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QUANTITATIVE COMPUTED TOMOGRAPHY DENSITOMETRY IN EMPHYSEMA AND ITS RELATIONSHIP WITH QUALITATIVE VISUAL SCORING AND PULMONARY FUNCTION TESTS

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Abstract: Emphysema as common and rather pathological entity is classified among the chronic obstructive pulmonary diseases (COPD) and defined as abnormal and irreparable increase in size of the airspaces located caudally to the terminal bronchioles that may go along with alveolar wall destruction but no evident fibrosis. Not only is CT being used as a regular diagnostic tool in the detection of emphysema, but in recent years offers a phenotypic classification and quantification of lung abnormalities that assists the clinical characteristics of the patients involved.
The aim of this study was to demonstrate significant correlation between quantitative CT densitometry on one side, and the visually assessed CT subtypes as well as the function lung tests on the other side in patients with emphysema.
In total of 10 patients diagnosed with emphysema, 8 male and 2 female, with the mean age of 61. 3± 14. 84 , who underwent a CT exam, a quantitative CT densitometry was calculated and compared to 5 visually acquired CT subtypes using the Fleischner Society classification: normal, bronchial disease and centrilobular emphysema (trace, mild and advanced destructive). A correlation was also made with the pulmonary function tests (FEV1 and FEV1/ FVC ratio).
There is a strong positive correlation which is statistically significant for $p< 0.5$ for the parameters of quantitative assessment with -950HU calculated on the CT densitometry and the CT visual scoring, as well as statistically significant and strong negative correlation between the pulmonary function tests, FEV1 and FEV1/ FVC ratio, respectively. The pulmonary function tests, according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD), revealed that 30% of our patients had mild, severe and very severe obstructive defect respectively, where only 10% had moderate obstructive defect.
Quantitative CT densitometry, already being a non- invasive study, also plays a major role in detecting, clearly depicting and quantifying lung zones involved with emphysema and provides rapid evaluation of the severity of emphysema. Quantitative CT densitometry with its accurate illustration of the extent and distribution of lung abnormalities in emphysema may aid the selection of patients who are suitable for lung reduction surgery.
Keywords: emphysema, quantitative computed tomography (QCT), densitometry, visual score and pulmonary function tests (PFT).

