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Guidelines and Recommendations

Chest CT in the evaluation of chronic obstructive pulmonary disease: recommendations of Asian Society of Thoracic Radiology

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Abstract

Chronic Obstructive Pulmonary Disease (COPD) is a significant public health challenge globally, with Asia facing unique burdens due to varying demographics, healthcare access, and socioeconomic conditions. Recognizing the limitations of pulmonary function tests in early detection and comprehensive evaluation, the Asian Society of Thoracic Radiology presents this recommendations to guide the use of chest computed tomography (CT) in COPD diagnosis and management. This document consolidates evidence from an extensive literature review and surveys across Asia, highlighting the need for standardized CT protocols and practices. Key recommendations include adopting low-dose paired respiratory phase CT scans, utilizing qualitative and quantitative assessments for airway, vascular, and parenchymal evaluation, and emphasizing structured reporting to enhance clinical decision-making. Advanced technologies, including dual-energy CT and artificial intelligence, are proposed to refine diagnosis, monitor disease progression, and guide personalized interventions. These recommendations aim to improve the early detection of COPD, address its heterogeneity, and reduce its socioeconomic impact by establishing consistent and effective imaging practices across the region. This recommendations underscore the pivotal role of chest CT in advancing COPD care in Asia, providing a foundation for future research and practice refinement.

Keywords: chronic obstructive pulmonary disease; CT; pulmonary function test.

Introduction

Chronic obstructive pulmonary disease (COPD) is a major public health issue of global concern. According to the World Health Organization (WHO), COPD is the third leading cause of death worldwide, affecting approximately 213 million people and imposing a profound burden on healthcare systems and economies. Over half of COPD cases and 68% of COPD-related deaths and disability-adjusted life-years occurred in low- and middle-income countries.[1] In 2019, China bore the largest COPD death toll in absolute terms, followed by India and the United States.[2] South Korea had the highest COPD death rate, followed by Nepal, Denmark, and China.[2] Among World Bank regions, the macroeconomic burden of COPD was highest in East Asia and Pacific. East Asia and Pacific and south Asia were projected to experience the second-largest and third-largest percentage losses by 2050, respectively.[2] The low awareness rate of COPD among the Chinese population (only 0.9%) has directly led to delays in early diagnosis and treatment. When the disease is diagnosed, it is often in the advanced stage, the corresponding poor efficacy and prolonged course of disease can greatly increase the medical expenses of patients and socio-economic burden.[3]

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Similarly, Korea and Japan, 2 other economically advanced countries in Asia, face significant COPD challenges. In Korea, the prevalence of COPD has been rising steadily, fueled by historical smoking habits and an aging population.[4] The economic impact of COPD in Korea is substantial, with both direct and indirect costs contributing to the overall burden. Japan, renowned for its advanced healthcare system, still faces significant challenges in managing COPD. The disease's prevalence is on the rise, primarily due to the aging population and high prevalence of smoking, particularly among men.[5] Expect for aging and smoking, air pollution, infections, tuberculosis as a confounder, and cor pulmonale is also the high risk factor for COPD.

Pulmonary function test (PFT) is currently the gold standard for clinical diagnosis of COPD. However, the sensitivity of early diagnosis is not high, and usually abnormalities occur only when the lung structure is damaged by more than 30%, and cannot reflect the heterogeneity of COPD.[6] In addition, the single threshold diagnostic criterion for PFT (FEV1/FVC) <0.70 after using bronchodilators can lead to over diagnosis in the elderly and missed diagnosis in the young population.[7] Since the 2022 Global Initiative for Chronic Obstructive Lung Disease (GOLD) guidelines pointing out that attention should be paid to the prevalence of COPD among people aged 20-50. Due to the low awareness of COPD among young people and the frequent missed diagnosis of COPD among young people, it is necessary to strengthen the screening of COPD and pre-COPD in young people. Pre-COPD refers to the occurrence of respiratory symptoms at any age group, with or without lung structural damage and/or abnormal lung function, without airflow restriction, but chest CT may present with emphysema. Therefore, international and domestic experts have appealed to attach importance to the comprehensive evaluation of structural quantification and functional imaging of COPD, as well as to the establishment of more sensitive diagnostic methods and quantitative indicators for patients with pre-COPD.[8-10]

COPD is a heterogeneous lesion that can undergo remodeling of small pulmonary vessels and airways as the disease progresses, leading to the formation of emphysema. Chest CT could not only evaluate the damage of lung function with the degree of emphysema, the morphological and structural change of large and small airways in patients with COPD but also evaluate the severity of COPD, then, could predict the risk of acute exacerbation by quantifying the changes of lung parenchyma, airways, and pulmonary vessels. Paired respiratory phases CT (end inspiratory and end expiratory CT) is used to detect air trapping, distinguish emphysema from air trapping, achieve early diagnosis and personalized evaluation of COPD, guiding treatment and management. Therefore, there are many advantages of Chest CT for the COPD accurate, quantitative and focal evaluation on the aspect of lung density, small airway and pulmonary vessels in comparison with PFT. However, current clinical practice does not pay enough attention to this aspect. Quantitative analysis of chest CT mainly focuses on evaluating pulmonary nodules, while the analysis of emphysema mainly focuses on subjective qualitative evaluation. There is still a lack of consistent agreement of chest CT scanning methods and evaluations for COPD.

