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Routine pulmonary lung function tests: Interpretative strategies and challenges

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Abstract

Introduction: The diagnosis and management of common chronic respiratory diseases depend on various parameters obtained from pulmonary function tests (PFTs), such as spirometry, plethysmography, and carbon monoxide diffusion capacity (DLCO). These tests are interpreted following guidelines established by reputable scientific societies like the European Respiratory Society and the American Thoracic Society (ERS/ATS). **Aim and Methods:** This review aimed to offer a comprehensive framework for interpreting PFTs, incorporating the latest ERS/ATS update (i.e.; 2022), and to briefly explore some complex cases to shed light on their implications for understanding PFTs. **Results:** The ERS/ATS update outlines a systematic approach to interpreting PFT results, which involves several steps. Initially, results are compared to those of a healthy reference population to determine normal, low, or high parameters. Then, potential ventilatory impairments (VIs), such as obstructive or restrictive VIs, are identified, which could indicate specific chronic respiratory or extra-respiratory diseases. The severity of identified VIs or reductions in DLCO is then assessed. If bronchodilator testing is performed, its response is evaluated. Lastly, any significant changes in PFT parameters over time are noted by comparing current results with previous ones, if available. Despite the clarity provided by the ERS/ATS update, certain uncertainties persist and require clarification, such as the identification of new patterns (e.g.; non-obstructive abnormal spirometry, isolated low forced expiratory volume in 1 s), and classifications of mixed VI or lung hyperinflation in terms of functional severity. **Conclusion:** This review is a comprehensive framework for interpreting PFTs. Since some issues pose uncertainty in clinical practice, it would be beneficial to the ERS/ATS to reconcile some inconsistencies and provide clearer guidance on different classifications and VIs.

Keywords

Algorithm, asthma, COPD, PFT, interpretation, scientific societies, FEV_1Q, z-score

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Introduction

Chronic obstructive pulmonary disease (COPD), asthma, and interstitial lung diseases (ILDs) are among the most prevalent respiratory conditions necessitating precise diagnostic and monitoring approaches.[1] Pulmonary function tests (PFTs), including spirometry, plethysmography, and diffusing capacity of the lungs for carbon monoxide (DLCO) assessment, serve as pivotal tools in this regard.[2,3] PFTs are crucial not only for diagnosis, but also for

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assessing disease severity and monitoring its progression.[2,3] Therefore, it is crucial that the PFT parameters are of reliable quality and that the interpretation is based on the latest available scientific data and guidelines.

The interpretation of PFT results relies heavily on guidelines established by esteemed organizations (e.g.; American Thoracic Society (ATS), European Respiratory Society (ERS)).[4,5] These guidelines undergo periodic revisions to integrate the latest advancements in respiratory medicine. Notably, the 2005 ERS/ATS guidelines[5] were substantially updated in 2022.[4] This update is important, emphasizing the need for healthcare professionals to adjust their practices accordingly and integrate the changes into their daily routines.[6] In clinical practice, and some years after the publication of the ERS/ATS update,[4] there are still a number of issues that pose uncertainty[7,8] and therefore need to be clarified. On August 29, 2024, to the best of the authors' knowledge, among the 474 papers that cited the ERS/ATS update[4] as a reference (source: Scopus), only 11 papers[8–18]—all written as letters, editorials, or short communications—criticized the guideline.[4]

The primary aim of this review was to offer a comprehensive framework for interpreting PFTs, including spirometry, plethysmography, and DLCO assessment, incorporating the latest ERS/ATS update.[4] The secondary aim was to briefly explore and discuss some complex cases to shed light on their implications for understanding PFTs.

What is measured through routine pulmonary function tests?

Spirometry, plethysmography, and DLCO are techniques used to determine various parameters, such as bronchial flow rates, lung volumes, lung capacities, and DLCO.[19–25] The technical aspects[19–21] and international norms[22–25] for these PFTs have been extensively detailed in previous publications.[19–28]

Box 1 shows the main measured parameters during each technique.

How to interpret pulmonary function tests' parameters?

Before starting the interpretation of PFTs, it is essential to ensure that the measurements conform to the technical quality requirements during their execution.[19–21,27–31] This step, extensively described in previous publications,[19–22,27–31] ensures that the interpreted results genuinely reflect the patient's pulmonary function. Consequently, PFTs of lower quality should be handled with caution as they may not provide an accurate depiction of ventilatory impairments (VIs).[29]

The interpretation of PFT parameters can be summarized into five steps[32,33]:

(i) Comparison of the determined parameters to those observed in an appropriate reference population.[22–25] This step helps determine if the functional parameter is low, normal, or high.[32,33]
(ii) Identification of potential VIs, such as obstructive (OVI) and/or restrictive (RVI) ones, commonly observed in certain chronic respiratory or extra-respiratory conditions.[32,33]
(iii) Assessment of the severity of the identified VI or low DLCO.[32,33]
(iv) Evaluation of the response to bronchodilator testing, if performed.[32,33]
(v) If previous PFT results are on record, detection of any notable changes in specific parameters over time by comparing current findings with past ones.[32,33]

Step 1: comparing determined ventilatory parameters to norms and the place of race and ethnicity in PFT interpretation

In the absence of a specific intra-individual reference point, it is necessary to compare the determined parameters with the reference values established using standards (i.e.; norms).[22–25,34] These norms are derived from the results of PFTs performed on a large and representative sample of the general population with anthropometric, ethnic, socioeconomic, and environmental characteristics similar to those of the patient undergoing PFTs.[22–25]

In general, the normal range is defined as the range of values encompassing 90% of the healthy population.[22–25,32,33] Thus, the lower limit of normal (LLN) corresponds to the value below which 5% of the healthy population is located, and conversely for the upper limit of normal.[32,33] The Global lung function initiative (GLI) published norms for spirometric parameters (GLI-2012),[22] DLCO (GLI-2017),[24] and static lung volumes (SLVs) (GLI-2021).[25]

Historically, lung function was assessed using race-specific reference equations, which assumed that differences in lung function were due to variations in thoracic cavity size among racial and ethnic groups.[23] However, this method overlooked the impact of environmental and social factors, potentially disadvantaging marginalized populations.[23] In response to new evidence questioning the use of race-specific norms for the interpretation of lung function, the GLI created race-neutral norms (GLI-2023-Global), which do not require race/ethnicity as an input in spirometry interpretation.[23] The GLI-2023-Global norms were derived from the same data as the GLI-2012 norms,[22] but applied inverse probability weights so that each racial

Box 1. Main measured/determined parameters during spirometry, plethysmography, and carbon monoxide diffusion capacity (DLCO).

