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Research Advances on Chest CT Features in Populations with Preserved Ratio Impaired Spirometry: Postprint

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Abstract

Preserved ratio impaired spirometry (PRISm) is a common pulmonary function disorder considered a pre-chronic obstructive pulmonary disease stage that has attracted considerable academic attention in recent years. Although researchers have reviewed the etiology, epidemiology, and risk factors of the PRISm population, a comprehensive review of chest CT imaging findings remains lacking. To achieve a deeper and more comprehensive understanding of this population, this article summarizes the chest CT imaging characteristics of individuals with PRISm, encompassing both visual and quantitative assessment methods to evaluate changes in airway, lung parenchymal, and vascular features. This article demonstrates that CT imaging features based solely on visual assessment have limited reference value in the PRISm population, while quantitative chest CT assessment combined with pulmonary function test metrics facilitates a deeper understanding of pulmonary structural characteristics in PRISm. We recommend future systematic investigations, such as prospective, large-scale, multicenter cohort studies, to further elucidate the chest imaging features of the PRISm population.

Full Text

Research Progress on Chest CT Features of the Preserved Ratio Impaired Spirometry Population

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Abstract

Preserved Ratio Impaired Spirometry (PRISm) is a common pulmonary functional impairment considered a pre-chronic obstructive pulmonary disease (COPD) stage that has received increased attention from the academic community in recent years. Despite comprehensive reviews of the etiology, epidemiology, and risk factors of the PRISm population, a systematic review of chest CT imaging is lacking. To gain a more comprehensive understanding of this population, this article summarizes the chest CT imaging features of the PRISm population using both visual and quantitative assessment methods, including characteristic changes of airways, lung parenchyma, and vessels. The article indicates that the reference value of visual assessment of chest CT results for the PRISm population is limited, while quantitative assessment of chest CT combined with pulmonary function testing is advantageous for gaining a deeper understanding of the lung structural features of the PRISm population. Future studies should employ a more systematic approach through prospective, large-sample, multi-center cohort studies to elucidate the chest imaging characteristics of the PRISm population.

Keywords: Preserved ratio impaired spirometry; Chronic obstructive pulmonary disease; Chest CT; Pulmonary function test; Review

1. Introduction

In 2021, the European Respiratory Society (ERS) and American Thoracic Society (ATS) jointly released an updated technical standard for interpreting routine lung function tests, defining "nonspecific ventilatory impairment" as reduced forced vital capacity (FVC) and/or forced expiratory volume in 1 second (FEV1) with a normal FEV1/FVC ratio and normal total lung capacity (TLC). In smokers where TLC cannot be measured, this condition is defined as preserved ratio impaired spirometry (PRISm) [1]. Although the PRISm population does not meet the Global Initiative for Chronic Obstructive Lung Disease (GOLD) diagnostic criteria for COPD, previous studies have found that this population exhibits significantly higher incidence and all-cause mortality rates compared to individuals with normal lung function [2-5]. Consequently, this group has attracted widespread attention in the academic community.

Currently, large-scale cohort studies on the PRISm population are limited in China. However, domestic scholars have provided detailed elaborations on the characteristics of this population, including epidemiology, prognosis, and outcomes [2,3,8-10], and have explored the clinical correlations between PRISm and COPD [11]. As PRISm patients may progress to COPD over time, some researchers consider it a pre-clinical or early stage of COPD. It is well established that computed tomography (CT) can provide additional information on

lung structural abnormalities in COPD patients [12]. However, existing studies have not yet summarized the imaging features of chest CT examinations in the PRISm population. Therefore, this article reviews recent studies on PRISm retrieved from PubMed, CNKI, and Chinese Medical Journals websites, with a focus on summarizing the imaging characteristics (primarily chest CT findings) of this population to provide reference value for in-depth understanding of their clinical features.

