CT was tested for by means of intraclass correlation [16]. Inter-rater agreement in diagnosing or excluding emphysema on chest radiography was assessed by means of the kappa statistic [17]. The standard normal distribution was used for testing whether interobserver agreement was better than chance [17]. Ninety-five percent confidence intervals (95% CI) were calculated according to the binomial distribution. The relation between the severity of airflow obstruction or the number of chest radiographic criteria for emphysema and the CT score of emphysema was assessed by Kruskal-Wallis nonparametric test. Patients' characteristics across the two diagnostic groups (emphysema versus no emphysema) were compared by contingency tables for categorical variables (exact Fisher’s test). For the continuous variables, differences between the two groups were tested for by Mann-Whitney nonparametric test. Two-tailed P values <0.05 were considered statistically significant throughout.

**RESULTS**

**I. Chest radiography versus CT in the diagnosis of emphysema**

Emphysema was diagnosed consistently by two independent radiologists in 87 (56%) of 154 CT scans. The median CT score of emphysema was 60 (IQR, 38 to 74). Intraclass correlation yielded a coefficient of 0.9987 (95% CI, 0.9983 to 0.9991), indicating excellent inter-rater reliability in scoring emphysema on CT. The prevalence of emphysema in the sample increased as a function of the severity of airflow obstruction (Figure 1A). Similarly, the CT scores of emphysema were significantly higher in patients with severe or very severe airflow obstruction than in those with mild or moderate obstruction (Figure 1B).

By adopting the radiographic criteria of Table 1, the 5 independent raters agreed that emphysema was present in 77 patients, and that it was absent in 70. The
overall inter-rater agreement was 95% (147/154), and the value of kappa 0.95 (95% CI, 0.90 to 1.00) indicating that inter-rater agreement was significantly better than chance (P<0.0001).

The sensitivity and specificity values of chest radiography in the diagnosis or exclusion of emphysema are reported in Table 2 for each of the 5 independent raters. The weighted sensitivity was 90% (95% CI, 87 to 93%), and the weighted specificity 98% (95% CI, 96 to 99%). The positive predictive value was 98% (95% CI, 96 to 99%), and the negative predictive value 88% (95% CI, 85 to 91%).

In the 87 patients with CT-confirmed emphysema, there was a highly significant, positive relation between the number of chest radiographic criteria for emphysema and the CT score (Figure 2).

Table 3 reports the CT scores, type of emphysema, and regional distribution of emphysematous lesions in the 11 patients whose chest radiographs had been rated as negative for emphysema by at least one of the 5 independent observers. The CT scores were consistent with trace or mild emphysema.

II. Value of chest radiography in phenotyping COPD

The baseline characteristics of the 458 patients with COPD are given in Table 4. Emphysema was diagnosed consistently by the two independent raters in 245 (53%) of 458 patients. Patients with emphysema did not differ from those without emphysema as regards age, gender or, surprisingly, pack-years of smoking. By contrast, BMI, FEV₁ and DL₉₀ were significantly lower in patients with emphysema than in those without. Among the 200 patients in whom radiologic TLC was measured, those whose chest radiographs met the criteria for emphysema had a significantly higher TLC than those without emphysema.

As to the results of the St. George’s questionnaire, there was no difference between the two groups in terms of frequency of respiratory symptoms. Yet, emphysemic patients had significantly greater limitation of their physical activity, and worse quality of life than non emphysemic ones.
DISCUSSION

The value of chest radiography in the assessment of emphysema has been a matter of contention for over 40 years [18]. In radiologic-pathologic correlation studies, the agreement between chest film interpretation and morphologic findings ranged from excellent [8] to poor [19] depending on the radiographic criteria used, and the strictness applied by the investigators in matching their interpretation to the presence or absence of structural emphysema [18].

Even though CT is now regarded as the most accurate imaging technique for emphysema, it is questionable whether it should be obtained for the specific purpose of diagnosing emphysema because of the high cost and substantial radiation exposure. Standard-dose multidetector CT of the thorax yields an effective radiation dose of 6 to 8 milliSievert (mSv) [20]. By contrast, digital chest radiography entails a much lower radiation burden than CT (0.04 to 0.07 mSv for postero-anterior and lateral chest radiographs), it is far less expensive and is ubiquitously available.