Technique	Interest	Measured parameters (unit)	Recommended norms
Spirometry[20]	Determination of mobilizable volumes	Forced vital capacity (FVC, L) Forced expiratory volume in 1 s (FEV_1, L) FEV_1/FVC ratio (absolute value) Expiratory airflow rates (L/s): ✓ Peak expiratory flow rate ✓ Instantaneous flow rates Maximal mid-expiratory flow	[22,23,26]
Plethysmography (or gas dilution methods)[21,27]	.Determination of static lung volumes	Expiratory reserve volume (L) Thoracic gas volume (~functional residual capacity (FRC, L)) Residual volume (RV, L) Total lung capacity (TLC, L) FRC/TLC ratio (absolute value) RV/TLC ratio (absolute value	[25]
DLCO[19,28]	.Assess the diffusion of oxygen from the alveoli to its chemical combination with hemoglobin	DLCO [traditional units (ml/min/mmHg), system international units (mmol/min/kPa)] Alveolar volume (VA, L) Carbon monoxide transfer coefficient (KCO = DLCO ÷ VA) (ml/min/mmHg/L or mmol/min/kPa/L)	[24]

and ethnic group contributes equally to the predicted values. According to the ERS, the GLI-2023-Global norms,[23] designed to encompass the broad range of lung function across populations, should be applied with careful consideration of an individual's symptoms and medical history, particularly in clinical, employment, and insurance contexts. Several scholarly societies recommended these standards when interpreting PFTs parameters.[22–25] Bowerman et al.[23] have reanalyzed existing data (i.e.; national health and nutrition examination survey III data; n = 6984 Mexican American, non-Hispanic White, and non-Hispanic Black participants) to develop a race-neutral norm, considering factors like sitting height and the Cormic index. The authors suggested that a single global spirometry norm could more accurately reflect lung function across diverse populations, though careful consideration of individual patient histories remains crucial for clinical decisions.[23] In April 2023, the ATS issued an official statement[26] recommending the use of the aforementioned norms for PFT interpretation, in order to improve accuracy and reduce potential harms, such as delayed diagnoses or inappropriate clinical decisions. The statement highlights the need for further research and education to understand the impact of this shift, emphasizing that race should not be used to infer biological characteristics.[26] The transition to race-neutral norms[23] requires careful consideration, particularly in clinical, employment, and insurance contexts, to avoid unintended consequence.

One of the main advantages of the GLI norms[22–25] is the possibility of standardizing the reporting and interpretation of PFTs.[35] Indeed, the GLI norms[22–25] are consistent with each other, which allows for a single set of PFT equations, thus avoiding discordant results between different PFTs and potential errors in the classification of physiological phenotypes.[9] This is not the case for the ATS new norms.[23,26]

The GLI equations include the largest samples of healthy individuals and represent a single standard for comparing observed measurements, applicable at all ages.[22–25] The use of GLI norms[22–25] involves the calculation of a z-score for each of the PFT parameters.[24,33,36] The z-score indicates how much a measurement deviates from its predicted value, and 90% of healthy individuals have a z-score between −1.645 and +1.645.[22,25,37] The z-score has the advantage of being free of any bias related to age, height, sex, or ethnic group, and it also facilitates the interpretation of PFTs.[22–25] The algorithms and software for the GLI equations[22–25] are freely available from two websites (i.e.; https://www.lungfunction.org, https://gli-calculator.ersnet.org/). To obtain race-neutral spirometry estimates using GLI-Global norms,[23] clinician are requested to select "race-neutral" in the spirometry section on the GLI websites.

In clinical practice, one challenge arises when interpreting PFT parameters in individuals over the age of 80 years.[25] For this specific population, while spirometric norms are available,[22] norms for SLVs are lacking.[25] In the elderly population, the ERS/ATS[4] provides the following

two options (which are difficult to apply in routine clinical practice) for interpreting SLVs:

(i) Use of the FEV_1 quotient (FEV_1Q), which can possibly be more meaningful than norms for this group.[4]
(ii) Extrapolation of predicted values from a younger age to estimate expected lung function in older individuals.[4]

In summary, a parameter is considered 'low' if its z-score is less than −1.645 and considered 'high' if its z-score is greater than +1.645.[4,33]

Step 2: identifying ventilatory impairments

This step involves comparing the determined parameters with the distinctive thresholds of the main VIs observed in respiratory diseases (e.g.; OVI, RVI, mixed VI (MVI), non-specific pattern (NSP), preserved ratio impaired spirometry (PRISm)). Some of these VIs can be objectified by spirometry (Figure 1), while others require the determination of SLVs and therefore the use of plethysmography (Figure 2).[4,6] The analysis of the flow-volume curve aspects for spirometry and the specific resistance loops for plethysmography is a crucial step in the interpretation of PFTs, as this analysis allows the evocation of specific VIs.[6,32] These aspects/loops have been detailed in previous publications.[5,20,32] In the following paragraphs concerning the interpretation of spirometry, plethysmography, and DLCO, the terms "low," "normal," and "high" correspond to z-scores of the parameters concerned, respectively, "<−1.645," between "−1.645" and "+1.645," and ">+1.645."

Figure 1 illustrates the algorithm of interpreting spirometric parameters. The initial step is to evaluate the ratio between forced expiratory volume in 1 s (FEV_1) and forced vital capacity (FVC), with two possible situations (Figure 1(A)). The first is a normal FEV_1/FVC ratio (*cell* A_2). In this case, if the FVC is normal (*cell* B_2), this suggests a normal spirometry. If the FVC is low (*cell* B_4), this suggests a RVI or a NSP, while a simultaneous decrease in FVC and FEV_1 points to a PRISm (not shown in the **figure**). The second situation concerns a low FEV_1/FVC ratio (*cell* A_1). In this case, if the FVC is normal (*cell* B_1), this indicates an OVI, whereas if the FVC is low (*cell* B_2), this suggests a MVI, but is also seen when more severe OVI is accompanied by air trapping (high residual volume (RV)).

Figure 2 illustrates the algorithm for interpreting SLVs.[4] The initial step is to evaluate total lung capacity (TLC), with three principal outcomes:

(i) High TLC (*cell* A_3). If the RV/TLC ratio (and/or the functional residual capacity (FRC)/TLC ratio) is high (*cell* B_5), this suggests lung hyperinflation (LH), whereas it normalization (*cell* B_6) points to large lungs.
(ii) Normal TLC (*cell* A_2). Here, a high RV/TLC ratio (or FRC/TLC ratio) (*cell* B_3) evokes LH, while its normalization (*cell* B_4) indicates normal SLVs. The presence of a low FEV_1, low FVC, and a normal FEV_1/FVC ratio indicates a NSP (not shown in the **figure**).
(iii) Low TLC (*cell* A_1). This verifies the presence of a RVI with three identifiable possibilities: (a) MVI: High RV/TLC (and/or FRC/TLC) (*cell* B_1) with low FEV_1/FVC (*cell* C_1); (b) *Complex RVI*: High RV/TLC (and/or FRC/TLC) (*cell* B_1) with normal FEV_1/FVC (*cell* C_2); and (c) Simple RVI: normal RV/TLC (and FRC/TLC) (*cell* B_2).

Figure 3 illustrates the algorithm for interpreting DLCO.[4] Three scenarios are outlined:

(i) Low DLCO (*cell* A_1). In this case, both alveolar volume (VA) and carbon monoxide transfer coefficient (KCO = DLCO ÷ VA) levels should be assessed. Low VA (*cell* B_1) and KCO (*cell* C_1) may indicate a loss of alveolar-capillary structure along with loss of lung volume. When accompanied by a normal KCO value (*cell* C_2), low VA (*cell* B_1) suggests a localized reduction in lung volume or incomplete lung expansion. Conversely, if VA is normal (*cell* B_2), it could indicate a pulmonary vascular anomaly, emphysema with preserved lung volume, or anemia.
(ii) Normal DLCO (*cell* A_2).
(iii) High DLCO value (*cell* A_3). This situation could suggest increased blood flow, erythrocytosis, or alveolar hemorrhage.

The following paragraphs will discuss the applied criteria to diagnosis some VIs such as OVI, RVI, MVI, PRISm, NSP, and gas transfer impairments.