2. Literature Search Strategy

We conducted a literature search in PubMed, China National Knowledge Infrastructure (CNKI), and Chinese Medical Journals websites using the Chinese search term "保留比值受损肺功能" and English search terms "Preserved ratio impaired spirometry,""PRISm,"and "CT."The search timeframe was from database inception to May 2023. A total of 353 original articles were retrieved. After reviewing titles and abstracts, 257 irrelevant articles were initially excluded. We then conducted a detailed review of 96 articles related to PRISm research, particularly those involving chest CT examinations. After excluding articles unrelated to the topic and those of poor quality, 40 articles were finally included. The specific screening process is shown in [Figure 1: see original paper].

3. Current Research Status of the PRISm Population

Large-scale international studies have reported PRISm prevalence rates ranging from 6.74% to 12.50%, as detailed in . The identified risk factors for PRISm include smoking, heart failure, hypertension, obesity, ischemic heart disease, dementia, type 2 diabetes, lung cancer, chronic kidney disease, obstructive sleep apnea syndrome, thyroid disease, and elevated IgA and IgG levels [7,13-18]. Through principal component analysis and unsupervised clustering analysis of clinical indicators, PRISm populations can be classified into three clinical subtypes: COPD-like (elevated FEV1 with lung texture changes similar to COPD), restrictive (simultaneous reduction in emphysema, air trapping, and total lung capacity), and hypermetabolic (higher rates of diabetes and comorbidities). Over time, lung function in PRISm populations may transition to normal, preserved, or airflow-limited status [10,19]. Since PRISm may encompass different subgroups, relying solely on pulmonary function testing may be insufficient for in-depth research, whereas chest CT imaging can better identify structural changes in lung tissue. Therefore, comprehensive chest CT imaging can provide additional quantitative information for assessing pulmonary health status in PRISm populations.

4. Chest CT Assessment Methods

A substantial proportion of smokers with respiratory symptoms and imaging abnormalities do not exhibit airflow limitation as defined for normal populations. Given these individuals' significant risks of mortality and disease progression,

some scholars have suggested integrating environmental exposure, clinical symptoms, CT imaging, and spirometric criteria for comprehensive COPD diagnosis [20]. PRISm may represent a subclinical or early stage of COPD, though no unified standard currently exists for evaluating chest imaging manifestations in this population. Lynch et al. [21] proposed and elaborated a classification system that provides a structured approach for visual and quantitative assessment of COPD, offering valuable reference for evaluating chest imaging features in PRISm populations.

Visual assessment content includes emphysema, airway wall thickening, inflammatory small airway disease, tracheal abnormalities, interstitial lung abnormalities, pulmonary artery dilation, and bronchiectasis. Quantitative assessment primarily comprises the following parameters: (1) lung parenchyma parameters, including emphysema index (EI), air trapping index (ATI), mean lung density on inspiration (MLD), parametric response mapping (PRM), and percentage of small airway dysfunction in PRM (PRMfSAD); (2) airway parameters including wall thickness, wall area, and lumen area; and (3) vascular parameters including total vascular volume, vessel count, mean vessel diameter, vessel area, and low attenuation surface area.

Visual assessment relies primarily on physicians' visual judgment, which is more subjective, whereas quantitative assessment compares various indicators with reference values, making it more quantifiable.

5. Visual Assessment Features of Chest CT in PRISm Populations

Current studies on chest CT findings in PRISm populations indicate the presence of certain airway wall thickening and emphysema manifestations [22], particularly among smokers. However, the overall rate of normal CT findings in PRISm populations is roughly equivalent to that in GOLD 0 populations (52.7% vs. 51%) [2]. Additional studies have shown that among smokers with PRISm, the prevalence of paraseptal emphysema (PSE) and centrilobular emphysema (CLE) (44.6% and 46.7%, respectively) is higher than in non-smokers with PRISm but comparable to smokers with normal lung function, confirming smoking as a risk factor for PRISm. Compared to smokers with airflow limitation, PRISm populations show significantly lower prevalence rates of PSE and CLE. Multivariate analysis of these two emphysema types revealed that among smokers with PRISm, CLE was independently associated with reduced FVC/TLCCT (indicating air trapping), whereas PSE was not, suggesting that CLE better reflects air trapping status in smokers with PRISm than PSE [23].