Therefore, the Asian Society of Thoracic Radiology (ASTR) takes the lead in organizing experts to discuss and compile the "Current Status in Asia and Recommendations of Asian Society of Thoracic Society on Chest CT Examination and Evaluation of Chronic Obstructive Pulmonary Disease" with reference to the current diagnosis and treatment status of COPD in the world and Asian clinical practice of chest CT, aiming to guide medical institutions to standardize the chest CT scanning scheme and CT-based qualitative and quantitative evaluation, to improve the early diagnosis and evaluation of COPD.

Organization and methods

Committee composition

The working group comprised thoracic radiologists with expertise in COPD who volunteered to contribute to report the current status of Asia since the 2023 ACTI held in Seoul, South Korea. The Executive Committee members of the ASTR volunteered to be part of this initiative.

Generating recommendations

The working group first performed the systemic literature search published by the Asian, then, made the clinical practice and research survey in the Asia through ASTR. A tentative list of recommendations was circulated among the working group members to discuss, continuing until consensus was achieved. The recommendation document, along with supporting materials, was sent to all the working group members via e-mail to finalize the consensus.

To understand the current status of the clinical practice and research about chest CT for the evaluation of COPD in Asia, the working group has retrieved the following datasets including PubMed, Cochrane Library, Embase, and Web of Science for a systematic literature search. All original articles published by the Asia in English before September 30, 2024 were searched. The retrieved key words were showed in Table 1. All the literatures were reviewed by 2 thoracic radiologists and evaluated the method of each literature. A total of 140 papers were finally included, published by China 39, South Korea 39, Japan 56, India 3, Turkey 1, Malaysia 1, and Vietnam 1. We have made the literature analysis on the aspect of chest CT scanning technique, respiratory phase, visual and quantitative evaluation parameters, and AI related work.

Based on the literature, the working group then designed the survey for COPD Chest CT scanning and evaluation in the Asian countries and regions.

Results of literature review and survey

Table 2 showed the detailed current status of chest CT for COPD evaluation in Asia from the aspect of respiratory phase, CT radiation dose, reconstruction algorithms, reconstruction slice thickness, evaluation parameters, and clinical topics.

Table 3 showed the survey results from China, South Korea, Japan, Vietnam, and Thailand for COPD in the clinical practice and research.

List of recommendations

CT indications

GOLD 2024 recommend chest CT for COPD patients with persistent exacerbation, symptoms out of proportion to disease severity on lung function testing, FEV1 less than 45% predicted with significant hyperinflation and gas trapping,

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Table 1. Keywords for the systemic literature search about COPD with CT.

Keyword 1	Pulmonary disease, chronic obstructive
Free word 1	COPD
	Chronic Obstructive Pulmonary Disease
	COAD
	Chronic Obstructive Airway Disease
	Chronic Obstructive Lung Disease
	Airflow Obstruction, Chronic
	Airflow Obstructions, Chronic
	Chronic Airflow Obstructions
	Chronic Airflow Obstruction
Keyword 2	Tomography, X-Ray Computed
Free word 2	X-Ray Computed Tomography
	Tomography, X-Ray Computerized
	Tomography, X Ray Computerized
	Computed X Ray Tomography
	X-Ray Computer Assisted Tomography
	X Ray Computer Assisted Tomography
	Tomography, X-Ray Computer Assisted
	Tomography, X Ray Computer Assisted
	Computerized Tomography, X Ray
	Computerized Tomography, X-Ray
	X-Ray Computerized Tomography
	CT X Ray
	CT X Rays
	X Ray, CT
	X Rays, CT
	Tomodensitometry
	Tomography, X Ray Computed
	X Ray Tomography, Computed
	X-Ray Tomography, Computed
	Computed X-Ray Tomography
	Tomographies, Computed X-Ray

or for those who meet criteria for lung cancer screening (*adapted from GOLD 2024).

Other clinical scenarios suggest to consider chest CT:

1) COPD patients confirmed on PFT but in situations to rule out comorbidities such a lung cancer, or ILD;
2) Patients with high risk or clinically suspected of COPD but are unable to do PFT;
3) Patients with high risk or clinically suspected of COPD but in caring units that PFT is not available;
4) Patients with high risk or clinically suspected of COPD but negative on PFT. (Considering the advantages of chest CT is more sensitive in detection of emphysema than PFT, CT should be performed in PFT-negative patients with dyspnea, chronic cough, or expectoration, or a history of recurrent lower respiratory tract infection and/or exposure to risk factors of the disease, aiming the early screening of COPD.)

CT scanning recommendations

Based on the current status of Chest CT for COPD in clinical practice and research (Tables 2 and 3), we recommend the standard dose, low-dose chest CT protocols, and respiratory phases for different population cohorts based on the GOLD 2024 population classification with PFTs.