Obstructive ventilatory impairment. The specific cases of central and upper airway obstructions have been described in previous publications.[5,20,32]

Regarding distal OVI, it has been historically thought that increased instantaneous flows at low lung volumes and maximal mid-expiratory flow (MMEF) are indicative of such impairment.[32] However, the performance of these parameters has proven to be poor.[4,6] Instantaneous flows and MMEF exhibit high variability, poor reproducibility, and lack specificity for small airway disease.[38] Consequently, there is insufficient evidence to confirm the existence of distal OVI based solely on spirometry

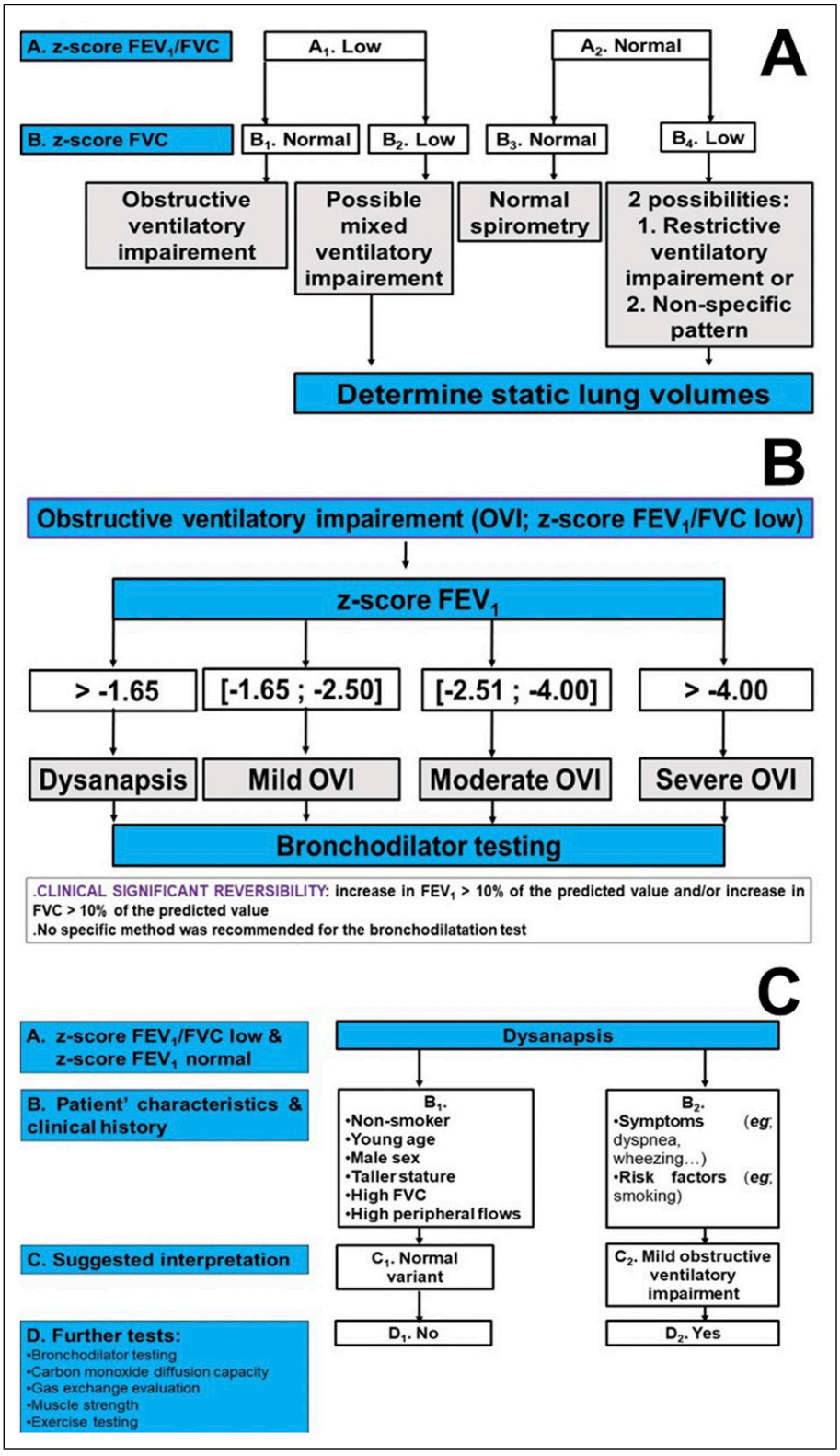

Figure 1. Spirometry: algorithm of interpretation (figure A), classification of impairment severity (figure B), and interpretation of dysanapsis (figure C). FEV_1: Forced expiratory volume in 1 s. FVC: forced vital capacity. Notes: ✓ Low: z-score <−1.645. ✓ Normal: z-score: $-1.645 \leq Z \leq +1.645$. ✓ Figure 1C (*Cells* D_1 and D_2): "no" means "not to be performed" and "Yes" means "to be performed."

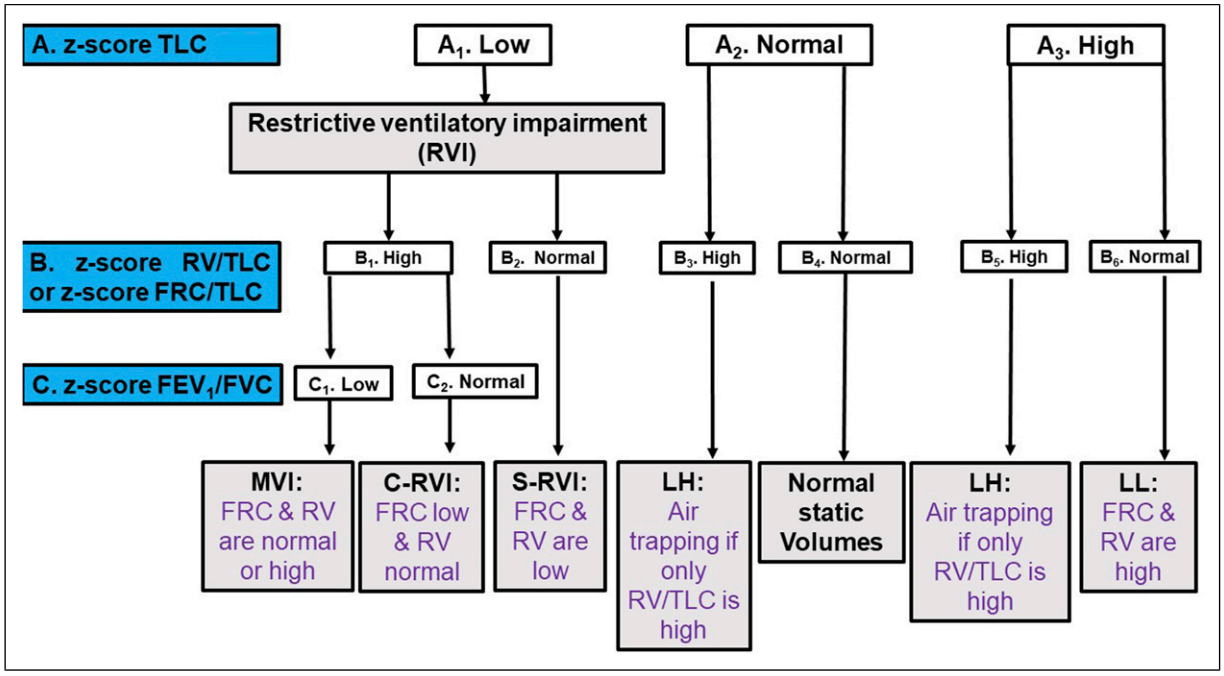

Figure 2. Static lung volumes: algorithm of interpretation. C-RVI: complex RVI. FEV_1: forced expiratory volume in 1 s. FVC: forced vital capacity; LH: lung hyperinflation; LL: large lungs; MVI: mixed ventilatory impairment; RV: residual volume; S-RVI: simple RVI; TLC: total lung capacity; Z: z-score. Notes: ✓ Low: z-score <−1.645. ✓ Normal: −1.645 ≤ z-score ≤+ 1.645. ✓ High: z-score >+1.645.

