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Original Article

Association of CT phenotype with pulmonary function in patients with chronic obstructive pulmonary disease and influencing factors of prognosis

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Abstract: Objective: To determine the correlation between computed tomography (CT) phenotype and pulmonary function in patients with chronic obstructive pulmonary disease (COPD) and to analyze the influencing factors of prognosis. Methods: In this retrospective study, a total of 174 COPD patients admitted to the First Affiliated Hospital of Hebei North University from May 2017 to October 2020 were enrolled and assigned to the M-type group (n = 48), E-type group (n = 56) or A-type group (n = 70) according to their CT features. The CT features and pulmonary function indexes of all the patients and their correlation were analyzed, and the acute exacerbation in one-year follow-up of the patients was recorded. Logistic regression was carried out to analyze the influencing factors for the prognosis of COPD. Results: The A-type group showed significantly better pulmonary function than the E-type group and M-type group ($P < 0.05$), and the degree of emphysema was negatively correlated with pulmonary function. The A-type group showed a significantly lower one-year acute exacerbation rate than the other two groups ($P < 0.05$). A relatively longer course of disease, a relatively lower forced expiratory volume in 1 second (FEV1)/forced vital capacity (FVC) ratio and CT phenotype were correlated with the unfavorable prognosis of patients. Conclusion: According to determination of the pulmonary function of patients with COPD through CT, the degree of emphysema worsens with the progression of the disease. A relatively longer course of disease, a relatively lower FEV1/FVC ratio and CT phenotype are independent risk factors for unfavorable prognosis of COPD patients.

Keywords: Chronic obstructive pulmonary disease, CT phenotype, pulmonary function, prognosis

Introduction

Chronic obstructive pulmonary disease (COPD) is a common but serious chronic disease. It was the fourth primary cause of death worldwide, and now it has developed into the third primary cause of death. Thus, it has brought great challenges to public health [1, 2]. People who have been exposed to tobacco and smoke for a long time are more likely to suffer from COPD [3]. COPD, as a heterogeneous disease, shows various phenotypes clinically, and different phenotypes indicate different morbidity and prognosis. Different COPD-related phenotypes may be attributed to different molecular mechanisms [4, 5]. The pulmonary function of COPD patients decreases rapidly because of the limited airflow [6]. Pulmonary function test is often the main means to diagnose COPD, grade the severity of patients, and predict their mortality. However, with deeper research into COPD, one single index is not sufficient to fully reflect the progress and prognosis of patients [7, 8], so it is necessary to search for a new diagnosis method.

Although the exact mechanism of COPD remains unclear, excessive production of free radicals and excessive inflammation are important mechanisms giving rise to the progress of COPD [9]. COPD is triggered by multiple pathological changes of airway and lung parenchyma, characterized by persistent respiratory symptoms and airflow restriction [10, 11]. In order to better treat COPD, it is necessary to carry out individualized treatment according to different clinical types of COPD [12]. Moreover, it is more helpful to distinguish the prognosis