Standard dose CT protocol

At least 64 multidetector CT (64-MDCT) with spiral scanning is recommended. Tube voltage 120 kVp, Dose modulation or automatic tube current modulation technology, Collimation ≤ 1.25 mm; Reconstruction thickness ≤ 1.25 mm (1 mm is optical), Reconstruction interval: no interval or 80% of the thickness depending on the thickness is 0.625 mm or thicker, Scan matrix 512 × 512, Reconstruction algorithm or filter function with standard algorithm and lung algorithm reconstruction; Reconstruction mode: FBP or iterative reconstruction; Lung window setting level −600 to −650HU, window width 1500-1600HU; Mediastinal window setting level 40-50HU, window width 350-380HU.

Low dose CT protocol

If CT has iterative reconstruction technology, 120 kVp and less than 30 mAs could be used as scanning parameters; If CT does not have iterative reconstruction technology, the fixed scanning parameters of 120 kVp, 30-50 mAs could be considered.

Inspiratory and expiratory phase

- For patients with confirmed COPD, recommended to perform standard dose or low dose Chest CT scanning with paired respiratory phases.
- For middle-aged and elderly people with suspected COPD but insufficient diagnostic criteria or at high risk, low dose chest CT scanning with paired respiratory phases is recommended.
- For young people aged 20-40 years who have a history of premature infants, childhood asthma, or childhood respiratory tract infections, a family history of respiratory system diseases, or smoking, passive smoking, steam, or electronic cigarettes, recommended to perform low-dose chest CT scans only on the end of inspiration.

Comment

Radiation dose is very important for the pulmonary lesion detection and accurate diagnosis. There are many studies focusing the scanning technique of chest CT of patients and phatoms. Quantitative Imaging Biomarkers Alliance (QIBA) lung density profile has recommended the scanning protocol with standard and low dose CT for different vendors. Based on QIBA, 120 KV is recommended for both standard and low dose CT. For low dose CT, the mAs varied from 35 to 50 mAs. Dose modulation or automatic tube current modulation technology, and iterative reconstruction (noise reduction) is also recommended in QIBA. It has been reported that a combination of volume adjustment and noise reduction filtering improved the reproducibility of lung density measurements computed using serial full dose (200 mAs) and reduced dose (40-80 mAs varied owing to dose modulation) CT scans.[177] Acquisition and reconstruction methods are significantly affecting radiation dose reduction and accuracy of CT number measurements on a phantom study by Ohno et al.[178] It has been proven that low dose CT protocol at 50 mAs on 64-detector row CT scanner can produce the screening results consistent with standard dose CT protocol (150 mAs), supporting routine use of low dose chest CT protocol.[179] Other studies also showed low dose chest CT scanning does not affect the quantitative analysis of lung density based on iterative reconstruction algorithms.[25] To give consideration to the accuracy of subjective qualitative evaluation and objective quantitative evaluation, it is recommended to adopt a consistent scanning scheme for paired respiratory phases scanning for middle-aged and elderly people.

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Table 2. Current status of chest CT for COPD evaluation in Asia.

Country	China ($n=69$)	South Korea ($n=39$)	Japan ($n=62$)	India ($n=3$)	Turkey ($n=1$)	Malysia ($n=1$)	Vietnam ($n=1$)
Scanning respiratory phase							
Inspiratory	41[11-51]	12[52-63]	15[64-79]	3[80-82]			1[83]
Paired respiratory	18[64,84-100]	15[65,101-114]	16[115-130]			1[131]	
Standard or reduced dose							
120 kVp/140 kVp/							
50-120 mA	14[13,20,23,28,34,41,42,47,89,91,97,99,132,133]	18[53,55,57,63,65,102,104-106,108-111,113,114,131,134-136]			1[137]		
140-150 mA	5[30,37,43,50,138]		16[66,75,116,124,127-129,139-147]				
150-220 mA	8[12,18,24,26,31,38,46,51]	5[59,107,112,148,149]					
250-440 mA	5[16,44,85,86,150]		2[125,151]				
Tube current modulation	6[15,29,38,88,92,93]	1[52]	22[67,71,76-79,115,119-123,126,130,152-156]				
Low-dose							
110 kV/120 Kv , 20-50 mA	14[11,21,25,27,36,39,40,44,49,84,90,94,96,98]	3[54,157,158]					
70,80, 90 KV, Sn100 kV	4[48,150,159,160]						
Reconstruction thickness							
≤1 mm	44[11,15-23,25,27-29,31,34,36,38-40,43-49,84,86,88,89,91-93,96-99,132,133,138,159-161]	24[52,54-57,63,101,102,104-106,108-114,131,134-136,157,158]	37[67-72,75,76,78,79,87,115-117,119-122,124-127,130,139,141,144,145,147,151,152,154-156,162-165]	2[80,82]		1[131]	1[83]
>1 mm	12[12-14,24,35,37,50,51,85,94,150,161,166]	7[53,54,59,61,65,103,149]	10[66,87,123,128,142,143,145-147,153]	1[81]	1[137]		
Reconstruction algorithm							
Standard algorithm	19[12,15,17-20,23-26,28,29,64,86,94,98,99,159,161]	17[53,55,56,102,103,106,108-114,131,134,135,158]	11[71,87,116,117,125,127,129,147,154,164,165]		1[137]	1[131]	
Lung algorithm	6[11,42,89,90,93,96,139]	4[54,59,65,105]	8[66,67,75,77-79,146,156]				
Lung/standard algorithm	1[132]		1[70]				
Others	1[21]		3[73,115,164]				
Visual evaluation	2[23,91]	5[54,106,109,148,167]	5[129,140,141,147,168]				