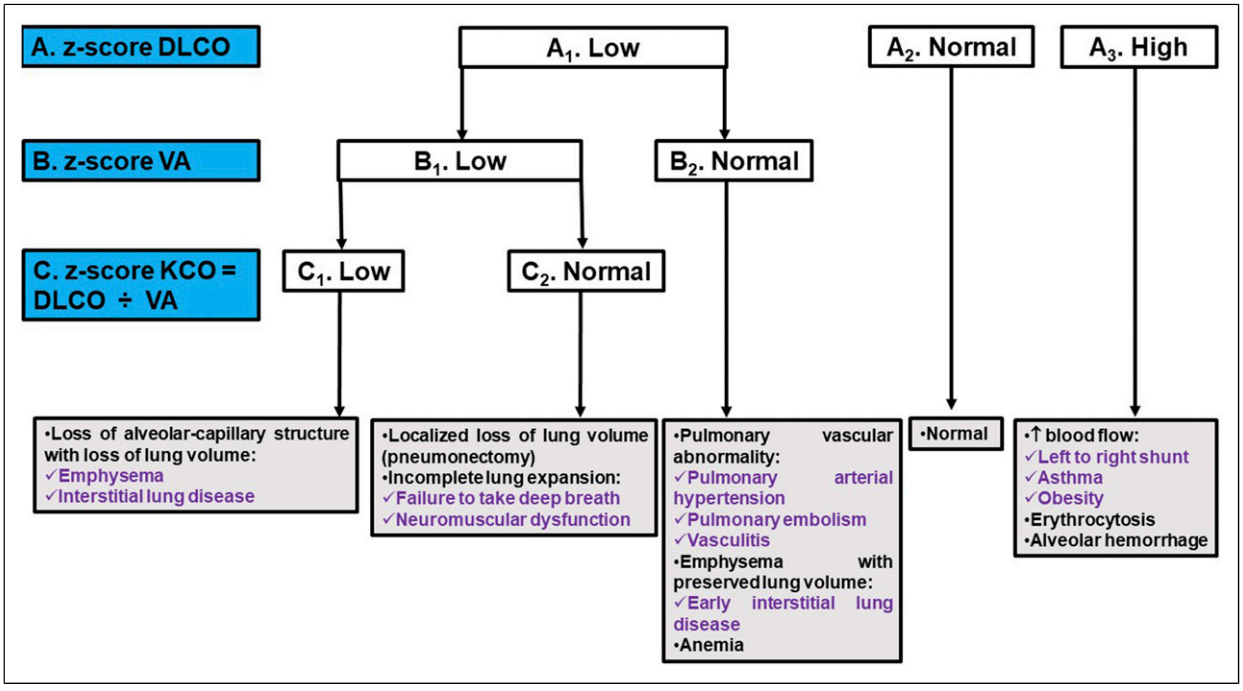

Figure 3. Carbon monoxide diffusion capacity (DLCO): algorithm of interpretation. VA: alveolar volume. KCO: carbon monoxide transfer coefficient. Notes: ✓ Low: z-score <−1.645. ✓ Normal: −1.645 ≤ z-score ≤+ 1.645. ✓ High: z-score > +1.645.

parameters.[4,6] Nonetheless, visual analysis of the flow-volume curve may suggest the presence of distal OVI by demonstrating an upwardly concave curve aspect.[4,6] Additionally, as any pulmonologist recognizes, a low MMEF, especially when FVC remains normal, is often the earliest abnormality detected in individuals at risk for COPD.[9] These individuals typically exhibit a high pre-test probability of airway disease.[9] A low MMEF (e.g.; <50% predicted value (%pred), as the LLN is often set too low[39]) is valuable in identifying "pre-COPD" cases, serving as a crucial tool in encouraging smokers, who still have a preserved FEV_1, to quit smoking sooner rather than later.[9] The SPIROMICS cohort,[40] which included smokers and ex-smokers, reported a significant variability between MMEF %pred and FEV_1 %pred when the latter was within the normal range, and identified that MMEF %pred was linked to imaging evidence of increased emphysema and functional small airway disease, even after adjusting for FEV_1 or FVC. Finally, other tools such as oscillometry or the "multibreath flush test" may aid in identifying distal OVI, although they are not commonly utilized in clinical practice.[41,42]

An OVI is characterized by a FEV_1/FVC ratio falling below the LLN.[4] While this spirometric criterion for OVI aligns with the 1991-ATS[43] and the 2005-ATS/ERS[5] guidelines, it differs from the definitions provided by the global initiative for chronic obstructive lung disease (GOLD)[2,44] and the ATS/ERS[45] guidelines on COPD, which use a fixed FEV_1/FVC threshold of 0.70 to identify OVI. It is high time to definitively discard the 0.70 cut-off in the diagnosis of COPD.[46,47] First, failing to account for the fact that the FEV_1/FVC ratio changes with age leads to an underestimation of OVI prevalence in younger individuals and an overestimation in the elderly.[46–48] The FEV_1/FVC ratio decreases with age and height, even in non-smokers, where the LLN falls below the fixed threshold of 0.70 starting around 45 years of age.[47] The use of the 0.70 threshold results in up to a 50% overdiagnosis (misclassification) beyond this age.[47] Moreover, the fixed ratio does not adequately distinguish mild OVI, and its use introduces significant age and sex biases.[46–48]

While spirometry alone is generally adequate to diagnose an OVI, additional abnormalities identified during SLV measurement may serve as indirect signs supporting an OVI diagnosis (Box 2). SLV abnormalities often indicate LH (evidenced by high FRC/TLC or RV/TLC) or air trapping (evidenced by a high RV/TLC only) (Figure 2, Box 2).

Under conditions of maximal effort, the presence of low FEV_1/FVC with normal FEV_1 in a healthy individual may result from dysanapsis growth of the airways and lung parenchyma[4] (Figure 1(B)). Dysanapsis involves unequal growth of the airways and lung parenchyma, with greater growth occurring in lung parenchyma and airway length than in airway caliber.[49] While this profile may represent a normal variant in healthy individuals, it can also indicate a predisposition to develop obstructive disease (Figure 1(C)).[49–52] It is worth considering the possibility that this functional profile corresponds to a variant of normal, especially in healthy, asymptomatic adults, especially if they are male, tall and young, even more so as FVC is increased and distal flows are normal (Figure 1(C), *cells B_1 and C_1*).[49] In children, the dysanapsis growth is associated with obesity or rapid weight gain in early childhood, and is predictive of expiratory flow limitation, thus constituting an indicator of the propensity for obstruction.[50–52] Determining whether dysanapsis growth signifies obstruction or a normal variant requires consideration of the clinical context and results of other complementary explorations, such as bronchodilation tests, DLCO measurements, respiratory muscle strength assessment, and cardiopulmonary exercise tests (Figure 1(C)).[4] Additionally, it is essential to verify the correct execution of forced expiratory maneuvers before drawing any conclusions. Since FEV_1 exhibits inverse effort-dependence, sub-maximal effort may lead to an overestimation of FEV_1 and consequently explain such results.[49]

Restrictive ventilatory impairment. RVI is defined by a low TLC[4] (Figure 2, *cell A_1*). It may result from the alteration of one of the following three forces: (i) Decrease in muscle strength (e.g.; myopathies), (ii) Increase in elastic recoil pressure (e.g.; pulmonary fibrosis), mainly due to the presence of rigid fibrotic tissue in the lungs, and (iii) Reduction in parietal compliance.[53]