Comparisons among three groups with different CT visual assessment results —pure airway disease (APD), pure emphysema disease (EPD), and combined APD-EPD—showed that the APD group was younger and had lower FEV1% [24]. This may be because small airway disease precedes emphysema development [25]. Inflammation in small airways gradually progresses, leading to airway constriction and narrowing. Over time, persistent inflammation and constriction

ultimately result in emphysema. The mortality rate was 26% in the pure APD group, 21% in the pure EPD group, and 54% in the combined APD-EPD group, indicating that PRISm populations face the highest risk when small airway disease and emphysema coexist. Another study demonstrated that compared to GOLD stages 0-4, PRISm populations with initial emphysema were more likely to experience progressive emphysema (OR = 5.73; P < 0.01) [26].

Furthermore, Amaza et al. [27] compared physician visual assessment with quantitative assessment for diagnosing emphysema on chest CT, finding only 61% agreement between the two methods (Kappa = 0.22, 0.17-0.28). Compared to quantitative assessment, visual assessment of CT imaging results showed poorer diagnostic accuracy, likely because visual assessment relies primarily on physicians' subjective judgment, which may be influenced by individual radiologists' experience.

In summary, visual assessment of chest CT provides some auxiliary value for determining imaging results in PRISm populations, but the reference value of visual assessment alone is limited.

6. Quantitative Assessment Features of Chest CT in PRISm Populations

6.1 Airway Features PRISm may represent an early stage of COPD development. Before lung parenchymal destruction becomes apparent, small airways may already exhibit pathological changes [25]. VASILESCU et al. [28] proposed that PRMfSAD can identify areas of terminal bronchiole injury, narrowing, and obstruction. Compared to healthy controls, PRISm patients exhibit more severe small airway dysfunction (SAD) and lower TLCCT [29]. Additionally, one study found that compared to normal controls, PRISm patients showed increased wall area percentage in the left upper lobe fifth-generation bronchi [30]. Significant differences in airway parameters between normal and PRISm groups suggest that lumen area can also serve as a basis for distinguishing normal individuals from PRISm patients, while no significant differences were observed between PRISm and mild-to-moderate COPD groups [31]. Finally, this research team developed a binary logistic model for predicting COPD severity, incorporating factors such as smoking, MLD, PRMfSAD, and lumen area. The model demonstrated good fit and ROC value (0.786) with 82.35% sensitivity and 65.96% specificity. These studies indicate that airway parameters such as PRMfSAD, wall area, and lumen area in PRISm groups are similar to those in mild-to-moderate COPD groups but differ significantly from normal populations, making chest CT airway parameters more likely to serve as reference indicators for distinguishing PRISm from normal populations. Future studies should increase sample sizes and include external validation data to further improve model reliability and clinical applicability.

6.2 Lung Parenchyma Features Current research on imaging features of lung parenchyma exceeds that on small airways and pulmonary vessels. Even

among smokers with a smoking index $ $10 pack-years, only one-third exhibit abnormal spirometry, while over two-thirds show chest imaging abnormalities of emphysema or small airway disease [32], suggesting that chest imaging more directly reflects lung structural changes than pulmonary function tests.

6.2.1 Assessing Lung Parenchyma Changes Through Adjusted Lung Density (ALD) One study analyzed 5-year changes in quantitative CT measurements during inspiration in COPDGene [33], revealing that adjusted ALD mean values changed over 5 years in PRISm, GOLD 0, and GOLD 1-4 groups (-2.26 g/L, -1.67 g/L, and -5.26 g/L, respectively). This indicates that the 5-year ALD decline in PRISm populations is slightly higher than in normal populations, suggesting that ALD can reflect parenchymal changes in PRISm to some extent.