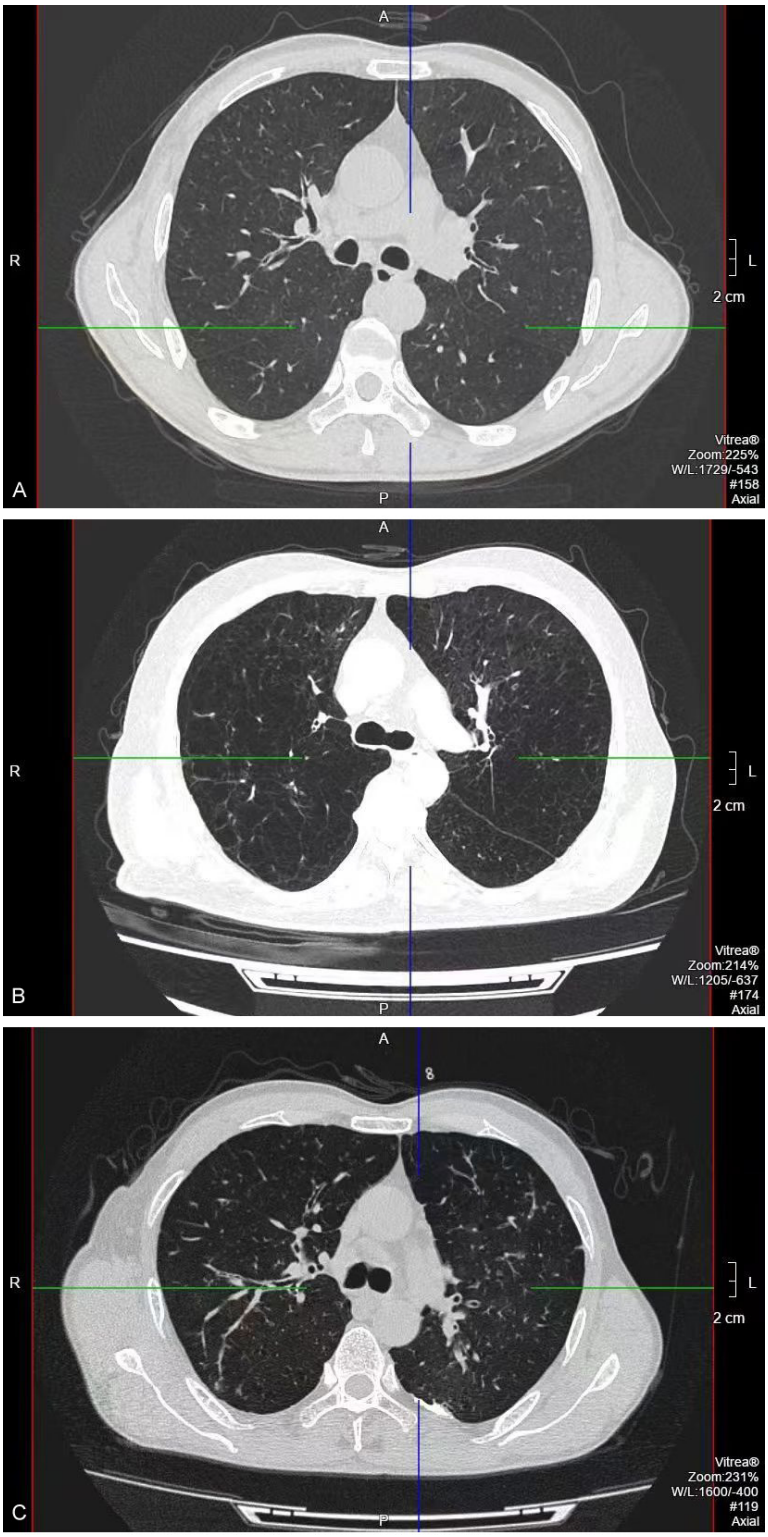

Figure 1. Typical CT figures of the M-type, E-type and A-type. A. Representative image of A-type. B. Representative image of E-type. C. Representative image of M-type.

and treatment characteristics of patients according to different clinical manifestations, physiology, imaging and treatment response [13, 14]. High-resolution computed tomography (HRCT) can help observe the abnormal changes of lung parenchyma, including emphysema and bronchitis, so as to distinguish the different pathophysiological mechanisms of COPD [15]. In areas severely affected by emphysema, the small pulmonary artery will narrow, thus aggravating the airflow obstruction. The severity of emphysema can be reflected by CT images. Based on this, COPD patients can be classified with different CT phenotypes [16].

The present study detected COPD patients with different CT phenotypes, so as to analyze the association of CT phenotypes with pulmonary function indexes, and observe their influence on the patients' prognosis, with the goal of providing important references for the implementation of disease prevention measures.

Materials and methods

Patient information

In this retrospective study, the clinical data of 174 COPD patients admitted to the First Affiliated Hospital of Hebei North University from October 2017 to October 2020 were analyzed. The patients were assigned to the M-type group (n = 48), E-type group (n = 56) or A-type group (n = 70) according to their CT features. Patients without emphysema or with only slight emphysema and without bronchial wall thickening were assigned to the A-type group (**Figure 1A**), including 48 males and 22 females, with an average age of 72.02±8.84 years old. Pa-

tients with significant emphysema but no bronchial wall thickening were assigned to the E-type group (**Figure 1B**), including 40 males and 16 females, with an average age of 72.31±9.95 years old; those with significant emphysema and bronchial wall thickening were assigned to the M-type group (**Figure 1C**), including 36 males and 12 females, with an average age of 73.54±7.74 years old. Informed consent of all patients or their families was been obtained in this study, and the study was approved by the Medical Ethics Committee of our hospital, approval number: 20170518.

Inclusion and exclusion criteria

The inclusive criteria: Patients with COPD that were confirmed by chest CT and pulmonary function examination; patients with forced expiratory volume in 1 second (FEV1)/forced vital capacity (FVC) < 0.7; patients meeting the diagnosis criteria of Global Initiative for Chronic Obstructive Lung Disease (GOLD) [17]; patients whose pulmonary function examination was based on the guidelines in the American Thoracic Society (ATS)/European Respiratory Society (ERS) [18]; patients who were followed up for at least 1 year; patients in the stable stage of COPD, namely without aggravation in cough, sputum and dyspnea in the past 2 months; and those with complete clinical data.