Measurement of SLVs is necessary to confirm a low TLC. However, RVI may be suspected on spirometry when FVC is low (Figure 1(A), *cells B_2 and B_4*) while FEV_1/FVC is low (Figure 1(A), *cell A_1*) or normal (Figure 1(A), *cell A_2*). This last situation may suggest either a RVI or a NSP.[4] It is important to note that an isolated low FVC does not prove the existence of RVI, as it is associated with RVI in at least 50% of cases.[54] Since the complexity of FVC interpretation warrants careful consideration,[9] the ERS/ATS[4] conclusion that "a normal FVC can exclude RVI" should be approached with caution.[9] In practice, a significant number of patients with established ILD exhibit low TLC despite a preserved FVC, especially when RV decreases concurrently with TLC.[55]

In most patients with a restrictive process, such as ILD, TLC, FVC, and FEV_1 are reduced in a proportional way.[6] Thus, when expressed as a %pred, the difference between TLC%pred and FVC%pred is negligible.[6] This scenario corresponds to "simple" RVI[56] (Figure 2, *cell B_2*). However, many patients have RVI with a difference between TLC%pred and FVC%pred exceeding 10%.[56] This disproportionate decrease in FVC%pred compared to TLC%pred leads to an increase in RV and RV/TLC, indicating the presence of air trapping, without being associated with a

Box 2. Classifications of ventilatory impairments defined according to static lung volumes (modified from reference)[4].

Ventilatory impairments	z-score					Comments
	Total lung capacity (TLC)	Functional residual capacity (FRC)	Residual volume (RV)	FRC/TLC	RV/TLC	
Obstructive ventilatory impairment	Normal or ↑	Normal or ↑	Normal or ↑	Normal or ↑	Normal or ↑	• Lung hyperinflation: FRC/TLC or RV/TLC ↑ • Air trapping: only RV/TLC ↑
Simple restrictive ventilatory impairment	↓	↓	↓	Normal	Normal	• Example: interstitial lung disease
Complex restrictive ventilatory impairment	↓	↓	Normal or ↑	Normal	↑	• FEV_1/FVC normal • Process that disproportionately reduces FVC relatively to TLC • Examples: Small airway diseases with air trapping, obesity
Mixed ventilatory impairment	↓	Normal or ↓	Normal or ↑	Normal or ↑	Normal or ↑	• FEV_1/FVC ↓
Large lungs	↑	↑	↑	Normal	Normal	• Normal variant
Muscle weakness	↓	Normal or ↓	↑	↑	↑	• Weakness of muscle: TLC ↓ • Weakness of expiratory muscles: RV ↓
Obesity	Normal or ↓	↓	Normal or ↑	Normal or ↓	Normal or ↑	• Expiratory reserve volume ↓ • Morbid obesity (body mass index ≥40 kg/m^2): TLC ↓
Suboptimal effort	↓	Normal	↑	↑	↑	• Insufficient effort

Notes: ✓ ↓: z-score < −1645. ✓ Normal: −1645 ≤ z-score ≤ + 1645. ✓ ↑: z-score > +1645).
FEV_1: forced expiratory volume in 1 s; **FVC**: forced vital capacity; ↓: low parameter; ↑: high parameter.

decrease in FEV_1/FVC.[56] This characterizes complex RVI (Figure 2, *cell C_2*). The air trapping observed in this case may reflect occult obstruction or mechanical incapacity to reduce thoracic cavity volume, as seen in neuromuscular diseases or obesity.[56] Lastly, according to the ERS/ATS update,[4] obesity can only be incriminated in a restrictive process for body mass index values >40 kg/m^2[57] (Box 2). It appears that the ERS/ATS update[4] overlooks the interpretative challenges posed by the obesity epidemic, including cases of extreme obesity.[58]

Mixed ventilatory impairment. The combination of a low TLC and a low FEV_1/FVC indicates the simultaneous presence of obstruction and restriction, referred to as MVI[4] (Figure 2, *cell C_1*). MVI is typically characterized by pulmonary parenchymal and extra-pulmonary damage.[6] The most common scenario is the association between COPD and congestive heart failure or obesity.[59] In the absence of SLVs measurements, the association of a low FEV_1/FVC with a normal FVC allows the exemption of MVI (Figure 1(A), *cell B_1*).[4] However, when both the FEV_1/FVC and FVC are low (Figure 1(A), *cell B_2*), associated restriction cannot be ruled out, and the presence of MVI is thus possible.[59] SLVs measurements generally confirm this situation by indicating a low TLC in 10% of cases.[59] Typically, TLC is found to be normal, while RV and FRC are high.[4] The decrease in FVC is actually due to the increase in RV.[6] These abnormalities often signify air trapping or LH, serving as indirect indicators of obstruction (Figure 2, Box 2). In clinical practice, strict adherence to the ERS/ATS[4] recommendation that "low FVC in cases of OVI (Figure 1(A), *cell B_2*) should trigger suspicion of associated restriction, necessitating SLVs assessments" could lead to a surge in unnecessary testing[9]: In the majority of patients with COPD, but not in conditions like sarcoidosis where a low FVC might indicate associated restriction,[60] a low FVC typically reflects gas trapping.[61]

Preserved ratio impaired spirometry and non-specific pattern. In the absence of TLC determination, the presence of a low FVC or FEV_1 with a normal FEV_1/FVC corresponds to the PRISm.[62,63] PRISm is a relatively common entity, with a prevalence of approximately 10%.[62,63] It may be observed in cases of true restriction or damage of small airways,[64] or may result from reduced effort, reflecting the individual's inability to fully inspire or expire, leading to an overestimation of FEV_1 and FVC.[4] In such situation, the flow-volume curve may exhibit a

downward concavity at the end of the maneuver.[4] Under conditions of optimal effort, and in the absence of TLC determination, performing a bronchodilation test may be useful.[4,57] If this test is clinically significant, it may indicate the existence of a certain degree of bronchial reactivity.[4,57] It is also possible to complete the evaluation with a measurement of slow-vital capacity. If FVC differs from slow-vital capacity by more than 100 mL (i.e.; slow-vital capacity minus FVC ≥100 mL), this may reflect collapse of small-airways with air trapping occurring during forced expiration.[65] The aforementioned proposed 100 mL difference appears overly stringent[9]; and a more realistic threshold of 200 mL is recommended to prevent overdiagnosis of airway disease.[32,61] It is essential to note that the use of the term PRISm in situations where TLC is not available introduces a challenge.[6] The term PRISm did not exist in the Figure 8 of the ERS/ATS update[4] (nor in our Figure 1), which causes uncertainty, questions its utility, and challenges its validity in easing clinicians' decisions.

A NSP is defined by the presence of a low FEV_1, low FVC, normal FEV_1/FVC (Figure 1, *cell B_4*), and normal TLC.[57,66] The significance of NSP is unclear.[57] It may be a precursor sign of a restrictive or obstructive process.[66] Long-term follow-up of these patients identified that NSP remains stable in two-thirds of patients, while it progresses to restriction or obstruction in one-third of cases.[66] In the case of a restrictive process, the decrease in FVC is not yet accompanied by a decrease in RV.[4,66] In contrast, in the case of an obstructive process, collapse of small-airways can lead to a decrease in FVC and an increase in RV before FEV_1/FVC decreases.[4] Finally, it should be mentioned that during the evaluation of patients with pneumothorax or non-communicating bullous emphysema, a discrepancy is often observed between a low FEV_1 and FVC, while FEV_1/FVC and TLC determined by plethysmography are within normal limits.[32] In such situations, it is recommended to determine TLC using other techniques, particularly gas dilution.[32] It is interesting to note that the ERS/ATS update[4] presents inconsistencies between the definition of the NSP (provided in their table 5) and the complementary text, which leads to potential confusion. While in table 5 of the guideline,[4] the NSP was characterized by "low" FEV_1 and FVC, with "normal" FEV_1/FVC and TLC, in the complementary paragraph titled (*The* "*non-specific*" *pattern: a* "*low*" *FEV_1 and FVC with* "*normal*" *FEV_1/FVC*") in *page 19*,[4] the NSP was defined as having "low" FEV_1 or/and FVC.[4] Furthermore, in their Figure 8,[4] the suspicion of the NSP did not take into account FEV_1.