Therefore, the present study was undertaken to reappraise chest radiography as a simple means for diagnosing or excluding emphysema. In doing so, we used four radiographic criteria that were validated against lung pathology [8]. Since the study from which these criteria are derived was published long before the introduction of CT, we thought it reasonable to test the validity of such criteria against this newer imaging modality.

Emphysema was diagnosed on chest films in most patients with CT-confirmed disease (sensitivity 90%). However, chest radiography failed to detect trace or mild emphysema that was apparent on CT. The rate of false positive results was very small (specificity 98%). These findings are remarkable inasmuch as three out of 5 independent raters had very limited experience in interpreting chest radiographs.

The high inter-rater agreement may be explained as follows. First, the radiologic diagnosis of emphysema is based primarily on the evaluation of the shape of the lungs rather than on signs of vascular attenuation that are hardly recognised by unexperienced clinicians or technologists. Second, the diagnosis of emphysema requires that at least two of the four radiologic criteria be present, and this helps
reducing interobserver variability. Third, the less experienced raters were trained to recognise the chest radiographic abnormalities using an appropriate set of standards. Fourth, all the patients were studied under stable clinical conditions. However, we acknowledge that the inter-rater agreement reported in our study may not be easily replicated. Therefore, it would be desirable that the validity of the proposed radiologic criteria be tested in different clinical settings.

In the sample of 154 patients with a 56% prevalence of emphysema, chest radiography yielded a positive predictive value of 98% and a negative predictive value of 88%. Epidemiological surveys in samples of the Italian general population indicate that the prevalence of chronic obstructive lung disease in subjects aged 50 years or older is about 30% [21]. We may then hypothesise that the prevalence of structural emphysema be in the range of 10 to 15%. In this range, chest radiography would yield a positive predictive value of about 86% and a negative predictive value close to 99%.

Our results differ from those reported by Thurlbeck and Simon who examined the value of chest radiography by comparing film interpretation with inflation-fixed, paper-mounted lung specimens [19]. The radiographs were interpreted by one rater only, and the diagnosis of emphysema was made whenever characteristic vascular changes, termed “arterial deficiency”, were seen. This criterion permitted correct diagnosis in only 16% of the patients with mild to moderate emphysema, and in 42% of those with moderately severe to severe emphysema. The specificity of chest radiography was 98%.

Strictly speaking, the results reported by Thurlbeck and Simon apply to the single rater involved and to the use of a single radiologic criterion, arterial deficiency. Therefore, they have no bearing on the results of our study where different criteria were used.

Our second objective was to establish whether scoring chest films for the presence or absence of emphysema might help characterizing COPD phenotype. Patients who met the radiologic criteria for emphysema had significantly lower BMI, FEV₁, and DL_co than those who did not. Conversely, radiologic TLC was significantly higher in patients with emphysema than in those without. This lends support to the validity of the criteria we used that primarily reflect lung hyperinflation [8]. Also, emphysemic patients experienced greater restriction of
physical activity, and had a much worse quality of life than non emphysemic patients.

Optimal bronchodilation is recommended as the first step in the management of stable COPD [2]. However, substantial improvements in exercise tolerance, symptoms, and health-related quality of life are often achieved only after the implementation of pulmonary rehabilitation [22]. Randomised trials are, therefore, needed to establish whether rehabilitation programs are as effective or more effective than standard pharmacological treatment in emphysemic patients.

Correct recognition of emphysema on chest radiography would be equally valuable in patients who either do not have, or are not known to have COPD. This is quite likely to occur in clinical practice because chest radiographs are often taken for reasons other than a chronic respiratory illness. If the chest radiograph of one of such patients meets the criteria for emphysema, it is likely that the disease be present, and the patient should be tested for airflow obstruction. Should the patient be a smoker, the diagnosis of emphysema would be a particularly strong indication to quit smoking because such patient is one of those whose lungs are overtly damaged by inhaled smoke.

In summary, the results of our study indicate that chest radiography is a valuable, inexpensive means to diagnose moderate to severe emphysema. However, it is less sensitive than CT in detecting mild emphysema and less accurate in evaluating the regional distribution of emphysema.