The exclusion criteria: Patients comorbid with other pulmonary diseases, such as bronchiectasis, pneumonia and lung cancer; patients with severe cardiac insufficiency; patients with thoracic deformity or pleural diseases; patients with positive bronchiectasis test; patients with a previous history of chest surgery; or patients in pregnancy.

CT detection method

The Canon Aquiline ONE Vision spiral CT was used for a whole lung scan and enlarged target scan for the right upper lobe. All subjects were in a supine position, and scanned at the end of deep inhalation, with the head entering first. The scanning parameters for the whole lung: Effective tube voltage: 100 kV; automatic tube current mAs; scanning collimation: 128 mm × 0.625 mm; rotation time: 0.5 s; pitch: 0.915; scanning bed speed: 146.4 mm/s; FOV: 35 cm × 35 cm; scanning slice thickness: 5 mm; reconstruction slice thickness: 1 mm, and scanning range: from the tip of the lung to the bottom of the lung. With the ADW4.3 workstation, the scanned images were processed and the lung lobes, total lung volume, total lung volume at the end of deep inhalation (Vin) and total lung volume at the end of deep exhalation (Vex) were outlined. Vin reflects the total lung capacity, and Vex reflects the residual capacity. The emphysema index at the end of deep exhalation (Elex) was calculated. Elex represents the proportion of end expiratory emphysema in total lung volume. The higher the Elex, the worse the emphysema. All the values were analyzed by two experienced imaging doctors, and the average value was taken.

Pulmonary function test

The ratio of FEV1/FVC, ratio of FEV1 to the expected value (FEV1%pred), and ratio of the residual volume/total lung volume (RV/TLC) of patients were all acquired by an CareFusion Germany 234 GmbH Pulmonary function Tester. The values of each patient were measured three times, and the results were averaged. Patients with COPD were divided into 4 grades according to GOLD [19]. Grade I (mild): FEV1 accounted for ≥ 80% of the predicted value; grade II (moderate): FEV1 accounted for < 80% of the predicted value and ≤ 50% of the predicted value; grade III (severe): FEV1 accounted for ≥ 30% of the predicted value and < 50% of the predicted value; IV (very severe): FEV1 accounted for < 30% of the predicted value or FEV1 accounted for < 50% of the predicted value and was accompanied by chronic respiratory failure.

Follow-up

All patients were followed up for one year by means of telephone and outpatient reexamination, and the number of patients with acute exacerbation in one year was counted. During one year of follow-up, the patients were required to inhale Budesonide and Formoterol Fumarate Powder twice a day, and Tiotropium Bromide Powder once a day.

Outcome measures

(1) The pulmonary function indexes FEV1/FVC, FEV1%pred, RV/TLC of the three groups were compared; (2) Pearson correlation was adopted to analyze the associations of CT parameters (Vin, Vex, and Elex) with pulmonary function indexes (FEV1/FVC, FEV1%pred, and RV/

Table 1. Baseline data

	A-type group (n = 70)	E-type group (n = 56)	M-type group (n = 48)	X^2/F	*P*-value
Age (years)	72.02±8.84	72.31±9.95	73.54±7.74	0.437	0.646
Gender				0.576	0.750
Male	48 (68.57)	40 (71.43)	36 (75.00)		
Female	22 (31.43)	16 (28.57)	12 (25.00)		
Course of disease (years)	6.21±2.48	6.45±2.62	6.69±2.76	0.489	0.614
BMI (kg/m^2)	23.77±3.26	23.16±3.24	23.51±3.35	0.539	0.585
Smoking status				2.991	0.559
Smoke	29 (41.43)	22 (39.29)	21 (43.75)		
Has quitted smoking	20 (28.57)	23 (41.07)	15 (31.25)		
Do not smoke	21 (30.00)	11 (19.64)	12 (25.00)		
Past medical history					
History of asthma	13 (18.57)	8 (14.29)	9 (18.75)	0.506	0.776
History of pneumonia	7 (10.00)	4 (7.14)	6 (12.50)	0.848	0.654
GOLD grade				2.711	0.607
Stage I	13 (18.57)	7 (12.50)	6 (12.50)		
Stage II	36 (51.43)	31 (55.36)	22 (45.83)		
Stage III and Stage IV	21 (30.00)	18 (32.14)	20 (41.67)		
Respiratory symptoms					
Phlegm	48 (68.57)	37 (66.07)	33 (68.75)	0.116	0.944
Dyspnea	32 (45.71)	30 (53.57)	29 (60.42)	2.521	0.284
Cough	44 (62.86)	35 (62.50)	32 (66.67)	0.239	0.888

QuitNo, Body Mass Index; GOLD grade, Global Initiative for Chronic Obstructive Lung Disease grade.