In brief, other than putting a name on an atypical spirometry impairment/pattern, the utility of **NSP** and PRISm may be only an alert to a possible future problem.[6]

Gas transfer impairments. Four abnormal situations are possible for DLCO[4]: (i) Low DLCO, VA and KCO; (ii) Low DLCO and VA, with normal KCO; (iii) Low DLCO with normal VA; (iv) High DLCO. The possible causes of each situation are detailed in Figure 3.

According to the ERS/ATS,[4] when interpreting results, it is important to account for changes in hemoglobin, carboxyhemoglobin, met-hemoglobin, and carbon monoxide back-pressure. This is especially crucial in cases where patients are being regularly monitored for potential drug toxicity and when hemoglobin levels may fluctuate significantly, such as during chemotherapy for cancer.[4] Clinicians should consider hemoglobin concentrations on an individual basis when interpreting results, and it is recommended that reference values be adjusted according to the measured hemoglobin concentration.[4]

Pristi and Johnson[16] identified some significant issues in the proposed algorithm for interpreting DLCO.[4] While the algorithm acknowledges that KCO increases at lower VA, it does not account for the predictable relationship between KCO, DLCO, and VA.[16,31,67] The algorithm also overlooks the fact that patients with ILDs can have low, normal, or high KCO, and that patients with low VA due to incomplete lung expansion could have a normal DLCO when adjusted for VA.[16] Pristi and Johnson[16] suggested reporting the predicted DLCO for the patient's VA (i.e.; DACO[68]) alongside the measured DLCO. Instead of incorporating KCO into the DLCO interpretation algorithm, the focus should be on the %pred DACO, which corresponds to the % pred KACO and tends to be low in ILD.[16,69] According to Neder,[9] the notes in the ERS/ATS update[4] that 'defining an impaired KCO in the context of a low VA has minimal evidence to guide interpreters' is a concern and poses misinterpretation of VA and KCO. Figure 3 modified from the ERS/ATS update,[4] suggests that a low KCO (Figure 3, *cell C_1*) in conjunction with a low VA (Figure 3, *cell B_1*) indicates loss of alveolar-capillary structure with loss of lung volume. However, an important consideration was omitted from Figure 3,[4] which is the VA/TLC ratio.[9] While a normal KCO with a low VA/TLC ratio (e.g.; <0.80) due to airway disease or emphysema may not be informative, a normal or low KCO when VA is near TLC suggests intraparenchymal restriction.[9] In contrast, a supra-normal KCO indicates extraparenchymal restriction.[70]

Step 3: evaluation of ventilatory impairment' severity and diffusing capacity of the lungs for carbon monoxide' decrease

The ERS/ATS[4] introduced a significant innovation in the classification of the severity of OVI (Figure 1(B)), RVI and low DLCO.[4] For both OVI and RVI, a three-level severity scale is employed, based on the FEV_1 z-score. Similarly, the severity scale for DLCO is based on the DLCO z-score and also includes three levels. The recommended three-level

severity scale would deem a z-score >−1.645 as normal, z-scores between −1.65 and −2.50 as mild impairment, z-scores between −2.5 and −4.0 as moderate impairment, and z-scores <−4.0 as severe impairment.[4] It is important to point out that this classification solely considers mortality risk as a benchmark, and may not necessarily reflect symptom severity, risk of exacerbations, or social consequences.[4] According to Neder,[9] it is axiomatic that such classification should primarily reflect current functional impairment, not future risk, the latter a complex construct that goes well beyond lung function in individual patients. According to Bhatt et al.,[10] there is a gap in the classification scheme recommended the ERS/ATS for staging OVI severity.[4]

Assessing the VI severity is often challenging and uncertain.[71,72] Traditionally, this assessment has involved using arbitrary thresholds to categorize results into 3–5 levels,[4,5,71–73] loosely correlating with disease symptoms and mortality rates.[74,75] It remains uncertain whether the ERS/ATS derived z-score three-level severity scale[4] will prove more effective than the older %pred scales.[71] When comparing different severity scales, such as FEV_1 %pred, FEV_1 z-score, or the recently proposed FEV_1/FVC ratio, it is crucial to consider the chosen cut-off points.[76,77] It seems that the suggested FEV_1/FVC scale differs from the GOLD[44] criteria mainly because its tier-1 includes lower FEV_1 values than GOLD 1, which only includes FEV_1 >80%.[76,77]

Step 4: assessment of the bronchodilator test response

The bronchodilator test is utilized to assess the extent of improvement in pulmonary function following the administration of a bronchodilator.[6,20] In practical terms, it entails spirometry (or a plethysmography) conducted after inhaling 400 µg of a short-acting β-2 mimetic bronchodilator (e.g.; salbutamol) and/or 30 min after inhaling 160 µg of a short-acting parasympatholytic (e.g.; ipratropium bromide).[6,20] When the bronchodilator test is employed for diagnostic purposes, bronchodilators should be discontinued prior to the test with the duration of discontinuation dependent on the type of bronchodilator used.[6]

According to the ERS/ATS,[4] reversibility is considered clinically significant when there is an increase in FEV_1 and/or FVC of more than 10% compared with the predicted value, irrespective of the patient's age.[4] This new reversibility criterion differs from previous guidelines[5] and may result in many patients -some with 30–50% improvement from baseline- no longer being classified as having a clinical significant reversibility.[16] This could lead to them being denied the best treatment with bronchodilators.[16] The 10% criterion does not take into account reproducibility or other indicators.[16] The main reason behind the ERS/ATS update[4] recommendation is evidence showing improved survival rates in patients with OVI who experience a reversibility of more than 8% of predicted FEV_1.[78] Some experts have suggested using non-binary reversibility criteria instead,[79] especially in pediatric population.[80]

According to the ERS/ATS update,[4] the choice of bronchodilator, its dosage, and method of administration are left to clinical judgment. It is worth noting that the advantages of various bronchodilator test protocols, such as the delivered dose, remain unspecified.[4,81] Furthermore, while a response to bronchodilators may indicate changes in clinical status, its utility in differentiating between various airway diseases is imprecise.[4,81]

Step 5: identifying significant changes over time

When patients have previous PFT results, it is important to compare current findings with past ones to detect any significant changes over time.[4] Longitudinal assessment of PFT parameters enables the identification of excessive decline in pulmonary function caused by exposure to harmful agents or an underlying disease.[82] Ideally, measuring an individual's pulmonary function before the onset of their illness should serve as a reference point.[82] To assess the decline in pulmonary function, it is crucial to compare it to the physiological one observed in the healthy population.[4] However, it is important to consider biological variability and measurement errors.[6] Therefore, to label a decline in PFT as accelerated, the observed decrease in a patient must exceed both the physiological decline and account for biological variability and measurement errors.[4,6] Since test-to-test variability (e.g.; up to 150 mL for FEV_1) greatly exceeds even an accelerated annual rate of decline, several measurements over an extended time are needed to establish a valid rate of decline for an individual.[5,30]