(continued)

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Table 2. (continued)

Country	China ($n = 69$)	South Korea ($n = 39$)	Japan ($n = 62$)	India ($n = 3$)	Turkey ($n = 1$)	Malysia ($n = 1$)	Vietnam ($n = 1$)
Quantitative evaluation							
Emphysema	35[12,14,15,20,21,24-29,32-34,36,42,43,45,46,49,85,86,88,90-92,94,95,97-99,132,133,161]	27[52-59,62,63,65,102-114,131,167,169]	30[64,66,68,70,73,74,76-79,87,115,118,120-126,128,139,144,146,151,152,154,155,164,170]	2[80,82]	1[137]	1[131]	1[83]
Blood vessels	8[13,18,21,22,30,49,50,133,138]	4[52,57,110,148]	7[68,71,72,127,139,145,146]			1[131]	
Distal small airway	20[12,14,15,17,20,21,27,29,42,48,86,90-92,96,97,132,133,159,161]	7[57,101,105,107,109,131,171]	24[64,66,71,73,75-77,79,115,116,118-121,139,144,151,154,156,162,164,165,170,172]				
Mucus secretion		1[60]	2[121,122]				
PRM	5[45,89,91,92,133]	4[102,104,106,169]	6[115,116,118,121,125,130]				
Lung ventilation/perfusion	1[160]	4[59,61,65,101]	1[126]				
Topic							
CT technique	20[18,21,25,26,28,30,33,34,42,47,84,86,90,92,99,115,133,138,150,159]	14[52,54,56,58,59,62,65,101,102,106,110,112,113,135]	6[129,147,152,155,163,165]				
Diagnosis	22[13,15,16,23,31,35,36,38-41,43,88,89,91,96,97,101,132,173-176]	10[53,55,57,103,111,114,148,149,158,167]	6[78,94,120,143,151,168]				
Severity	12[13,16,22,37,48-51,95,100,132,175]	1[111]		2[80,81]			
Acute exacerbation	5[12,22,29,45,46]	1[60]	1[72]				
Survival	1[24]	8[54,107,108,131,134,136,158,171]	4[64,74,77,142]			1[131]	
Phenotype	4[11,33,94,161]	1[109]	5[73,87,141,155,164]				
Treatment response	1[19]						
Radiomics	13[16,35,36,38-41,45-47,51,92,150]	1[136]				1[131]	
AI	19[19,35,36,38-41,45-47,51,92,132,138,150,173-176]	9[52,56,102,135,148,157,158,167,169]	2[67,79]				

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Table 3. Imaging evaluation of COPD survey in Asia.

		China	Japan	South Korea	Vietnam	Thailand	Comment
General awareness of COPD		0.9%	10%-30%	31.6%	10%-30%	10%-30%	
Chest CT for COPD screening		Yes	Yes	No, perform if clinicians need to evaluate	No, perform when doctors indicates	No	
Chest CT for lung cancer screening		Yes	Yes	Yes	Yes	Yes	
Smoking rate		24.1%	16.7%	17.7%	10%	10%	
Prevalence of COPD		13.7% (≥40 y)	8.6% (≥40 y)	10.8% (≥40 y)	10%	7%	
Prevalence of lung cancer		Man: 91.36	Man: 137.3	Man: 71.73	Man: 34	Man: 32 Women: 10	
(*n*/100 000)		Woman: 58.18	Woman: 65.2	Woman: 50.02	Women: 10		
Subjective evaluation in clinical work?		1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5	
1) Emphysema 2) Airway wall thickening 3) Mucus plug 4) Mosaic pattern 5) D main pulmonary artery/D descending aorta > 1							
Lung volume analysis	Analysis level	Lobe level	Lobe level	Lobe level	No	No	
	Clinic or research use	Both	Both	Both	No	No	
Lung density analysis	**Analysis level**	Lobe level	Lobe level	Lobe level	No	No	
	Emphysema analysis	Yes	Yes	Yes	No	No	
	Air trapping analysis	Yes	Yes	Yes	No	No	
	PRM analysis	Yes	Yes	Yes	No	No	
	Clinic or research use	Both	Both	Both	No	No	
Airway analysis	Generation of airway	6th	8-10th	6-8th	No	No	
	standardized airway wall thickness parameter	Yes	Yes	Yes	No	No	
	total airway counting	Yes	No	Yes	No	No	
	Clinic or research use	Both	Research	Both	No	No	
Lung vessels analysis	small vessel analysis (CSA 5 mm^2, or CSA 10 mm^2)	Yes	No	Yes	No	No	
	Clinic or research use	Research	No	Research	No	No	
Do you plan to perform COPD quantification?		Yes	No for daily clinical practice, but do for research	Already in use for some clinical practice and research	Yes	Yes	

CT qualitative evaluation recommendations

A comprehensive evaluation of the condition of emphysema, airways, and blood vessels is suggested. It is recommended to indicate the specific type and severity of emphysema, and evaluate the severity using a semi-quantitative method (Table 4). The presence of mucus plug in the airway and air trapping is suggested to evaluate. For those diagnosed with COPD, the imaging phenotype and the possibility of pulmonary hypertension is recommended to evaluate guiding clinical treatment. The qualitative evaluation flowchart is shown in Figure 1.

