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ORIGINAL ARTICLE

CT quantification of emphysema: Is semi-quantitative scoring a reliable enough method?

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KEYWORDS

COPD;
CT emphysema index;
Modified Goddard score;
Mean lung attenuation;
Emphysema.

Abstract *Objective:* To evaluate whether a simple semi-quantitative method aided by software enhanced visualization can be reliable enough for the quantification of emphysema during the daily workload.

Patients and methods: Thirty patients with COPD were included. Patients had a standard non enhanced MDCT study of the chest using a 16 slice machine. The images were evaluated visually and scored. This scoring was repeated after applying a density mask. Three radiologists evaluated the images on separate occasions. Repeatability was also tested. The CT emphysema index and the mean lung attenuation were calculated. The extent of airway disease was not assessed.

Results: Kappa test between the 3 readers revealed slight agreement ($k = 0.122$, $p = 0.001$) before the density mask and substantial agreement ($k = 0.75$, $p < 0.0005$) after its application. A high degree of repeatability was found. The median visual score after density mask application, showed a stronger correlation to the emphysema index ($r = 0.81$, $p < 0.0005$) than before.

Conclusion: We present a simple visual score for quantitation of emphysema, that when combined with a simple density mask, the inter-rater agreement and repeatability of scoring are markedly improved. This method appears to be fast and easy to perform.

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1. Introduction

Chronic obstructive pulmonary disease is a common health problem that we encounter in everyday patients. The pathogenesis of the disease is still not fully understood and is probably a combination of several factors. The factors that were frequently under study are the degree of airway obstruction and the extent of emphysema.

The volumetric CT quantification of emphysema is not part of the routine chest CT study in COPD patients until now. The visual evaluation methods are highly dependent on the radiologist and his experience level. The quantitative methods, on the other hand, are time-lengthy and require certain image

Abbreviations: COPD, chronic obstructive pulmonary disease; MLA, mean lung attenuation; GOLD, global initiative for chronic obstructive lung disease; MDCT, multi-detector computed tomography; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; LVRS, lung volume reduction surgery.

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preparation, e.g. manual extraction of trachea and bronchi. The aim of our study is to evaluate some of the common emphysema quantification methods in a group of COPD patients in our community, to determine whether a simple semi-quantitative method aided by software enhanced visualization can be reliable enough for the complete evaluation of emphysema in COPD patients during the daily workload of a busy radiology department.

2. Patients and methods

Thirty patients (20 males and 10 females; mean age: 60.2 ± 4.4 years old) diagnosed clinically as having COPD were included in our study. The inclusion criteria were as follows: (1) ability to have a standard MDCT study of the chest. (2) CT findings of normal or emphysematous changes only were accepted (see #1 in exclusion criteria for explanation). (3) Complete pulmonary function tests.

Exclusion criteria were as follows: (1) Patients with chest CT findings of consolidation, collapse, malignancy, or pleural abnormalities that might affect the total lung volume. (2) Patients with incomplete records. (3) Patients with respiratory failure.

Patients had a standard non enhanced MDCT study of the chest using a 16 slice GE BrightSpeed machine (GE Healthcare Medical Systems, Milwaukee, WI). Before the MDCT study, patients were instructed that they will be required to take and hold deep inspiration upon request during the study. They were trained on this manoeuver 5 min before the scanning starts. The parameters of the CT scan include: 120 kV, auto tube mAs, slice thickness 5 mm, inter-slice gap 5 mm and resolution 512 × 512.

All patients had complete pulmonary function tests and according to the FEV_1 and FEV_1/FVC, they were classified into the respective GOLD stage (2). None of our patients were stage IV.

Stage I	Mild COPD	$FEV_1/FVC < 0.7$	FEV_1: ⩾80%
Stage II	Moderate COPD	$FEV_1/FVC < 0.7$	FEV_1: 50–79%
Stage III	Severe COPD	$FEV_1/FVC < 0.7$	FEV_1: 30–49%
Stage IV	Very severe COPD	$FEV_1/FVC < 0.7$	FEV_1: < 30%

2.1. Image analysis

Emphysema is identified as areas of hypovascular low attenuation. The images were evaluated visually and scored according to the modified Goddard scoring system which states that: (1) no signs of emphysema (score 0). (2) Emphysema in ⩽5% (score 0.5). (3) Emphysema in ⩽25% (score 1). (4) Emphysema in 26–50% (score 2). (5) Emphysema in 51–75% (score 3). (6) Emphysema in ⩾75% (score 4) (3). This scoring system was first done on the grey scale images. Then this scoring was repeated again after applying a density mask to the image sequence. The density mask is a density threshold (−950 to −1024 HU) that highlights voxels within this density range (4). This level was chosen because it correlated best to the emphysematous changes in the lungs (5). The trachea, mainstem bronchi, bowel gas and the background of the image are included in this density range and were not excluded as this was a visual score. The local software of the MDCT workstation (Advantage Windows 4.4 software, GE Healthcare Medical Systems, Milwaukee, WI) was used for the density mask application. Three independent radiologists evaluated the images in the same manner and on separate occasions and their readings were recorded. Repeatability of scoring was done by one of the authors (L.A.M.) on 2 separate occasions, 1 week apart.

For the quantitative evaluation, again the local software of the MDCT workstation (Advantage Windows 4.4 software) was used for the segmentation and CT emphysema index calculation. The CT emphysema index is defined as the proportion of the lung affected by emphysema (1,4). Segmentation of the lung was done as a prior step to exclude soft tissues and fat from the field of analysis. A threshold of −200 to −1024 HU was applied to the entire image sequence and the rest of tissues were excluded. Trachea, main stem bronchi, bowel gas and the background of the images were excluded manually (6). The image sequence was then revised for correct segmentation. After image manipulation, the segmented image sequence is saved and transferred to another computer. Image J software (National Institutes of Health, USA) was used for the calculation of the mean lung attenuation (MLA) and the emphysema index. The images were quantitatively evaluated considering a density level of −950 HU as the threshold level for emphysema (5).

The extent of airway disease was not assessed in this study.

2.2. Statistical analysis

Statistical analysis was run on SPSS v16 for Windows (SPSS, Cary, NC). The tests included the kappa test for inter-rater reliability of visual analysis. Repeatability was tested by calculating the intra-class correlation coefficient (ICC) and only after applying the density mask to the images. Spearman bivariate correlation test was then used to flag the correlations with the emphysema index. Analysis of Variance (ANOVA) was used to compare the means of MLA and emphysema index between the GOLD stages. The median visual score (of the 3 readers) was recorded before and after applying the density mask. Kruskal–Wallis test was used to compare the visual score between the GOLD stages. Statistical significance was used at $p \leqslant 0.05$.

3. Results

Thirty patients with clinically diagnosed COPD were included in this study. The mean age and standard deviation was 60.2 ± 4.4 years old. The study included 20 males and 10 females. Four patients had GOLD stage I, 18 patients had GOLD stage II while 8 patients had GOLD stage III.

3.1. Inter-rater agreement and repeatability

The modified Goddard scale used for visual analysis of emphysema varied between the 3 readers as follows (Table 1).

The kappa test run between the 3 readers revealed slight agreement ($k = 0.122$, $p = 0.001$).

After density mask application, the visual analysis scoring varied as follows (Table 2).

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