In adults, the FEV_1Q is an interesting method for evaluating the decline in pulmonary function.[83] The FEV_1Q expresses FEV_1 relative to a lower limit that represents the "survival threshold" below which the risk of mortality is greatly increased.[83] The FEV_1Q value is the numerical quotient obtained as FEV_1 (in Liters) divided by 0.5 for males and by 0.4 for females.[83] Under normal conditions, FEV_1Q decreases by one unit every 18 years in healthy individuals and by one unit every 10 years in smokers and elderly individuals.[83] FEV_1Q should remain stable over a short period (and up to 1 year), and a rapid decline in its value should indicate a significant change in pulmonary function.[4] However, there are no specific thresholds to define stability or rapid decline of the FEV_1Q (e.g.; what is the level of change that constitutes the minimal important difference between FEV_1Q' measurements),[13] and it can be challenging in practice to reliably detect any excessive

changes. Therefore, it appears that FEV_1Q may be useful, but not helpful.[13] Moreover, according to Neder,[9] FEV_1Q is fraught with complexities since the first centile is likely to vary markedly as a function of age, body dimensions, and the underlying disease(s). Additionally, FEV_1Q has been used to assess the severity of COPD, and unlike the traditional method based on FEV_1 %pred, the FEV_1Q was able to distinguish the most severe classes of COPD from less severe stages.[73]

In pediatric populations, several considerations should be taken into account.[4] A child/adolescent is not simply a miniature version of an adult.[36,80,84–86] Assessing pulmonary function longitudinally during a period of rapid growth and development in children/adolescents cannot be extrapolated from studies conducted on adults.[4,80] Therefore, interpreting decline in children/adolescents must consider the complexity of pulmonary function during this stage of life.[87] In 2020, a conditional change score (CCS) was developed to assess decline in pulmonary function in children/adolescents.[87] The CCS takes into account longitudinal changes in the z-score of FEV_1 using a specific formula detailed in Box 3. An Excel that facilitates the calculation and the interpretation of the CCS is available[88] (https://onlinelibrary.wiley.com/doi/10.1002/ppul.26637). The CCS is a promising tool for assessing decline in pulmonary function in children/adolescents, but further studies are needed to evaluate its relevance.[88]

The GLI has developed an online PFT tracker (LUNGTRACKER.V1.1), a tool freely available at https://gli-calculator.ersnet.org/lung_tracker/. This tool is designed to monitor/visualize changes in PFT over time in both children/adolescents and adults.[89] Physicians and researchers can enter individual-level data as age, height, sex, ethnicity and spirometry measures (FEV_1 and FVC) or upload an excel file. The tool returns pulmonary function level and potential change (if repeated data are entered) along with individual-level reference curves. FEV_1 and FVC can be mapped and plotted for any age across the life-course (4–90 years).[89]

The ERS/ATS update[4] does not address the use of additional parameters, such as FEV_1, FVC and DLCO, for monitoring pulmonary function over time.[13] Historically, the values of these parameters and their temporal changes have been critical for guiding treatment decisions, making advanced referrals, and including individuals in clinical trials.[13] The 2005 ERS/ATS guidelines[5] draw attention to the importance of significant changes in FEV_1, FVC, MMEF, and DLCO, which should alert healthcare providers to substantial changes in pulmonary function within the relevant clinical context. According to Rurak and Schotland,[13] the omission of these parameters raises the question of whether they should no longer be monitored, or if the significant changes reported in the 2005 ERS/ATS guidelines[5] remain the standard. The 2005 ERS/ATS guidelines[5] also pointed out that tracking too many indices simultaneously increases the risk of false-positive indications of change.[13] Was the decision to focus solely on FEV_1Q for monitoring changes intended to reduce the risk of false positives and simplify the process?[13] If so, there is concern that this approach may lead to the opposite effect, with many clinicians continuing to use varied standards.[13]

Challenges in interpreting the ERS/ATS update

Even years after the publication of the ERS/ATS update,[4] there are still a number of issues that pose uncertainty and require clarification.[8] ERS/ATS interpretation update was to encourage the recognition of uncertainty in the application

Box 3. Conditional change score (CCS) for the forced expiratory volume in 1 s (FEV_1) and examples of interpretation.

CCS formula and normal range		
CCS = $[FEV_1\ Z\ at\ T_2 - (r \times FEV_1\ Z\ at\ T_1)] / \sqrt{1 - r^2}$	R = $0.642 - 0.04 \times$ Period between the 2 visits (Y) $+ 0.020 \times$ Age at T_1 (Y).	CCS normal range $-1.96 \le CCS \le +1.96$
Examples of interpretation		
Example 1	Example 2	Interpretation
Sex: Girl Age at T_1: 10.00 FEV_1 Z at T_1 = −0.50 FEV_1 Z at T_2 = −1.50 Period between the 2 visits: 7 years (r = 0.562) **CCS = −1.47**	Sex: Boy Age at T_1: 11.5 FEV_1 Z at T_1 = +0.60 FEV_1 Z at T_2 = −1.40 Period between the 2 visits: 3 years (r = 0.752) **CCS = -2.81**	In both examples, both FEV_1 were diminished but remain in the normal range (Z > −1.645). **Example 1**: normal decline (ccs inside the normal range). **Example 2**: accelerated decline (CCS outside the normal range).

T: time; **T_1**: first visit; **T_2**: second visit; **Y**: year; **Z**: z-score.

Box 4. Six challenges in interpreting the ERS/ATS-2022 update.[4]

N°	Issue	Definition	Ambiguity	Suggestion
1.	NOAS	Either FEV_1 or FVC or both are low (*ie*; Z <−1.645) while the FEV_1/FVC ratio remains normal (*ie*; Z ≥−1.645) Prevalence: 30% (general population)[91] to 45.5% (symptomatic individuals)[92]	There is substantial variation in how NOAS is interpreted NOAS patterns, restrictive spirometry and preserved ratio impaired spirometry may not be the same entities	.Identification of 3 impairments by considering both abnormal FEV_1 and FVC in interpretation, as follows[17]: NOAS due to (i) Isolated low flow (FEV_1), which may indicate early OVI or suboptimal effort. (ii) Isolated low volume (FVC), which may represent early RVI or suboptimal effort; and (iii) Both low flow and volume, likely due to RVI or OVI with air trapping or suboptimal effort.
2.	ILFSI	Low FEV_1 (*ie*; Z <−1.645) with normal FVC and FEV_1/FVC ratio (*ie*; both Z >−1.645) Prevalence: 2%–9% (adults),[66,93,94] 2.15% (children)[8]	ERS/ATS-2022[4]: ILFSI is a normal pattern Some authors[7]: ILFSI is a key to pinpointing patients who could benefit from tailored treatment approaches	Integrate ILFSI into future updates[4]
3.	OVI severity	Determined by the FEV_1 Z	While the FEV_1/FVC Z is utilized to diagnose OVI, its severity is determined by the FEV_1 Z.[4] This contrasts with the approach used for both the diagnosis and classification of RVIs (based on TLC) and DLCO impairments (based on DLCO)[4]	Future studies comparing both criteria of OVI severity classification (*eg*; FEV_1 Z vs. FEV_1/FVC Z) are needed.
4.	RVI severity	Which parameter to use for classifying RVI severity?	ERS/ATS-2022[4]: No recommendations on which parameter to use for classifying RVI severity ERS/ATS-2005 guideline[5]: FEV_1% pred was used to classify the severity of both OVI and RVI ERS/ATS-2022,[4] it is unclear whether FEV_1 is still valid for severity classification in the case of RVI If FEV_1 z-score is retained: how to classify RVI severity when FEV_1 is normal	Classify the severity of RVI based on TLC Z. If the FEV_1 Z is preserved (*ie*; FEV_1 Z >−1.645), this situation possibly reflects an increase of lung elastic recoil
5.	MVI severity	The choice of parameter(s) for classifying MVI severity is uncertain	Should we prioritize TLC or FEV_1?	Evaluate the validity/contribution of the FEV_1/TLC Z Create norms for FEV_1/TLC ratio
6.	LH diagnosis and severity	High Z of RV/TLC and/or FRC/TLC[4]	LH definition: discrepancy between Table 7 (RV/TLC and FRC/TLC) and Figure 11 (RV/TLC or FRC/TLC) of the ERS/ATS-2022[4] No available Z for FRC/TLC FRC/TLC cannot be used to diagnose LH[25] No severity classification for LH	Establish norms for FRC/TLC Propose a severity classification for LH