TLC) in COPD patients; (3) The one-year acute exacerbation rate was compared among the three groups; (4) Logistics regression was conducted for analyzing the risk factors of unfavorable prognosis of COPD patients.

Statistical analyses

SPSS20.0 software was used for statistical analyses on the collected data, and GraphPad Prism 7 for figure rendering. Counting data (%) were analyzed using the chi-square test, and presented by X^2. Measurement data (Mean ± SD) were compared using the independent-samples t test between groups, and presented by t. Their multi-group comparison was conducted using the one-way ANOVA, and expressed as F. The LST test was adopted for post hoc test, and the Pearson test was used to analyze the association of CT parameters (Vin, Vex, and Elex) with pulmonary function indexes (FEV1/FVC, FEV1%pred, and RV/TLC) of COPD patients. According to the acute exacerbation of COPD in one-year follow-up, the patients were divided into two groups: poor prognosis group and good prognosis group. Multivariate Logistic regression was used to analyze the independent risk factors of poor prognosis. $P < 0.05$ suggested a notable different between groups.

Results

Patient information

According to comparison of baseline data, the groups were not greatly different in age, gender, course of disease, body mass index (BMI), smoking status, past medical history (history of asthma and pneumonia), GOLD grade and respiratory symptoms (phlegm, dyspnea and cough) ($P > 0.05$, **Table 1**).

Comparison of pulmonary function indexes

According to comparison of the pulmonary function indexes of the three groups, the A-type group showed significantly higher levels of FEV1/FVC and FEV1%pred and a significantly lower RV/TLC ratio than the E-type group and M-type group ($P < 0.05$), and the E-type group showed significantly higher levels of FEV1/FVC

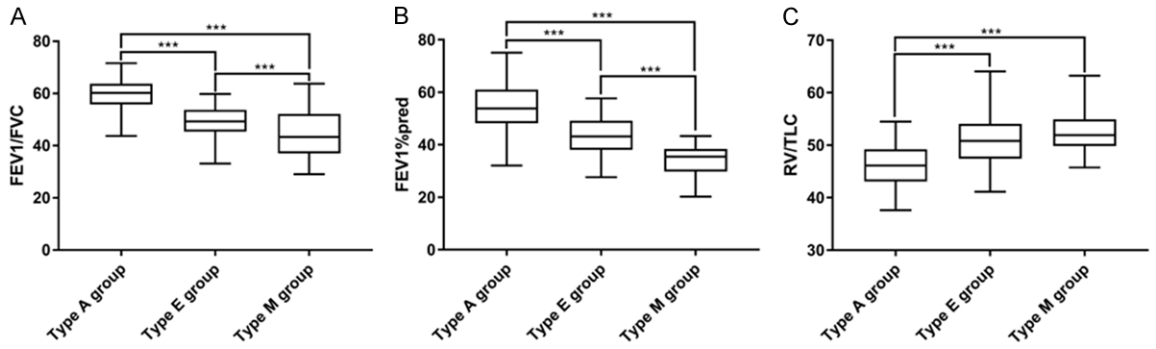

Figure 2. Comparison of pulmonary function indexes among the three groups. A. The A-type group showed a significantly higher FEV1/FVC ratio than the E-type group and M-type group ($P < 0.001$) and the E-type group showed a significantly higher FEV1/FVC ratio than the M-type group ($P < 0.001$). B. The A-type group showed a significantly higher FEV1%pred level than the E-type group and M-type group ($P < 0.001$) and the E-type group showed a significantly higher FEV1%pred level than the M-type group ($P < 0.001$). C. The A-type group showed a notable lower RV/TLC ratio than the E-type group and M-type group ($P < 0.001$). Note: ***$P < 0.001$. FEV1/FVC, forced expiratory volume in 1 second (FEV1)/forced vital capacity (FVC); FEV1%pred, ratio of FEV1 to the expected value; RV/TLC, ratio of the residual volume/total lung volume; volume at the end of deep inhalation.