6.2.2 CT Quantitative Indicators Are More Precise Than Spirometric Results Most quantitative CT parameters show mild to moderate correlation with pulmonary function parameters [31]. Diagnosis of smoking-related lung disease based on spirometry or symptoms is often insufficient, whereas CT scanning significantly improves sensitivity and specificity [34]. The SPIROMICS cohort study demonstrated that among all PRISm subjects, despite normal FEV1/FVC ratios, CT-measured residual volume (RVCT) to total lung capacity (TLCCT) ratios (RVCT/TLCCT) varied widely from 21% to 59%. After 2.5 ± 0.7 years of follow-up, higher RVCT/TLCCT ratios were associated with disease progression.

7. Conclusion and Future Directions

In conclusion, visual assessment of chest CT provides limited reference value for evaluating imaging results in PRISm populations. Quantitative assessment of chest CT combined with pulmonary function testing offers advantages for understanding the lung structural features of PRISm populations. Future research should construct PRISm risk prediction models integrating CT findings, clinical manifestations, comorbidities, and inflammatory markers to improve sensitivity and specificity for more accurate assessment of PRISm populations.

Author Contributions: Jinhai Huang was responsible for conceptualization, literature collection and organization, table editing, and manuscript drafting. Yun Li and Yi Gao were responsible for manuscript revision, quality control, and supervision. Yun Li and Yi Gao take overall responsibility for the article.

Conflict of Interest: The authors declare no conflict of interest.

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References

[1] STANOJEVIC S, KAMINSKY D A, MILLER M R, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests[J]. Eur Respir J, 2022, 60(1): 2101499. DOI: 10.1183/13993003.01499-2021.

[2] WAN E S, FORTIS S, REGAN E A, et al. Longitudinal phenotypes and mortality in preserved ratio impaired spirometry in the COPDGene study[J]. Am J Respir Crit Care Med, 2018, 198(11): 1397-1405. DOI: 10.1164/rccm.201804-0663OC.

[3] HIGBEE D H, GRANELL R, DAVEY SMITH G, et al. Prevalence, risk factors, and clinical implications of preserved ratio impaired spirometry: a UK Biobank cohort analysis[J]. Lancet Respir Med, 2022, 10(2): 149-157. DOI: 10.1016/S2213-2600(21)00389-9.

[4] PAREKH T M, BHATIA S, CHERRINGTON A, et al. Factors influencing decline in quality of life in smokers without airflow obstruction: the COPDGene study[J]. Respir Med, 2020, 161: 105820. DOI: 10.1016/j.rmed.2019.105820.

[5] WASHIO Y, SAKATA S, FUKUYAMA S, et al. Risks of mortality and airflow limitation in Japanese individuals with preserved ratio impaired spirometry[J]. Am J Respir Crit Care Med, 2022, 206(5): 563-572. DOI: 10.1164/rccm.202110-2302OC.

[6] ZHAO N N, ZHOU Y M. Research progress on preserved ratio impaired spirometry population[J]. Chin J Tuberc Respir Dis, 2022, 45(10): 1046-1050. DOI: 10.3760/cma.j.cn112147-20220518-00426.

[7] WANG Y R, WANG H L, LI T, et al. Research status and prospects of preserved ratio impaired spirometry[J]. Int J Respir, 2022(20): 1597-1600.

[8] WAN E S, BALTE P, SCHWARTZ J E, et al. Association between preserved ratio impaired spirometry and clinical outcomes in US adults[J]. JAMA, 2021, 326(22): 2287-2298. DOI: 10.1001/jama.2021.20939.

[9] HEO I R, KIM H C, KIM T H. Health-related quality of life and related factors in persons with preserved ratio impaired spirometry: data from the Korea national health and nutrition examination survey[J]. Medicina, 2020, 57(1): 4. DOI: 10.3390/medicina57010004.

[10] WAN E S, CASTALDI P J, CHO M H, et al. Epidemiology, genetics, and subtyping of preserved ratio impaired spirometry (PRISm) in COPDGene[J]. Respir Res, 2014, 15(1): 89. DOI: 10.1186/s12931-014-0089-y.

[11] ZHOU T R, ZHU H L. Clinical discussion on preserved ratio impaired spirometry and chronic obstructive pulmonary disease[J]. Int J Respir, 2022, 42(18): 1410-1414.