Comment According to the Fleischner Association Recommendation,[180] the types of emphysema are divided into 3 types: centrilobular type (CLE), panlobular type, and Para septal type (Figures 1 and 2); CLE emphysema is further divided into minimal CLE (very small lobular central type transparent shadows, distributed less than 0.5% of the lung lobes), mild CLE (scattered lobular central type transparent shadows, surrounded by normal lung tissue, accounting for 0.5% to 5% of the total lung lobes), moderate CLE (more clearly defined transparent shadows, more than 5% of the lung lobes), fusion CLE (aggregated centrilobular or lobar lucency, including multiple lucency occupying multiple secondary pulmonary lobules, but excluding significant expansion or distortion of secondary pulmonary lobules) and progressive destruction (accompanied by expansion and distortion of secondary pulmonary lobules). Panlobular emphysema is extremely rare in our population. The subjective visual Goddard scoring method can be used to assess the severity of emphysema (Table 2), which is particularly suitable for units without quantitative analysis software for emphysema. Airway morphology mainly includes thickening of segmental and subsegmental bronchial walls, inflammatory small airway diseases and obstructive small airway diseases,

Table 4. Subjective visual Goddard scoring method for emphysema.

Goddard score	Proportion of emphysema in this cross-sectional anatomical layer (emphysema%)
0	0
1	0% < emphysema% ≤ 25%
2	25% < emphysema% ≤ 50%
3	50% < emphysema% ≤ 75%
4	75% < emphysema% ≤ 100%

Generally, 3 cross-sectional anatomical levels of both lungs are selected for evaluation: the upper lung level is the aortic arch level; The middle lung level is at the carina level; The lower lung level is about 1 cm above the top of the right diaphragm;[13] The 2 lungs are divided into 6 anatomical layers, with 0-4 points for each anatomical layer, and a total score of 0-24 points; Mild, total score ≤8 points; Moderate, 8 points < total score ≤ 16 points; Severe, total score > 16 points.

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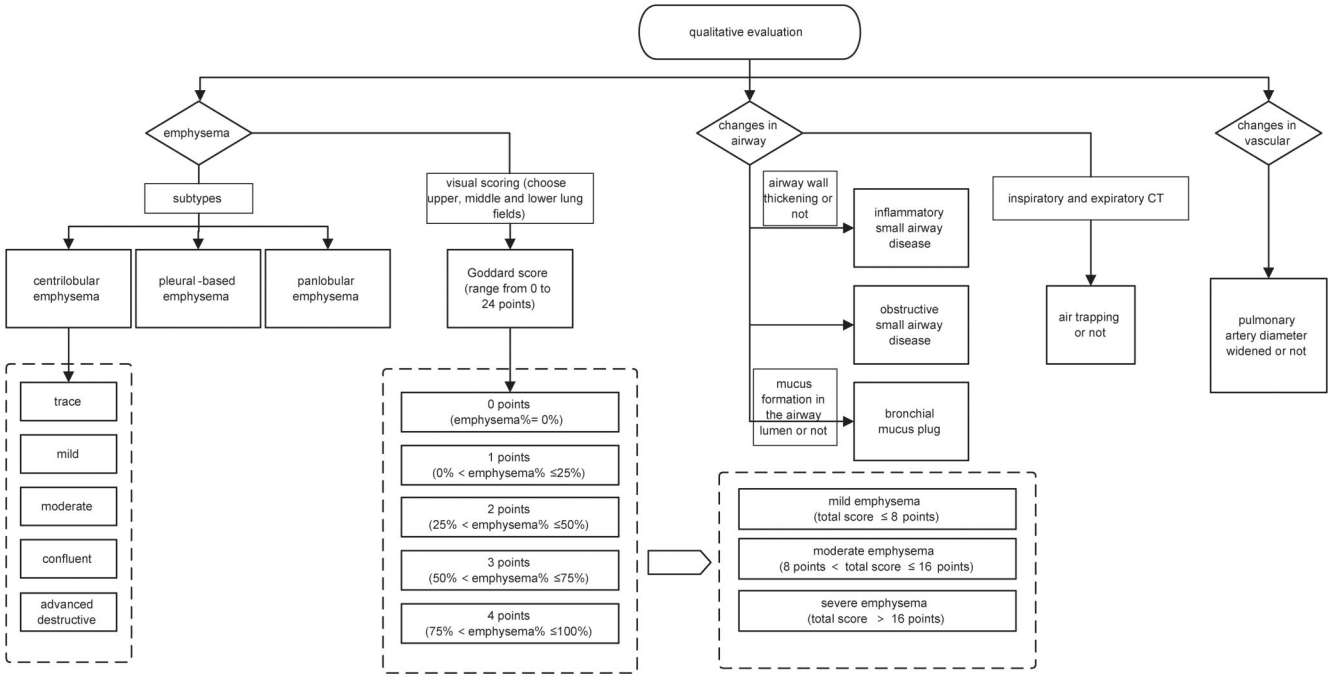


Figure 1. Flowchart for qualitative evaluation of Chest CT for COPD.