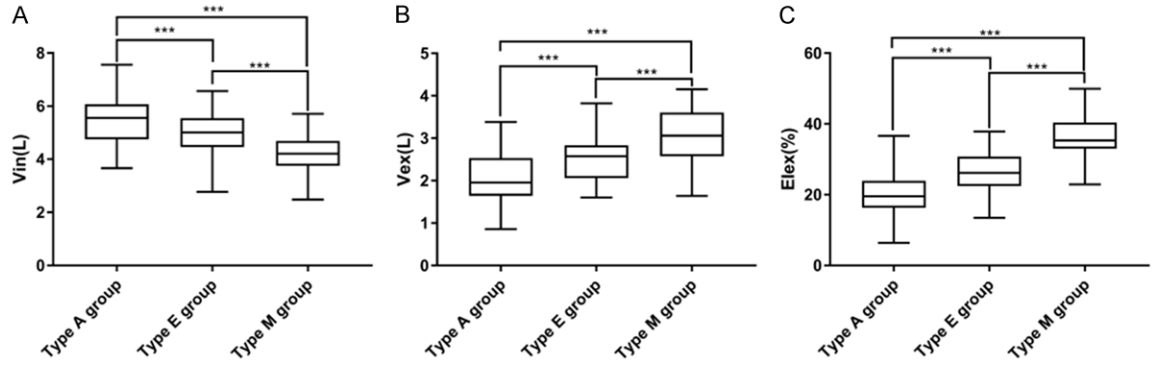

Figure 3. Comparison of CT parameters of the three groups. A. The A-type group showed a significantly higher Vin level than the E-type group and M-type group ($P < 0.001$) and the E-type group showed a significantly higher Vin level than the M-type group ($P < 0.001$). B. The A-type group showed a significantly lower Vex level than the E-type group and M-type group ($P < 0.001$) and the E-type group showed a significantly lower Vex level than the M-type group ($P < 0.001$). C. The A-type group showed a significantly lower Elex level than the E-type group and M-type group ($P < 0.001$) and the E-type group showed a significantly lower Elex level than the M-type group ($P < 0.001$). Note: ***$P < 0.001$. FEV1/FVC, forced expiratory volume in 1 second (FEV1)/forced vital capacity (FVC); FEV1%pred, ratio of FEV1 to the expected value; RV/TLC, ratio of the residual volume/total lung volume; volume at the end of deep inhalation; emphysema index at the end of deep exhalation (Elex); volume at the end of deep exhalation (Vex).

and FEV1%pred than the M-type group ($P < 0.05$, **Figure 2**).

Comparison of CT examination parameters

According to comparison of CT parameters (Vin, Vex and Elex) among the three groups, the A-type group showed a significantly higher Vin level and significantly lower levels of Vex and Elex than the E-type group and M-type group ($P < 0.05$), and the E-type group showed a significantly higher Vin level and a significantly lower Elex level than the M-type group ($P < 0.05$, **Figure 3**).

Correlations between CT parameters and pulmonary function

According to Pearson's correlation analysis, Vin was positively correlated with FEV1/FVC and FEV1%pred, and negatively correlated with RV/TLC; Vex and Elex were negatively correlated with FEV1/FVC and FEV1%pred, and positively correlated with RV/TLC (**Figure 4**).

Comparison of 1-year prognosis

The A-type group showed an one-year acute exacerbation rate of 5.71%, with 4 cases of