1. INTRODUCTION

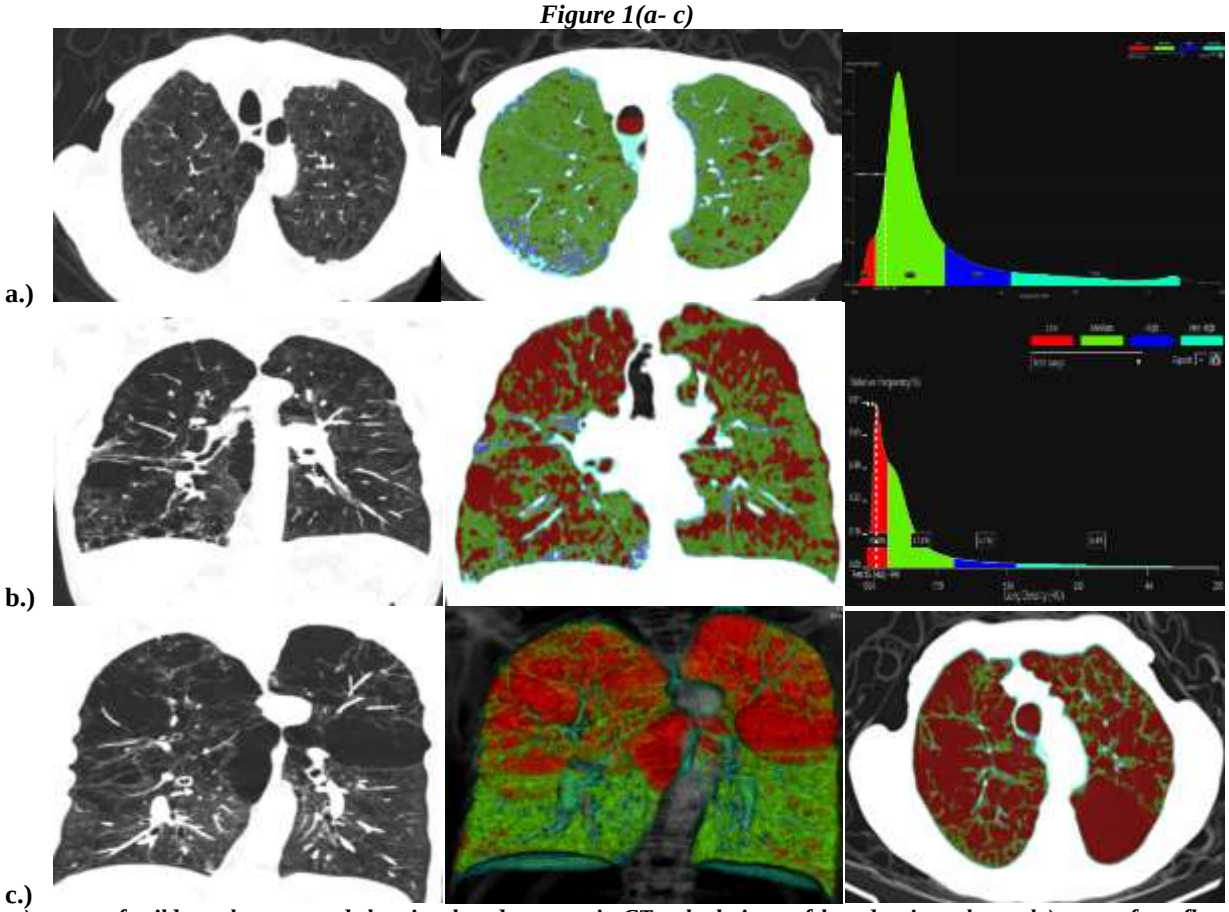
Chronic obstructive pulmonary disease (COPD) is a common and heterogeneous health disorder that is characterized by irreversible restriction of the airway flow due to several risk factors such as lifestyle habits, smoking as the most frequent one, and some occupational hazards and exposures, as well as the air pollution (Lowe, K. E., 2019). It has been reported that approximately 15-20% of smokers are at risk of developing COPD (Roca, J., 2014). The major pathological findings in COPD are inflammation and inadequate gas exchange, whereas the disease itself includes two phenotypically related conditions: emphysema and chronic bronchitis. Emphysema is classified among the chronic obstructive pulmonary diseases (COPD) and defined as abnormal and irreparable increase in size of the airspaces located caudally to the terminal bronchioles that may go along with alveolar wall destruction but no evident fibrosis. These two cannot be explained nor quantified solely by pulmonary function tests, history of exposure and respiratory symptoms (Koo, H. J., 2019). Not only is CT being used as a regular diagnostic tool in the detection of emphysema, but over the last few years additionally offers a phenotypic classification and quantification of lung abnormalities that assists the clinical characteristics of the patients involved.
The aim of this study was to demonstrate a significant correlation between quantitative CT densitometry on one side, and the visually assessed CT subtypes as well as the function lung tests on the other side in patients with emphysema.

2. MATERIALS AND METHODS

We included a total of 10 patients in the study that were already diagnosed with emphysema and they all underwent HRCT technique on a 16 channel Toshiba MSCT without intravascular application of contrast agent. Scans were acquired during full inspiration in supine position.

The quantitative CT densitometry is an automatic, machine based calculation of regions with low density and is performed by a special CT algorithm. The raw CT data was sent to a Vitrea workstation for further post- processing, reconstruction and manipulation. Lung parenchyma was then automatically extracted from other thoracic structures, such as chest wall, vascular and bronchial structures and mediastinum by selecting lung density presets. The distribution and extent of low density in both lungs, expressed in Hounsfield Units (HU), was then automatically computed by applying a density mask technique and using a cut-off value of – 950 HU because it was in perfect accord to the work presented by Wang et al. (Wang et al., 2013) ***(Figure 1 a-c).***

Figure 1(a- c)



a.) case of mild emphysema and the visual and automatic CT calculations of low density volume, b.) case of confluent emphysema and visual and low density volume calculations, c.) case of advanced destructive emphysema.

Then we compared the values from the CT densitometry to our 5 visually acquired CT subtypes using the Fleischner Society classification. Centrilobular emphysema was categorized as: 1. In traces (0.5%), 2. mild (0.5–5%), 3. moderate (>5%), 4. confluent (coalescent centrilobular or lobular lucencies) and 5. advanced destructive emphysema (panlobular lucencies with hyperexpansion and distortion). (Lynch at al., 2015; Park at al., 2020)

Our participants were classified into 5 subtypes based on our visual estimation of the CT images provided: 1. normal (no visible emphysema), 2. bronchial disease, 3. centrilobular emphysema in traces, 4. mild centrilobular emphysema and 5. confluent and advanced destructive emphysema.

A correlation was also made with the pulmonary function tests (FEV1 and FEV1/ FVC ratio).

The pulmonary function tests in patients with emphysema were categorized according to the GOLD guidelines. In patients with FEV1/FVC < 0.70: GOLD 1: mild FEV1 ≥ 80%, GOLD 2: moderate 50% ≤ FEV1 < 80%, GOLD 3: severe 30% ≤ FEV1 < 50%, GOLD 4: very severe FEV1 < 30%. (Global Initiative for Chronic Obstructive Lung Disease, 2018).

