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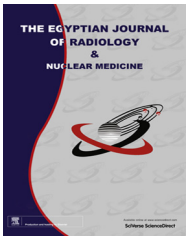

ORIGINAL ARTICLE

Quantitative validation of the severity of emphysema by multi-detector CT

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KEYWORDS

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PFTs

Abstract *Objectives:* To determine whether MDCT reflects the severity of chronic obstructive pulmonary disease (COPD) compared to the pulmonary function tests (PFTs).
Patients and methods: A prospective study included 63 COPD patients. Spirometry was done and included forced expiratory volume in 1 s (FEV1), forced vital capacity (FVC) and the ratio of forced expiratory volume in 1 s over forced vital capacity (FEV1/FVC). Patients were grouped according to GOLD guidelines. MDCT examinations were obtained during full inspiration. The extent of emphysema was quantified by using dedicated software. −950 Hounsfield units (HU) used as the percentage of low-attenuation (%LA) emphysematous areas. Statistical study between PFTs, and CT emphysema extent was performed.
Results: The study included 26 females and 37 males with a mean age of 53 years. A moderate significant relationship was found between lung volume less than −950 HU and FVC, FEV1, and FEV1/FVC ($p < 0.001$). Pulmonary function tests revealed that 23.8% had mild restrictive defect, 14.3% had moderate obstructive defect and 61.9% had severe obstructive defect. A good correlation was observed between the quantitative assessments for the lower lung regions with −950 HU (%LA) and pulmonary function variables ($p < 0.001$).
Conclusion: MDCT results are significantly related to the data of PFTs for defining the severity of emphysema.

1. Introduction

Pulmonary emphysema is characterized pathologically by an abnormal enlargement of air spaces distant to the terminal bronchioles, accompanied by destruction of the alveolar walls. Chest computed tomography (CT) and pulmonary function

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tests are usually used for the evaluation of emphysema. CT is widely used not only for an imaging of the radiological assessment of the thorax but also for the functional assessment including lung density and volume. Particularly, with the recent advances in multi-detector CT technology, faster volumetric data can be acquired easily and used for evaluation of the volume (1).

Lung volumes are routinely assessed using pulmonary function tests. These tests allow global measurement of static inspiratory volumes (total lung capacity); static expiratory volumes (intrathoracic gas volume after normal expiration and the residual volume after maximum expiration); and dynamic volumes, like the absolute and relative forced expiratory volume in 1 s (FEV1). However, measurement of unilateral or regional lung volumes is a major challenge in lung function testing (2). Computed tomography (CT) yields densitometric measurements that are highly reproducible and that have been correlated with morphometric measurements of alveolar tissue (3–6). New scanners require a breath hold of much shorter duration for imaging. In addition, reconstructions to 1.25 mm for calculation or interpretation can be made without exposing the patient to additional radiation (7). State-of-the-art multi-detector CT imaging (MDCT) allows acquisition of the whole lung in thin sections of 1 mm. These high resolution 3D datasets (HR–MDCT) are mandatory to distinguish parenchymal alterations exhibited in emphysema and to assess regional variations (8). Low attenuation areas on CT represent macroscopic and microscopic emphysematous changes of the lung (9). Objective quantification of emphysema can be obtained by measuring the relative lung area occupied by pixels with attenuation coefficients below a predetermined threshold (10–12). Quantitative evaluation of emphysema will be a key feature for serial follow-up examinations of patients with chronic obstructive pulmonary disease (COPD) (13,14).

The purpose of this study is to determine whether three-dimensional CT densitometry reflects the severity of chronic obstructive pulmonary disease compared to the pulmonary function.

2. Methods and materials

2.1. Patient population

A prospective study included 63 consecutive patients with clinical suspicion of COPD, between August 2011 and December 2012.

The study was approved by the local ethics committee. All subjects were informed prior to the investigation.

2.2. Pulmonary function tests (PFTs)

Pulmonary function tests expressed as percentages of the predicted values based on age, sex, height and weight, were completed within 1 week before or after MDCT scanning. Spirometry was obtained in all subjects and included forced expiratory volume in 1 s (FEV1), forced vital capacity (FVC) and the ratio of forced expiratory volume in 1 s over forced vital capacity (FEV1/FVC). For descriptive purposes, COPD subjects were staged according to GOLD guidelines (15).

2.3. Computed tomography

2.3.1. MDCT acquisition parameters

Multi-detector CT examinations were performed by using eight-multi-detector row (lightspeed–GE) in single breath-hold spiral technique without the need for intravascular contrast material. Scans were obtained during full inspiration while the patient was in supine position, with the following parameters: 120 kVp, 250 mAs, 2.5 mm collimation, 5-mm slice thickness, 1.25-mm reconstruction increment, and a pitch of 1 with a standard reconstruction algorithm. Scan volumes were extended craniocaudally from the thoracic inlet to the level of the diaphragms and were acquired in one breath-hold period. The average DLP was 440 (mGy-cm).

2.3.2. Quantitative MDCT image analysis

All raw data were transferred to advantage workstation (AW) where thoracic VCAR imaging software was used for CT estimation of emphysema. Lungs were segmented from the thoracic wall, the heart, and main pulmonary vessels, followed by segmentation of the individual lobes and the airways. The software provides automatic segmentation of the lungs and automatic segmentation and tracking of the airway tree. The software provides quantification of Hounsfield units and a colour-coded display of the thresholds within a segmented region.

Table 1 Patient characteristics and pulmonary function tests.

Characteristics	Mean ± SDs
No. of patients	63
Sex ratio (M/F)	37/26
Age (y)	53 ± 8.9 (35–66)
Smoking	35 patients (10–100 packs-years)
FEV1%	29.8 ± 18.4 (14–56)
FVC%	44.7 ± 19.6 (27–71)
FVC1/FVC%	52.4 ± 16.4 (35–72)

Table 2 Correlation between the pulmonary function tests and extent of emphysema (%LA) below −950 HU.

		FVC%	FEV1%	FEV1/FVC%
		Extent of emphysema (−950 HU)		
Right upper lobe	*r* value	−.252*	−.205	−.317*
	p value	.046	.106	.011
Middle lung lobe	*r* value	−.236	−.199	−.346**
	p value	.062	.117	.005
Right lower lung lobe	*r* value	−.622**	−.589**	−.735**
	p value	.000	.000	.000
Left upper lobe	*r* value	.029	−.007	−.250*
	p value	.821	.954	.049
Left lower lobe	*r* value	.865**	.867**	.659**
	p value	.000	.000	.000

Data given are *r*-squared (R^2) value.
* *p* value < 0.05.
** *p* value < 0.001.