[12] Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease (2023 report)[EB/OL]. [2023-06-11]. https://goldcopd.org/2022-gold-reports-2/.

[13] XIAO T, WIJNANT S R A, LICHER S, et al. Lung function impairment and the risk of incident dementia: the Rotterdam study[J]. J Alzheimer' s Dis, 2021, 82(2): 621-630. DOI: 10.3233/jad-210162.

[14] LI G C, JANKOWICH M D, LU Y Q, et al. Preserved ratio impaired spirometry, metabolomics, and the risk of type 2 diabetes[J]. J Clin Endocrinol Metab, 2023 Mar 10: dgad140. DOI: 10.1210/clinem/dgad140.

[15] KAAKS R, CHRISTODOULOU E, MOTSCH E, et al. Lung function impairment in the German Lung Cancer Screening Intervention Study (LUSI): prevalence, symptoms, and associations with lung cancer risk, tumor histology and all-cause mortality[J]. Transl Lung Cancer Res, 2022, 11(9): 1896-1911. DOI: 10.21037/tlcr-22-63.

[16] ZHENG J Z, ZHOU R, ZHANG Y C, et al. Preserved ratio impaired spirometry in relationship to cardiovascular outcomes[J]. Chest, 2023, 163(3): 610-623. DOI: 10.1016/j.chest.2022.11.003.

[17] ZHANG C, WEI S S, WANG Y X, et al. Association between preserved ratio impaired spirometry and sleep apnea in a Chinese community[J]. Curr Med Res Opin, 2023, 39(4): 621-626. DOI: 10.1080/03007995.2023.2182531.

[18] KHAN S R, VANOVERSCHELDE A, LAHOUSSE L, et al. Serum immunoglobulins, pneumonia risk, and lung function in middle-aged and older individuals: a population-based cohort study[J]. Front Immunol, 2022, 13: 868973. DOI: 10.3389/fimmu.2022.868973.

[19] WAN E S, HOKANSON J E, REGAN E A, et al. Significant spirometric transitions and preserved ratio impaired spirometry among ever smokers[J]. Chest, 2022, 161(3): 651-661. DOI: 10.1016/j.chest.2021.09.021.

[20] LOWE K E, REGAN E A, ANZUETO A, et al. COPDGene® 2019: redefining the diagnosis of chronic obstructive pulmonary disease[J]. Chronic Obstr Pulm Dis, 2019, 6(5): 384-399. DOI: 10.15326/jcopdf.6.5.2019.0149.

[21] LYNCH D A, AUSTIN J H M, HOGG J C, et al. CT-definable subtypes of chronic obstructive pulmonary disease: a statement of the fleischner society[J]. Radiology, 2015, 277(1): 192-205. DOI: 10.1148/radiol.2015141579.

[22] WAN E S, HOKANSON J E, MURPHY J R, et al. Clinical and radiographic predictors of GOLD-unclassified smokers in the COPDGene study[J]. Am J Respir Crit Care Med, 2011, 184(1): 57-63. DOI: 10.1164/rccm.201101-0021oc.

[23] SHIRAISHI Y, SHIMADA T, TANABE N, et al. The prevalence and physiological impacts of centrilobular and paraseptal emphysema on computed tomography in smokers with preserved ratio impaired spirometry[J]. ERJ Open Res, 2022, 8(2): 00063-02022. DOI: 10.1183/23120541.00063-2022.

[24] YOUNG K A, REGAN E A, HAN M K, et al. Subtypes of COPD have unique distributions and differential risk of mortality[J]. Chronic Obstr Pulm Dis J COPD Found, 2019, 6(5): 400-413. DOI: 10.15326/jcopdf.6.5.2019.0150.

[25] MCDONOUGH J E, YUAN R, SUZUKI M, et al. Small-airway obstruction and emphysema in chronic obstructive pulmonary disease[J]. N Engl J Med, 2011, 365(17): 1567-1575. DOI: 10.1056/NEJMoa1106955.