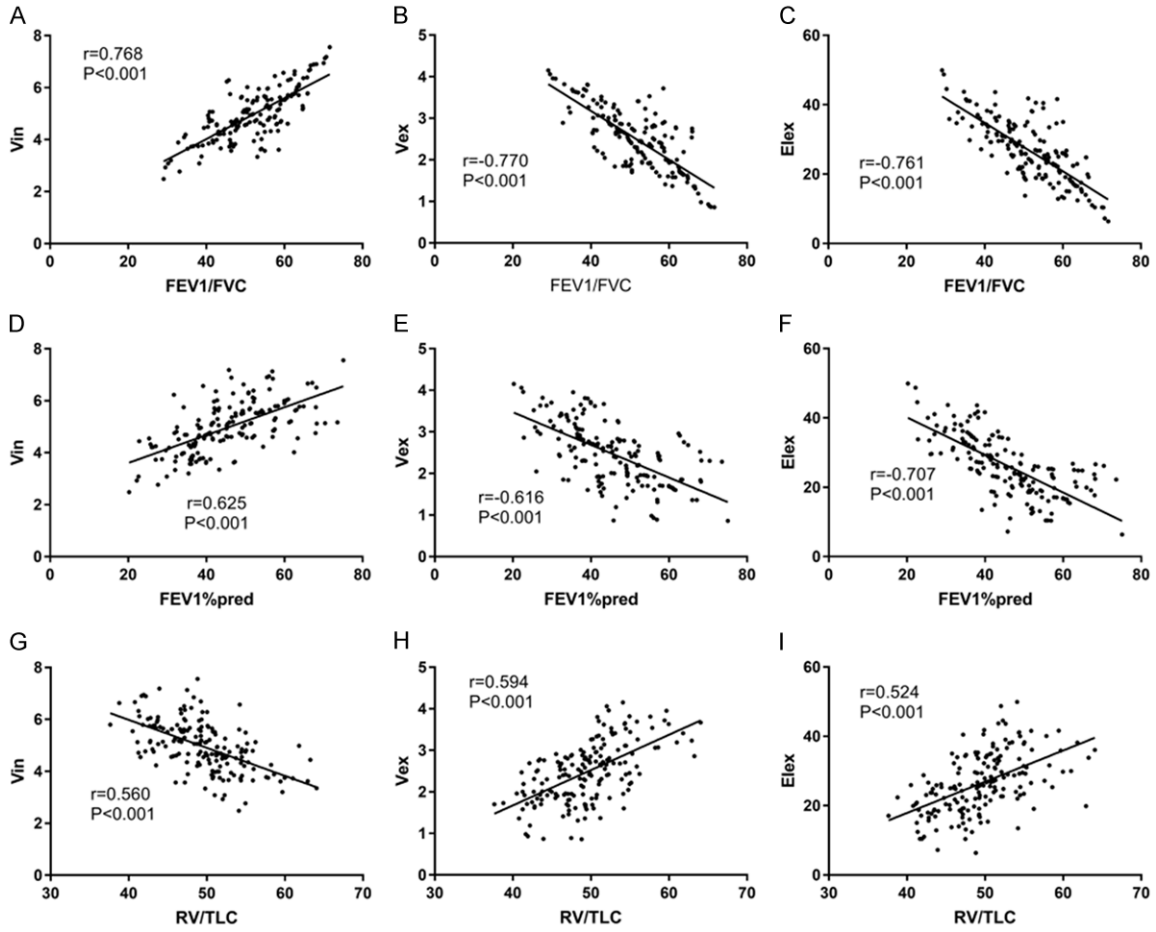

Figure 4. Correlations of CT parameters with pulmonary function. A. Vin had a positive correlation with FEV1/FVC (r = 0.768, P < 0.001); B. Vex had a negative correlation with FEV1/FVC (r = -0.770, P < 0.001); C. Elex had a negative correlation with FEV1/FVC (r = -0.761, P < 0.001); D. Vin had a positive correlation with FEV1%pred (r = 0.625, P < 0.001); E. Vex had a negative correlation with FEV1%pred (r = -0.616, P < 0.001); F. Elex had a negative correlation with FEV1%pred (r = -0.707, P < 0.001); G. Vin had a negative correlation with RV/TLC (r = -0.560, P < 0.001); H. Vex had a positive correlation with RV/TLC (r = 0.594, P < 0.001); I. Elex had a positive correlation with RV/TLC (r = 0.524, P < 0.001). FEV1/FVC, forced expiratory volume in 1 second (FEV1)/forced vital capacity (FVC); FEV1%pred, ratio of FEV1 to the expected value; RV/TLC, ratio of the residual volume/total lung volume; volume at the end of deep inhalation; emphysema index at the end of deep exhalation (Elex); volume at the end of deep exhalation (Vex).

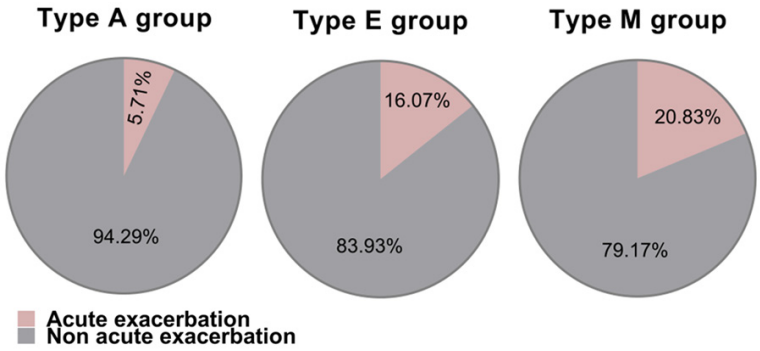

Figure 5. Comparison of 1-year prognosis of the three groups.

one-year acute exacerbation and 66 cases without exacerbation; the E-type group showed an one-year acute exacerbation rate of 17.86%, with 10 cases of one-year acute exacerbation, and 46 cases without exacerbation; the M-type group showed an one-year acute exacerbation rate of 22.92%, with 11 cases of one-year acute exacerbation, and 37 cases without exacerbation. According to comparison, the E-type group and M-type group showed a significantly higher one-year acute exacerbation rate than the A-type group (P < 0.05, **Figure 5**).