3. RESULTS

Out of 10 patients included in the study, 8 were male (80%) and 2 female, with the mean age of 61. 3± 14. 84. There was strong positive correlation which was statistically significant for p< 0.5 for the parameters of quantitative assessment, low density volume and low density index, calculated on the CT densitometry and the CT visual scoring, as well as statistically significant and strong negative correlation between the pulmonary function tests, FEV1 and FEV1/ FVC ratio, respectively. But there was a strong positive correlation which is statistically significant between the 15% percentile value (PD15) on CT densitometry and the pulmonary function test, and a strong negative correlation with the visual score on CT. ***(Table 1, Figure 1, 2a, b).***

Table 1. Correlation between the quantitative parameters of lung density on CT and the pulmonary function tests and the visual score on CT.

	FEV1	FEV1/FVC	VSCT
LDV	R= - 0.9695 p= .000011	R= - 09401 p= .000053	R= 0.8855 p= .000653
LDI	R= - 0.9722 p< .00001	R= - 0. 935 p= .000072	R= 0.9018 p= .000361
PD15(g/L)	R= 0.9555 p= .000016	R= 0.963 p< .00001	R=-0.9758 p< .00001

LDV(%)- low density volume; LDI- low density index; PD15(g/L)-15% percentile value(PD15); FEV1- forced expiratory volume; FVC- forced vital capacity; VSCT- visual score on CT.

Figure 1. Correlation between low density volume and CT visual score.

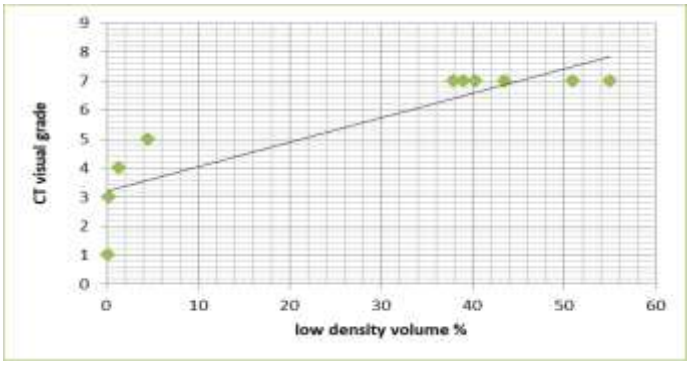
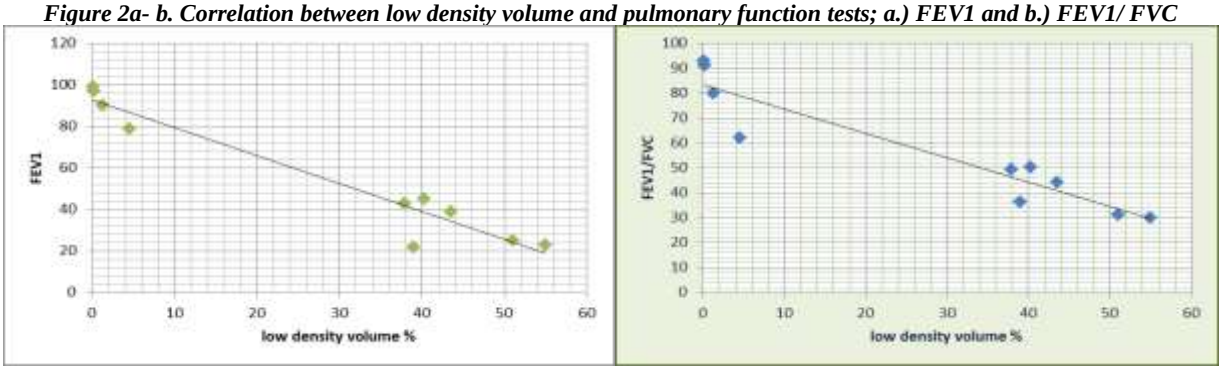
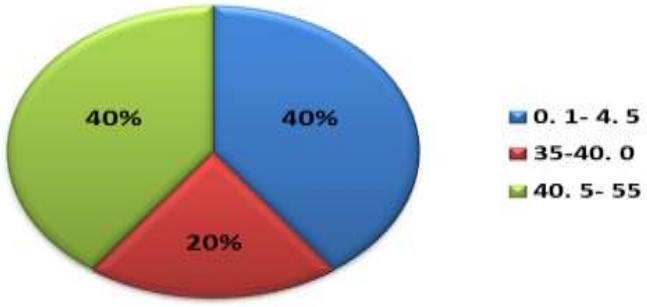