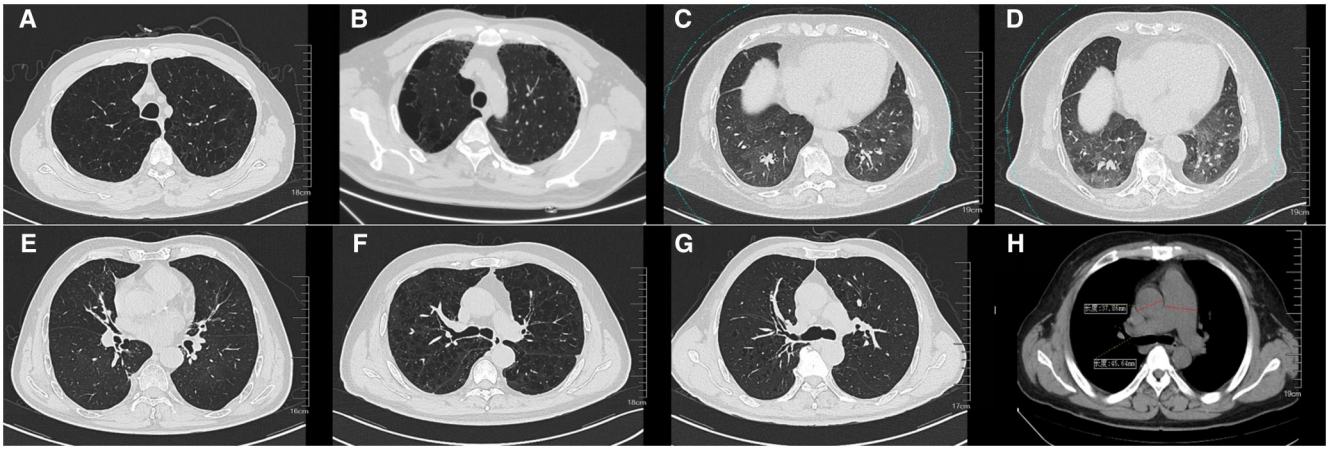


Figure 2. CT images of chronic obstructive pulmonary disease (COPD). (A) Shows the type of emphysema as centrilobular type, and (B) shows the type of emphysema as paraseptal type; (C) and (D) show air trapping in the lower lobes of both lungs in the inspiratory phase and expiratory phase respectively; (E-G) shows the different imaging phenotypes of COPD, (E) shows Type A, (F) shows Type E, and (G) shows Type M; (H) shows COPD with pulmonary hypertension, with a diameter ratio of the main pulmonary artery to the ascending aorta at the same level greater than 1.

the presence or absence of mucus plug in the airway, and the specific location of the tracheobronchial tree where they exist; Through the comparison of paired respiratory phases CT images, evaluate whether there is air trapping and the involved range (Figure 3). Due to the correlation between imaging phenotypes and clinical grading and treatment improvement, it is particularly important to determine imaging phenotypes. The commonly used imaging phenotypes include the following: Type A, without or with mild emphysema, regardless of the presence of bronchial wall thickening; Type E, with significant emphysema and no thickening of the bronchial wall; Type M, with significant emphysema and bronchial wall thickening.[181] Pulmonary vascular changes mainly include pulmonary arterial hypertension caused by pulmonary vascular remodeling, which ultimately leads to ventricular remodeling and pulmonary heart disease, characterized by widening of the pulmonary artery and enlargement of the right atrium and ventricle. The diameter of the main pulmonary artery and its ratio to the diameter of the ascending aorta at the same level on the inspiratory phase CT image are often evaluated. If the diameter of the main pulmonary artery is greater than 29 mm, and the diameter ratio of the main pulmonary artery to the diameter of the ascending aorta at the same level is greater than 1, it indicates that there is a greater possibility of secondary pulmonary hypertension. CT scanning radiation dose and reconstruction mode is important for the qualitative evaluation of chest CT images. IR is useful for image noise reduction and provides better image quality. With AIDR 3D assessment of radiologic findings obtained with reduced-(50 mAs) and low-dose