Table 2. Multivariate analysis

	Unfavorable prognosis group (n = 25)	Favorable prognosis group (n = 149)	X^2/t	*P*-value
Age (years)	74.87±8.13	72.14±8.55	1.487	0.139
Gender			1.088	0.297
Male	20 (80.00)	104 (69.80)		
Female	5 (20.00)	45 (30.20)		
Course of disease (years)	8.11±2.32	6.14±2.54	3.631	< 0.001
BMI (kg/m^2)	23.62±4.04	23.48±3.14	0.198	0.844
Smoking status			3.083	0.214
Smoke	11 (44.00)	61 (40.94)		
Quit	11 (44.00)	47 (31.54)		
No smoke	3 (12.00)	41 (27.52)		
Past medical history				
History of asthma	7 (28.00)	23 (15.44)	2.368	0.124
History of pneumonia	3 (20.00)	14 (9.40)	1.649	0.199
GOLD grade			0.457	0.796
Stage I	4 (16.00)	22 (14.76)		
Stage II	14 (56.00)	75 (50.34)		
Stage III and Stage IV	7 (28.00)	52 (34.90)		
Respiratory symptoms				
Phlegm	16 (64.00)	91 (61.07)	0.077	0.781
Dyspnea	16 (64.00)	75 (50.34)	1.602	0.206
Cough	17 (68.00)	94 (63.09)	0.224	0.636
FEV1/FVC	40.56±7.14	53.91±8.39	7.508	< 0.001
FEV1%pred	35.97±8.34	46.94±11.00	4.758	< 0.001
RV/TLC	52.65±4.61	48.90±4.92	3.557	< 0.001
Vin (L)	4.10±0.96	5.11±0.90	5.143	< 0.001
Vex (L)	3.18±0.62	2.36±0.67	5.720	< 0.001
Elex (%)	34.34±7.42	25.07±8.15	5.327	< 0.001
CT phenotype			7.666	0.022
Type A	4 (5.71)	66 (94.29)		
Type E	10 (17.86)	46 (82.14)		
Type M	11 (22.92)	37 (77.08)		

FEV1/FVC, forced expiratory volume in 1 second (FEV1)/forced vital capacity (FVC); FEV1%pred, ratio of FEV1 to the expected value; RV/TLC, ratio of the residual volume/total lung volume; volume at the end of deep inhalation (Vin); volume at the end of deep exhalation (Vex); emphysema index at the end of deep exhalation (Elex).

Univariate analysis of the prognosis of COPD patients

According to the one-year acute exacerbation of COPD patients, the patients were assigned to an unfavorable prognosis group or favorable prognosis group. The clinical data of the two groups were collected for univariate analysis. The two groups were found to be different in the course of disease, FEV1/FVC, FEV1%pred, RV/TLC, Vin, Vex, Elex and CT phenotypes ($P < 0.05$, **Table 2**).

Multivariate analysis of prognosis of COPD patients

The indexes with significant differences in univariate analysis (see **Table 3** for the assignment) were assigned and included into multivariate logistic regression analysis by LR, and the results showed that FEV1%pred, RV/TLC, Vin, Vex and Elex were not independent risk factors for unfavorable prognosis of patients, but the course of disease (OR: 1.639, 95% CI: 1.233-2.178), FEV1/FVC (OR: 0.761, 95% CI:

Table 3. Assignment

Factor	Assignment
Course of disease	Data belonging to continuous variables were analyzed with their raw data.
FEV1/FVC	Data belonging to continuous variables were analyzed with their raw data.
FEV1%pred	Data belonging to continuous variables were analyzed with their raw data.
RV/TLC	Data belonging to continuous variables were analyzed with their raw data.
Vin	Data belonging to continuous variables were analyzed with their raw data.
Vex	Data belonging to continuous variables were analyzed with their raw data.
Elex	Data belonging to continuous variables were analyzed with their raw data.
CT phenotype	type A = 1, type E = 2, type M = 3.
Prognosis	Unfavorable prognosis = 1, favorable prognosis = 0.

FEV1/FVC, forced expiratory volume in 1 second (FEV1)/forced vital capacity (FVC); FEV1%pred, ratio of FEV1 to the expected value; RV/TLC, ratio of the residual volume/total lung volume; volume at the end of deep inhalation (Vin); volume at the end of deep exhalation (Vex); emphysema index at the end of deep exhalation (Elex).

Table 4. Multivariate analysis results

	B	S.E.	Wals	Sig.	Exp (B)	95% C.I. of EXP (B)	
						Lower limit	Upper limit
Course of disease	0.494	0.145	11.558	0.001	1.639	1.233	2.178
FEV1/FVC	-0.273	0.087	9.844	0.002	0.761	0.641	0.902
FEV1%pred	-0.059	0.057	1.072	0.301	0.942	0.842	1.054
RV/TLC	0.111	0.097	1.31	0.252	1.117	0.924	1.35
Vin	0.651	0.69	0.889	0.346	1.917	0.496	7.413
Vex	-0.245	0.979	0.062	0.803	0.783	0.115	5.333
Elex	0.124	0.082	2.246	0.134	1.132	0.963	1.33
CT phenotype	-2.533	0.764	10.984	0.001	0.079	0.018	0.355

FEV1/FVC, forced expiratory volume in 1 second (FEV1)/forced vital capacity (FVC); FEV1%pred, ratio of FEV1 to the expected value; RV/TLC, ratio of the residual volume/total lung volume; volume at the end of deep inhalation (Vin); volume at the end of deep exhalation (Vex); emphysema index at the end of deep exhalation (Elex).