[26] POMPE E, MOORE C M, MOHAMED HOESEIN F A A, et al. Progression of emphysema and small airways disease in cigarette smokers[J]. Chronic Obstr Pulm Dis J COPD Found, 2021, 8(2): 198-212. DOI: 10.15326/jcopdf.2020.0140.

[27] AMAZA I P, O' SHEA A M J, FORTIS S, et al. Discordant quantitative and visual CT assessments in the diagnosis of emphysema[J]. Int J Chron Obstruct Pulmon Dis, 2021, 16: 1231-1242. DOI: 10.2147/COPD.S284477.

[28] VASILESCU D M, MARTINEZ F J, MARCHETTI N, et al. Noninvasive imaging biomarker identifies small airway damage in severe chronic obstructive pulmonary disease[J]. Am J Respir Crit Care Med, 2019, 200(5): 575-581. DOI: 10.1164/rccm.201811-2083oc.

[29] ZHAO N N, WU F, PENG J Q, et al. Preserved ratio impaired spirometry is associated with small airway dysfunction and reduced total lung capacity[J]. Respir Res, 2022, 23(1): 298. DOI: 10.1186/s12931-022-02216-1.

[30] WEI X, DING Q, YU N, et al. Imaging features of chronic bronchitis with preserved ratio and impaired spirometry (PRISm)[J]. Lung, 2018, 196(6): 649-658. DOI: 10.1007/s00408-018-0165-7.

[31] LU J J, GE H Y, QI L, et al. Subtyping preserved ratio impaired spirometry (PRISm) by using quantitative HRCT imaging characteristics[J]. Respir Res, 2022, 23(1): 309. DOI: 10.1186/s12931-022-02113-7.

[32] TRAN T V, KINNEY G L, COMELLAS A, et al. Prevalence of abnormal spirometry in individuals with a smoking history and no known obstructive lung disease[J]. Respir Med, 2023, 208: 107126. DOI: 10.1016/j.rmed.2023.107126.

[33] POMPE E, STRAND M, VAN RIKXOORT E M, et al. Five-year progression of emphysema and air trapping at CT in smokers with and without chronic obstructive pulmonary disease: results from the COPDGene study[J]. Radiology, 2020, 295(1): 218-226. DOI: 10.1148/radiol.2020191429.

[34] STRINGER W W, PORSZASZ J, BHATT S P, et al. Physiologic insights from the COPD genetic epidemiology study[J]. Chronic Obstr Pulm Dis J COPD Found, 2019, 6(3): 256-266. DOI: 10.15326/jcopdf.6.3.2019.0128.

[35] ARJOMANDI M, ZENG S Y, BARJAKTAREVIC I, et al. Radiographic lung volumes predict progression to COPD in smokers with preserved spirometry in SPIROMICS[J]. Eur Respir J, 2019, 54(4): 1802214. DOI: 10.1183/13993003.02214-2018.

[36] ALEJANDRO A, DIAZ, MD M, et al. Disease severity dependence of the longitudinal association between CT lung density and lung function in smokers[J]. Chest, 2018, 153(3): 638-645. DOI: 10.1016/j.chest.2017.10.012.

[37] FORTIS S, COMELLAS A, KIM V, et al. Low FVC/TLC in Preserved Ratio Impaired Spirometry (PRISm) is associated with features of and progression to obstructive lung disease[J]. Sci Rep, 2020, 10(1): 5169. DOI: 10.1038/s41598-020-61932-7.

[38] CAO X X, GAO X Y, YU N, et al. Potential value of expiratory CT in quantitative assessment of pulmonary vessels in COPD[J]. Front Med, 2021, 8: 761804. DOI: 10.3389/fmed.2021.761804.

[39] NARDELLI P, ROSS J C, SAN JOSÉ ESTÉPAR R. Generative-based airway and vessel morphology quantification on chest CT images[J]. Med Image Anal, 2020, 63: 101691. DOI: 10.1016/j.media.2020.101691.

[40] YANG T, CHEN C H, CHEN Z Y L. The CT pulmonary vascular parameters and disease severity in COPD patients on acute exacerbation: a correlation analysis[J]. BMC Pulm Med, 2021, 21: 1-10.

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