Acknowledgments

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REFERENCES

FIGURE LEGEND

Figure 1. (A) Prevalence of emphysema on computed tomography (CT) as a function of airflow obstruction in 154 patients. Mild obstruction: FEV₁/FVC<70% and FEV₁≥80% predicted. Moderate: 50%≤FEV₁<80%. Severe: 30%≤FEV₁<50%. Very severe: FEV₁<30%. (B) Box-and-whisker plot of CT score of emphysema as a function of airflow obstruction in 87 patients with CT-confirmed emphysema. The score on the ordinate is the average of 2 independent ratings. Line in box: 50th percentile (median); limits of box: 25th and 75th percentile; whiskers: 10th and 90th percentile. P<0.0001 by Kruskal-Wallis nonparametric test.
Figure 2. Box-and-whisker plot of CT score of emphysema as a function of the number of chest radiographic criteria for emphysema in 87 patients with CT-confirmed emphysema. The score on the ordinate is the average of 2 independent ratings. Data on the abscissa are the median of 5 independent ratings. Number of
patients in each category on the abscissa (from left to right): 10, 20, 28, and 29. P<0.0001 by Kruskal-Wallis nonparametric test.
Table 1. Criteria for radiographic diagnosis of emphysema

**Signs in the posteroanterior chest radiograph**

Depression and flattening of the diaphragm with blunting of costophrenic angles. The actual level of the diaphragm is not as significant as the contour. The body build of the subject should also be considered. In a short, stocky subject, this sign might be positive even if the diaphragm were at the level of the 10th rib posteriorly.

Irregular radiolucency of the lung fields. This manifestation is the result of the irregularity in distribution of the emphysematous tissue destruction.

**Signs in the lateral chest radiograph**

Abnormal retrosternal space. This is defined as a space showing increased radiolucency and measuring 2.5 cm or more from the sternum to the most anterior margin of the ascending aorta.

Flattening or even concavity of diaphragmatic contours. A useful index of this change is the presence of a 90-degree or larger sternodiaphragmatic angle. In most patients with emphysema, this junction is more readily seen than in subjects with normal chests.

Emphysema is considered to be present if the chest radiographs reveal any two or more of the above criteria (8). Sometimes, it may be unclear whether or not a particular diaphragmatic contour is flat. A useful way to resolve this in the posteroanterior film is to determine the straight line from the costophrenic junction to the vertebrophrenic junction on each side. If the highest level of the diaphragmatic contour is less than 1.5 cm above this line, the diaphragm can be recorded as flat. The same dimension can be used in the lateral film measuring from a line connecting the costophrenic junction posteriorly to the sternophrenic junction anteriorly (18).

Flattening of the diaphragmatic contours with blunting of costophrenic and sternophrenic angles are seldom, if ever, seen in conditions of acute lung hyperinflation. Also, areas of irregular radiolucency of the lung fields are absent in such conditions (18).
### Table 2. Chest radiography versus computed tomography in diagnosis or exclusion of emphysema

<table>
<thead>
<tr>
<th>Rater</th>
<th>True positive</th>
<th>Sensitivity %</th>
<th>True negative</th>
<th>Specificity %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>79</td>
<td>91</td>
<td>66</td>
<td>99</td>
</tr>
<tr>
<td>2</td>
<td>78</td>
<td>90</td>
<td>66</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>78</td>
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<td>97</td>
</tr>
<tr>
<td>5</td>
<td>79</td>
<td>91</td>
<td>65</td>
<td>97</td>
</tr>
</tbody>
</table>

CT: computed tomography.
Raters 1 and 2 are pulmonologists; raters 3 and 4 are medical students; rater 5 is radiology technician.
Two patients were rated false positive for emphysema based on depression and flattening of diaphragmatic contours in posteroanterior and lateral projections. One was an 81 year-old male with severe airflow obstruction (FEV₁=46% predicted); CT showed extensive vascular disruption in lower lobes without clear areas of low attenuation. The other was an 86 year-old male with no airflow obstruction (FEV₁=103% predicted); CT did not show areas of low attenuation.
Table 3. False negative ratings on chest radiography