0.641-0.902), and CT phenotype (OR: 0.079, 95% CI: 0.018-0.355) were independent risk factors for the unfavorable prognosis (**Table 4**).

Discussion

This study evaluated the pulmonary function of COPD patients with different CT phenotypes and its relationship with CT features. The A-type group showed significantly better pulmonary function than the E-type group and the M-type group. A relatively longer course of disease, a relatively lower FEV1/FVC ratio and CT phenotype were correlated with the unfavorable prognosis of patients.

COPD, as a progressive respiratory disease, can bring about serious complications such as heart failure and respiratory failure [20]. The pulmonary function is adopted to evaluate the disease severity of COPD patients, which could be repeatedly tested easily. However, the pulmonary function did not fully reflect the disease status, and sometimes it is difficult to conduct in some patients, especially patients with severe COPD treated in ICU, so other objective indicators are also needed [21, 22]. According to one study [23], a large number of smokers who have no airflow obstruction in spirometry would be diagnosed with structural lung diseases and respiratory diseases through CT, while the pulmonary function of 50% of smokers who have obvious respiratory symptoms, with obvious airway wall thickening cannot be detected.

Nowadays, arterial blood gas analysis and radiology methods such as X-ray and computed tomography (CT) are also used to evaluate the severity of COPD and monitor its progress and treatment response, and CT is superior to chest X-ray examination in emphysema and its distribution and scope [24]. With the gradual improvement of CT technology and parame-

ters, the whole situation of the whole lung and bronchi can be displayed in a multi-angle, all-round and three-dimensional way. The small structures such as bronchial wall, the diameter of blood vessels in the lung and alveoli can also be measured accurately, and emphysema can be quantitatively evaluated via pixel histogram analysis. Airway re-modelling is a crucial feature of COPD. With airway re-modelling, the thickness of bronchial wall and the area of airway cavity tend to gradually increase [25].

We found that CT parameters (Vin, Vex, and Elex), as quantitative indicators of emphysema, were strongly related with pulmonary function, among which Vin was positively related to FEV1/FVC and FEV1%pred, and negatively related to RV/TLC, while Vex and Elex were negatively related to FEV1/FVC and FEV1%pred, and positively related to RV/TLC. This indicates that with the aggravation of emphysema, patients show more serious pulmonary function damage, and the gas exchange efficiency also decreases due to the increased airflow obstruction of patients. Fan et al. [26] also compared the differences among patients with A phenotype, E phenotype and M phenotype, in which the emphysema volume and emphysema index of phenotype A were significantly lower than those of E and M phenotypes, while FEV1/FVC of A phenotype was significantly higher than that of M phenotype, indicating that the pulmonary function of patients with A phenotype was significantly better than that of patients with E and M phenotypes, which was similar to our study.

Finally, we found a significantly lower one-year acute exacerbation rate in the A-type group (5.71%) than in the E-type group (17.86%) and M-type group (22.92%). One of the pathogenesis of COPD is gas entrapment, which results in impaired expiratory function. Severe COPD patients have severe emphysema, which leads to gas exchange disorder in the lungs, oxygen deficiency and CO_2 retention, and the increase of lung gas content, resulting in impaired pulmonary function [27], and seriously affecting the patient's prognosis. Therefore, it is more beneficial to evaluate the patient's prognosis by judging the patient's CT phenotype earlier.

This study also has some limitations. Firstly, the patients included in this study were mainly the elderly, and we hope to explore the CT phenotypic characteristics of younger COPD patients. Secondly, we did not explore the treatment methods of patients in this study, so it is not clear how different treatments affect the phenotype of CT. However, this study has also found that the quantitative indexes of emphysema in CT examination can be used in the diagnosis of COPD patients because of their strong correlations with pulmonary function.

To sum up, according to determination of the pulmonary function of patients with COPD via CT, the degree of emphysema worsens with the progression of the disease, and the two are correlated to a certain extent. A relatively longer course of disease, a relatively lower FEV1/FVC ratio and CT phenotype are independent risk factors for the unfavorable prognosis of COPD patients.

Disclosure of conflict of interest

None.

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