Figure 2a- b. Correlation between low density volume and pulmonary function tests; a.) FEV1 and b.) FEV1/ FVC



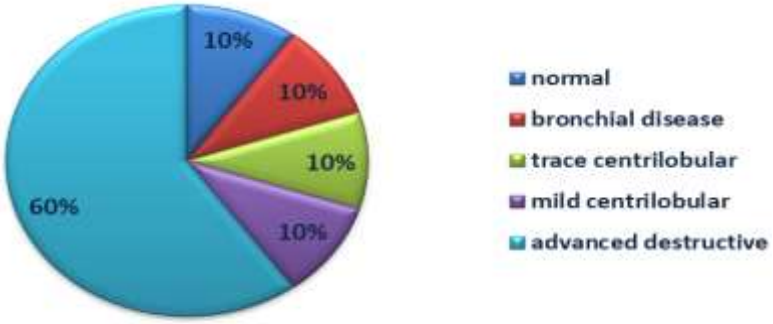
The CT densitometry revealed that 40% of our patients had low density volume of 0.1 to 4.5% in both lungs, 20% had low density volume from 35 to 40% and 40% patients showed low density volume in both lungs from 40.5 to 55% ***(Figure 3).***

Figure 3. Distribution of low density volume in both lungs



The pulmonary function tests, according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD), revealed that 30% of our patients had mild, severe and very severe obstructive defect respectively, where only 10% had moderate obstructive defect**.** The CT visual scores were normal in 10% of our patient group whereas bronchial disease, centrilobular emphysema in traces and mild centrilobular emphysema were encountered in 10%, and advanced destructive emphysema in 60% of patients. ***(Figure 4)***

Figure 4. Distribution of the CT visual score in our patient group.



4. DISCUSSION

Considering the fact that pulmonary function tests do not always offer a sufficient explanation of the diversity of the chronic obstructive pulmonary diseases, the CT can significantly help in differentiating patients with COPD who exhibit similar results on spirometry (Han, M. K. at al., 2010). Calculating the pixel attenuation on MDCT has become a sovereign method in quantifying emphysema (Temizoz, O., 2007). CT has an important role in accurate depicting of the zonal distribution and the volume of lung regions affected with emphysema (Bakker, M. E., 2005). While acquiring the basic information on CT in full inspiration, the value of -950HU has been reported as the most beneficial in the evaluation of emphysema on CT densitometry (Wang et al., 2013). All our exams were performed in full inspiration and without administering intravenous contrast agent, since it has been reported that the contrast material affects the attenuation of the lung (Mets, O. M., 2012). We chose not to conduct expiratory CT scans since it has been revealed that inspiratory scans show more detailed information in quantifying emphysema (Gevenois, P. A., 1996). In our current study we observed a strong positive correlation which is statistically significant for $p< 0.5$ for the parameters of quantitative assessment, the low density volume and low density index, calculated on the CT densitometry and the CT visual score, as well as statistically significant and strong negative correlation between the pulmonary function tests, FEV1 and FEV1/ FVC ratio, respectively. On the other side there was a strong positive correlation which was statistically significant between the 15% percentile value (PD15) on CT densitometry and the pulmonary function test, and a strong negative correlation with the visual score on CT. Similar correlation results were reported by Abd elsalam et al. in an article from 2020 (Abd elsalam et al., 2020) although their study was conducted on a larger study group and they performed calculation and comparison of the low density parameters in each lung lobe individually, with the visual CT score and the pulmonary function tests, whereas we decided to use the sum of values for both lungs. Similarly, Kang et al., reported in a study from 2021 that as the visual grade of centrilobular emphysema worsened, pulmonary function declined and quantitative assessment (emphysema index and air trapping) increased. They also included a correlation of the bronchial subtype and body mass index (BMI), in all participants (Kang, H. S., 2021). The CT analysis and quantification of lung density has its own limitations, one of which is the fact that it depends on the full cooperation with the patient, so if full inspiration is not achieved,

there will be minimal decrease in the density of the lung and many misinterpretations (Nhue, L. D. and Beek, Y. C., 2012).

5. CONCLUSION

Quantitative CT densitometry appears to exhibit strong correlation with emphysema visual CT score and pulmonary functional tests, so already being a non- invasive study and playing a significant role in detecting, clearly depicting and quantifying lung zones involved with emphysema, it can also provide rapid evaluation of the severity of emphysema and it can become a regular part of the routine CT studies of patients with emphysema. Quantitative CT densitometry with its accurate illustration of the extent and distribution of lung abnormalities in emphysema may also aid the selection of patients who are suitable for lung reduction surgery.

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