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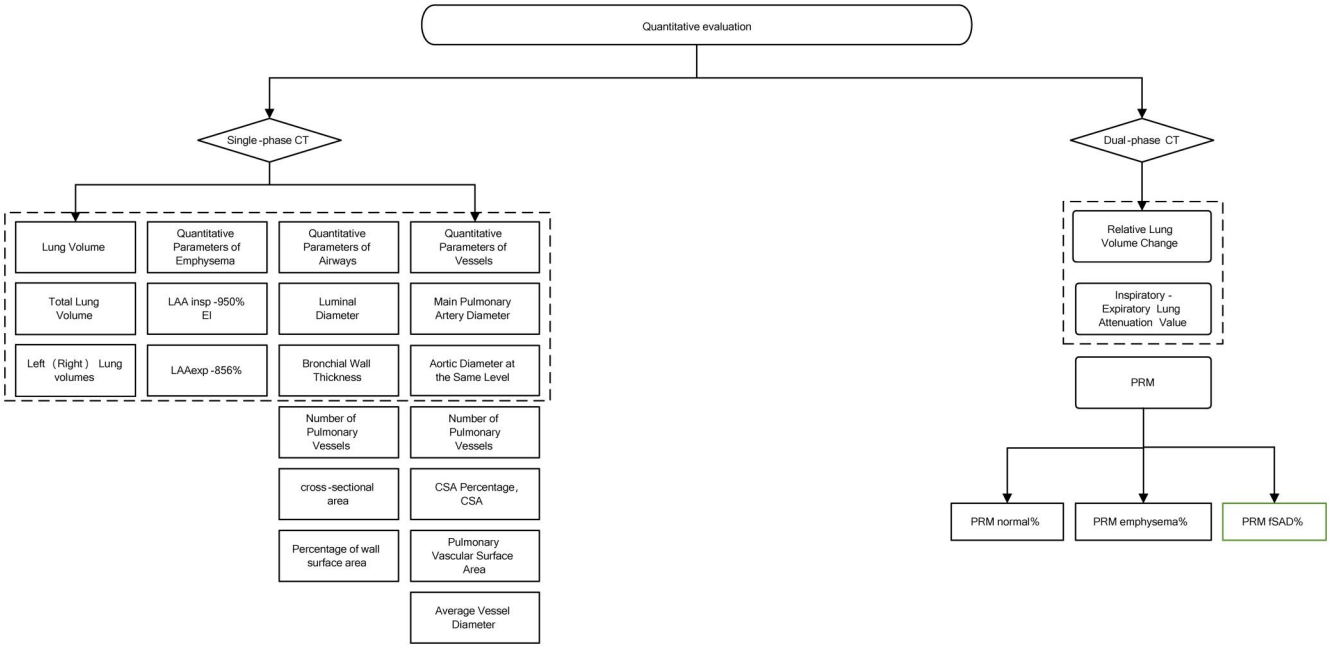


Figure 3. Flowchart for quantitative evaluation of Chest CT for COPD.

CT(25 mAs) for patients with various pulmonary diseases, the intermethod agreements for emphysema, bronchiectasis were almost perfect ($\kappa > 0.81$) with the standard dose (150 mAs).[182] Visual ranking of 10 different mAs settings from 10 mAs to 100 mAs in 10 mAs increments, found that simulated dose levels below 60 mAs (=42 mAseff) were clearly differentiated from higher dose levels by 3 readers.[183] It has been reported that reduced-dose (50 mAs) MDCT had a potential of substitution for standard-dose MDCT (150 mAs) on the visual assessment of emphysema in pulmonary emphysema patients.[184]

CT quantitative evaluation recommendation

For paired respiratory phases scanning, it is recommended to conduct at least quantitative evaluation of emphysema, large airway, air trapping, the ratio of main pulmonary artery diameter to ascending aorta diameter at the same level. Quantitative evaluation of functional small airways and blood vessels is suggested based on the functional status of the postprocessing software of each unit, as conditions permit. The quantitative evaluation process is shown in Figure 3. The parameters in the box are the minimum recommended measurement parameters.

Comment Chest CT quantitative evaluation has important clinical value in the early diagnosis, severity evaluation, phenotype analysis, and accurate identification of target lung tissue in lung volume reduction surgery for COPD.[74,136,185-190] CT quantitative evaluation combined with clinical basic information, clinical comprehensive evaluation scale, and PFT has great potential in the evaluation and prediction of acute exacerbation of COPD, readmission prediction, prediction of rapid decline in lung function, survival prediction and prognosis analysis, and prediction of complications. Quantitative evaluation is very important for the prediction of adverse events in COPD. Research has confirmed that partial naked eye observation of normal chest CT can be used for early diagnosis of emphysema through quantitative evaluation of CT lung density. For example, in the screening of lung cancer in Shanghai, the subjective evaluation of people over 60 years of age is normal, and through quantitative evaluation of CT, it is found that 8.3% of them have emphysema.[191] Therefore, conducting CT quantitative evaluation of COPD has important clinical value.

Quantitative evaluation of chest CT includes quantitative evaluation of lung volume, emphysema, airway, and pulmonary small vessels. When performing quantitative evaluation of chest CT, it is first necessary to automatically or manually segment the left and right lungs. Currently, some software can automatically segment 5 lung lobes after modeling using artificial intelligence algorithms; then, the physician conducts a slice by slice review of the segmentation results. After the review is completed, a quantitative evaluation is performed, outputting the average lung density, emphysema volume and proportion, and regional differences in lung density for the entire lung, left lung, right lung, or each lung lobe. Finally, determine the presence, severity, and distribution of emphysema. On inspiratory chest CT, the percentage of lung tissue volume with a CT attenuation less than −950 HU in the total lung volume is defined as the low attenuation area (LAA%) or emphysema index (EI). According to Fleischner's recommendation, EI ≥ 6% is defined as emphysema.[180] Small airway stenosis with diameter less than 2 mm is the main reason for COPD airflow restriction. However, because of its small diameter, most conventional CT images cannot be imaged or cannot be identified by the naked eye, so the degree of air trapping is often used to indirectly reflect the degree of small airway stenosis. End expiratory CT is the best method to evaluate COPD air trapping. Most studies quantitatively evaluate air trapping by evaluating the LAA% under the threshold of −856HU or −850HU (LAAexp-856 or LAAexp-850).