ATS: American thoracic society; **DLCO**: carbon monoxide diffusion capacity; **ERS**: European respiratory society; **FEV_1**: forced expiratory volume in 1 s; **FRC**: functional residual capacity; **FVC**: forced vital capacity; **ILFSI**: isolated low FEV_1 spirometric impairment; **LH**: lung hyperinflation; **MVI**: mixed ventilatory impairment; **NOAS**: non-obstructive abnormal spirometry; **OVI**: obstructive ventilatory impairment; **RV**: residual volume; **RVI**: restrictive ventilatory impairment; **TLC**: total lung capacity; **Z**: z-score.

of PFT data.[4] In a 2024 editorial,[11] some of the primary authors of the ERS/ATS update[4] stated that "understanding the inherent uncertainty of PFT interpretation and incorporating the uncertainty into making clinical decisions is an important step forward."

For instance, in even the most straightforward cases of OVI, there will be healthy individuals who have a low FEV_1/FVC ratio (i.e.; z-score <-1.645), similar to 5% of the healthy reference population.[4,90] Conversely, there will be many individuals with early-stage disease who still maintain a normal ratio (i.e.; z-score ≥ -1.645).[4,90] While, the z-score reflects whether an individual's value stands relative to the reference population, the diagnostic algorithms often force us into binary 'yes/no' decisions at the boundaries of these ranges.[12] Is it time to abandon binary interpretation of PFT data?[12] A more practical and necessary shift in practice could involve moving away from a binary interpretation of PFT data.[12] One proposed change in practice, advanced by Haynes,[12] involves implementing a three-tier system for data classification: abnormal (e.g.; z-score <-2.0), borderline (e.g.; $-2.0 \leq$ z-score ≤ -1.3), and normal (e.g.; z-score >-1.3 (10th percentile)). Instead, clinicians/physicians should integrate uncertainty directly into an interpretation strategy that is usable by both human interpreters and computer software.[12] In addition, when dealing with more atypical patterns (e.g.; NSP, PRISm, non-obstructive abnormal spirometry, isolated low FEV_1 spirometric impairment), physiological values can be compared to the normal range, but the uncertainty in interpretation increases significantly. This uncertainty should be explicitly acknowledged in the final report.[12]

Box 4 briefly exposes the following six practical challenging situations, which contributed to confusion among clinicians/researchers:

(i) Non-obstructive abnormal spirometry: Low FEV_1 or FVC or both with normal FEV_1/FVC ratio.[17,91,92]
(ii) Isolated low FEV_1 spirometric impairment: Low FEV_1 with normal FVC and FEV_1/FVC ratio.[4,7,66,93,94]
(iii) OVI' severity and place of SLVs: First, while the FEV_1/FVC z-score is utilized to diagnose OVI, its severity is determined by the FEV_1 z-score.[4] There is a suggestion to use FEV_1/FVC for classifying OVI severity.[10,95] In addition, future studies comparing both criteria of OVI severity classification (e.g.; FEV_1 z-score vs FEV_1/FVC z-score) are needed. Second, in their Table 7, the ERS-ATS[4] reported that RV is high during OVI. This is questionable since one previous study including 281 COPD (i.e.; FEV_1/FVC post-bronchodilator <0.70) heavy smokers of more than 40 pack/years reported that 25 patients (9%) had normal RV.[96] In the ERS/ATS-2005[5] guideline (*page 958*), we noted the following vague sentence "Finally, the reported increase in RV in obstruction is deemed to be a marker of airway closure.[97,98]"
(iv) RVI' severity: While, ERS/ATS specifies that RVI should be considered in the presence of a low TLC[4]; it does not provide recommendations on which parameter to use for classifying its severity.
(v) MVI' severity: The choice of parameter(s) for classifying MVI severity is uncertain. Should we prioritize TLC or FEV_1?
(vi) LH' diagnosis and severity: First, it is important to note that the LH definition advanced by the ERS/ATS update[4] is ambiguous. While in their Table 7,[4] LH is defined by high FRC/TLC and RV/TLC, in their Figure 10,[4] it is defined by high FRC/TLC or RV/TLC. Second, no z-scores are available for FRC/TLC. Third, no severity classification for LH was proposed. Given the ongoing debate surrounding the use of different scales for OVI, particularly when extensive population data is available, it is understandable that the ERS/ATS update[4] chose not to recommend severity scales for less common patterns such as LH.

The future of interpreting pulmonary function tests

With the advancements in artificial intelligence, one study has evaluated its diagnostic performance in interpreting PFTs.[99] This study demonstrated that artificial intelligence significantly surpasses human capabilities, especially when the clinician lacks experience.[99] However, it is also evident that collaboration between the physician and artificial intelligence can significantly enhance the interpretation of PFTs.[99]

One of the most significant challenges in standardizing the interpretation of PFTs lies in the persistent divide between the 'epidemiological population-based' and the 'clinical' patient-centered' approaches.[9] While technical standards are always beneficial,[4] their recommendations should be considered within the context of an n-of-1 trial.[9] Given the scarcity of large-scale prospective studies on PFT interpretation, a busy clinician is less likely to make errors when using a Bayesian approach to assess the probability of a suspected abnormality,[9] incorporating additional clinical information.[55]

Conclusion

This review is a comprehensive framework for interpreting PFTs, incorporating the latest ERS/ATS update.[4] PFTs are vital for diagnosing and monitoring chronic respiratory diseases. The GLI standards, which consider individual characteristics and ethnic origin, have significantly advanced PFTs. They provide a comprehensive view of an individual's lung function, aiding in early and reliable

diagnosis. Since some issues pose uncertainty in clinical practice,[100] it would be beneficial to the ERS/ATS[4] to reconcile some inconsistencies and provide clearer guidance on different classifications and VIs.

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Appendix

Abbreviations' list

ATS	American thoracic society
CCS	Conditional change score

COPD	Chronic obstructive pulmonary disease
DLCO	Diffusing capacity of the lungs for carbon monoxide
ERS	European respiratory society
FEV_1	Forced expiratory volume in 1 s
FEV_1Q	FEV_1 quotient
FRC	Functional residual capacity
FVC	Forced vital capacity
GLI	Global lung function initiative
GOLD	Global initiative for chronic obstructive lung disease
ILD	Interstitial lung diseases
KCO	Carbon monoxide transfer coefficient
LH	Lung hyperinflation
LLN	Lower limit of normal
MMEF	Maximal mid-expiratory flow
MVI	Mixed ventilatory impairment
NSP	Non-specific pattern
OVI	Obstructive ventilatory impairment
PFTs	Pulmonary function tests
PRISm	Preserved ratio impaired spirometry
RV	Residual volume
RVI	Restrictive ventilatory impairment
SLV	Static lung volume
TLC	Total lung capacity
VA	Alveolar volume
VI	Ventilatory impairment
%pred	Percentage of predicted value