<table>
<thead>
<tr>
<th>Patient</th>
<th>False negative n/N</th>
<th>CT score of emphysema</th>
<th>Type of emphysema</th>
<th>Regional distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5/5</td>
<td>5</td>
<td>paraseptal</td>
<td>upper lobe</td>
</tr>
<tr>
<td>2</td>
<td>5/5</td>
<td>5</td>
<td>paraseptal</td>
<td>upper lobe</td>
</tr>
<tr>
<td>3</td>
<td>4/5</td>
<td>5</td>
<td>paraseptal</td>
<td>upper lobe</td>
</tr>
<tr>
<td>4</td>
<td>5/5</td>
<td>5</td>
<td>paraseptal</td>
<td>upper lobe</td>
</tr>
<tr>
<td>5</td>
<td>3/5</td>
<td>10</td>
<td>paraseptal</td>
<td>upper lobe</td>
</tr>
<tr>
<td>6</td>
<td>5/5</td>
<td>10</td>
<td>centrilobular</td>
<td>upper lobe</td>
</tr>
<tr>
<td>7</td>
<td>3/5</td>
<td>15</td>
<td>centrilobular</td>
<td>upper lobe</td>
</tr>
<tr>
<td>8</td>
<td>5/5</td>
<td>15</td>
<td>centrilobular</td>
<td>upper lobe</td>
</tr>
<tr>
<td>9</td>
<td>3/5</td>
<td>15</td>
<td>centrilobular</td>
<td>upper lobe</td>
</tr>
<tr>
<td>10</td>
<td>3/5</td>
<td>20</td>
<td>centrilobular</td>
<td>upper lobe</td>
</tr>
<tr>
<td>11</td>
<td>1/5</td>
<td>25</td>
<td>centrilobular</td>
<td>upper lobe</td>
</tr>
</tbody>
</table>

CT: computed tomography.
n=number of false negative ratings.
N=total number of raters.
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All patients (n=458)</th>
<th>Emphysema (n=245)</th>
<th>No emphysema (n=213)</th>
<th>P-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex</td>
<td>375 (82)</td>
<td>204 (83)</td>
<td>171 (80)</td>
<td>0.48</td>
</tr>
<tr>
<td>Age (years)</td>
<td>66 (61-71)</td>
<td>66 (61-71)</td>
<td>66 (60-70)</td>
<td>0.54</td>
</tr>
<tr>
<td>Pack-years of smoking</td>
<td>46 (37-57)</td>
<td>46 (37-58)</td>
<td>45 (35-57)</td>
<td>0.42</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>27 (24-30)</td>
<td>25 (22-28)</td>
<td>29 (26-32)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>FEV₁, % predicted</td>
<td>48 (36-60)</td>
<td>42 (31-51)</td>
<td>56 (44-65)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>DLCO, % predicted</td>
<td>66 (50-80)</td>
<td>55 (40-67)</td>
<td>78 (64-92)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Radiologic TLC, % predicted †</td>
<td>114 (104-122)</td>
<td>122 (112-134)</td>
<td>107 (99-116)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SGRQ symptoms score, %</td>
<td>37 (20-55)</td>
<td>40 (21-59)</td>
<td>35 (20-53)</td>
<td>0.16</td>
</tr>
<tr>
<td>SGRQ activity score, %</td>
<td>54 (42-79)</td>
<td>59 (48-80)</td>
<td>53 (36-67)</td>
<td>0.0004</td>
</tr>
<tr>
<td>SGRQ impacts score, %</td>
<td>34 (18-51)</td>
<td>39 (22-53)</td>
<td>29 (13-46)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SGRQ total score, %</td>
<td>41 (27-57)</td>
<td>45 (30-61)</td>
<td>37 (25-51)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

COPD: chronic obstructive pulmonary disease; IQR: interquartile range; BMI: body mass index; FEV₁: forced expiratory volume in one second; DLCO: carbon monoxide lung diffusing capacity; TLC: total lung capacity; SGRQ: St. George's respiratory questionnaire.

* Emphysema versus no emphysema.
† Available in 200 patients (82 with emphysema and 118 without).