For paired respiratory CT images, after the left and right lungs are segmented, the quantitative analysis of air trapping can be carried out. The relevant parameters include the inspiratory to expiratory lung volume ratio, inspiratory to expiratory lung attenuation ratio, and inspiratory to expiratory relative volume changes of voxels with attenuation values between −860HU and −950HU at the whole lung, left and right

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lungs, and even 5 lung lobe levels. Alternatively, perform parametric response map (PRM) analysis to evaluate the condition of functional small airway diseases. Specific parameters include the volume and percentage of PRM_{normal}, $PRM_{emphysema}$, and PRM_{fSAD}.[192-194] Functional small airway disease is a transitional stage from normal lung parenchyma to emphysema. Early detection and intervention can reverse COPD. For a single inspiratory phase image, it is recommended to conduct at least a quantitative evaluation of the whole lung density, and the quantitative analysis of the lung lobe level depends on the specific configuration of each unit's postprocessing software. For paired respiratory images, it is recommended to conduct quantitative assessment of air trapping. The quantitative analysis of PRM depends on the specific configuration of post-processing software of each unit.

Large airway changes are also one of the phenotypes of COPD, mainly due to airway wall thickening and lumen narrowing. To quantitatively evaluate the airway and pulmonary vessels, it is necessary to first segment and extract the tracheobronchial bundle on the inspiratory phase to at least reach the sixth generation of bronchial tree, and then evaluate the quantitative parameters of the airway, including the thickness of the bronchial wall, the cross-sectional area of the bronchial wall, the area of the bronchial lumen, the diameter of the bronchial lumen, the percentage of the bronchial wall area (% WA), and the square root of the cross-sectional area of the bronchial wall with a circumference of 10 mm (Pi10). The changes of pulmonary vessels are closely related to the acute exacerbation of COPD, and the diameter of pulmonary artery significantly increases during the acute exacerbation of COPD. The quantitative parameters of pulmonary blood vessels based on CT plain scan include the diameter of the main pulmonary artery, the ratio of the diameter of the main pulmonary artery to the diameter of the ascending aorta at the same level, the number of pulmonary blood vessels in the whole lung, left and right lungs, and even at the level of 5 lobes, the cross-sectional area (CSA) of the pulmonary blood vessels, the percentage of $CSA < 5\ mm^2$, the surface area of the pulmonary blood vessels, and the average blood vessel diameter.[49]

Acquisition and reconstruction methods are significantly affecting radiation dose reduction and accuracy of CT number measurements, emphysema volume and airway wall thickness on a phantom study.[178,195] The use of adaptive iterative dose reduction using 3D processing resulted in greater consistency of emphysema quantiffcation by low-dose CT, with quantification by standard-dose CT.

Spectral CT imaging

Dual-energy CT (DECT) allows to the pulmonary ventilation and perfusion evaluation, which have important value in the early diagnosis, severity grading, and phenotype analysis of COPD. With the advent of DECT, pulmonary ventilation and perfusion imaging have become more convenient.[26] Energy CT enhanced scanning can obtain information such as iodine density maps that reflect pulmonary parenchyma perfusion, which has important reference significance for evaluating the heterogeneity and efficacy of blood perfusion in COPD.[196] In addition, energy CT imaging using xenon as a contrast agent after inhalation can be used to evaluate the ventilation function of COPD patients.[196]

For units with DECT, it is suggested to conduct functional imaging studies on COPD to provide more functional information and evidence-based medical evidence for the diagnosis and treatment of COPD.

Chest CT structure reporting recommendation

With the further improvement of quantitative evaluation of diseases, standardization of clinical diagnosis and treatment, and scientific research, structured reporting is the current trend of development. Quantitative and visual structured reports formed by extracting quantitative indicators of lung density, airway, and small blood vessels through artificial intelligence algorithms can provide more comprehensive quantitative data for clinical use and guide clinical treatment and follow-up management strategies. Currently, research on structured reports for quantitative analysis of COPD chest CT has been carried out in China. The implementation of structured reporting for COPD will contribute to the accurate evaluation of clinically assisted COPD.

Recommendation for one-stop CT screening for COPD and lung cancer

COPD and lung cancer share the same high-risk factors, such as smoking, aging, and air pollution. COPD has also been proven the high risk for lung cancer. It has been recommended the chest Big 3 diseases (lung cancer, COPD, and cardiovascular disease) screening with Chest CT by the NELSON-China programs. Annual low dose CT is recommended for lung cancer screening in patients with COPD due to smoking according to recommendations for the general population (GOLD 2024).

Perspective

With the development of CT technology and the progress of artificial intelligence algorithms, the CT quantitative evaluation of COPD in clinical practice would become more and more popular. Moreover, AI has show great potential for the COPD diagnosis, severity evaluation, prognosis prediction and management strategy with whole lung radiomics, deep learning and large language model. This recommendation will be gradually updated with the upgrade of CT hardware and post processing software, and the release of high-quality multi-center clinical research results, gradually establishing a more scientific and reasonable expert consensus.

In conclusion, this consensus establishes scanning protocols for different clinical scenarios. The qualitative and quantitative evaluation of lung density, airway, and small blood vessels by chest CT are of important guiding significance for the diagnosis, severity evaluation of COPD. Strengthening imaging evaluation of COPD and improving the level of understanding of COPD could reduce the socioeconomic burden.

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Conflicts of interest

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