PFTS: DIGGING THROUGH THE INTERPRETATION WEEDS

Rena Laliberte BS, RRT, CPFT –
Clinical Education Specialist
Henry Ford Hospital Detroit, Michigan

1

OBJECTIVES

Examine various lung function tests (As of 2005 ATS Criteria)

Discuss interpretation strategies (Spirometry and DLCO)

Review ATS test criteria NEW 2019 UPDATES

2

THE TESTS – VITAL CAPACITY

Vital capacity is the volume of gas measured from a slow complete expiration after a maximal inspiration without forced or rapid effort.

Vital capacity is also called slow vital capacity to distinguish it from the forced vital capacity.

Inspiratory capacity and expiratory reserve volume are portions of the vital capacity

Inspiratory capacity is the largest volume of gas that can be inspired from from the resting expiratory level

3

VITAL CAPACITY

Inspiratory capacity is further divided into the tidal volume and inspiratory reserve volume

Expiratory reserve volume is the largest volume of gas that can be expired from the resting end-expiratory level.

The ATS describes this as the volume change between TLC and RV

4

VITAL CAPACITY

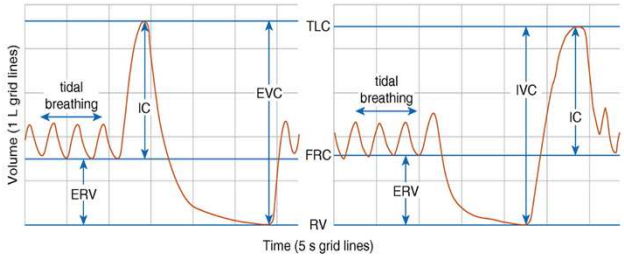


Figure 4. Measurement of VC and IC. VC may be measured either as EVC (left panel) or IVC (right panel). In these examples, divisions on the volume axis are 1 L, and those on the time axis are 5 seconds. ERV = expiratory reserve volume; EVC = expiratory VC; IC = inspiratory capacity; IVC = inspiratory VC; RV = residual volume.

Am J Respir Crit Care Med, 2019
https://www.atsjournals.org/doi/abs/10.1164/rccm.201908-1590ST

5

VITAL CAPACITY – THE TECHNIQUE

Vital capacity is having the patient tidal breath and then inspire maximally and expire maximally – vital capacity can also be measured from a maximal expiration to a maximal inspiration.

The spirometer does not need to produce a graphic display if only the VC is to be measured – if the subdivisions of vital capacity are desired recording of the volume change is required

6

VITAL CAPACITY CRITERIA FOR ACCEPTABILITY

1. End expiratory volume varies by less than 100 mL for the three preceding breaths.
2. Volume plateau observed at maximal inspiration and expiration
3. Two acceptable maneuvers should be obtained; volumes within 200 mL
4. VC should be withing 200 mL of FVC (if part of more complete testing)

7

STRATEGIES FOR INTERPRETATION

1. Was the test performed acceptably and is it reproducible ?

2. Are the reference values correct? Age, Sex, Height, *Race

3. Is the vital capacity less than predicted? If so to what extent? Is it less than the lower limits of normal?

4. How does the VC relate to the clinical question being answered? Is the VC correlated to the history and physical findings?

5. Are additional tests indicated? Lung volumes? FVC? Respiratory muscle strength? (MIP/MEP-NIF)

8

FORCED VITAL CAPACITY

FVC is the maximal amount of gas that can be expired when the patient exhales as forcefully and rapidly as possible after a maximal inspiration.

A similar maneuver beginning at maximal expiration and inspiring as forcefully as possible is called a Forced Inspiratory Vital Capacity or FIVC

The FVC and the FIVC are often performed in sequence to provide a continuous flow volume loop

9

FVC- FORCED VITAL CAPACITY, FORCED EXPIRATORY VOLUME AND FORCED EXPIRATORY FLOW

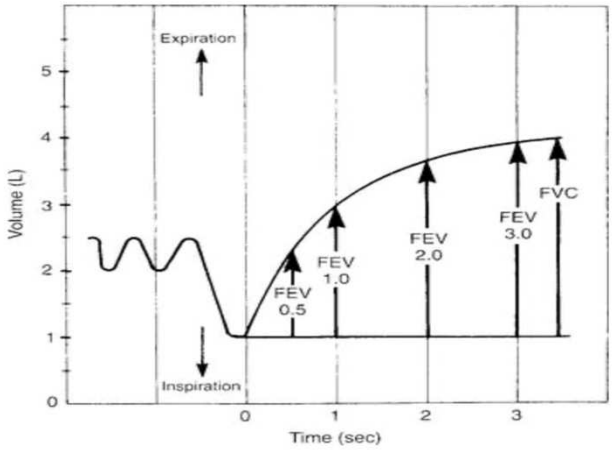
FORCED EXPIRATORY VOLUME IS THE VOLUME OF GAS EXPIRED OVER A GIVEN TIME PERIOD

THE TIME INTERVAL IS STATED AS THE SUBSCRIPT IN THE FEV – THE FEV1 IS THE MOST WIDELY USED.

THE MOST COMMONLY USED RATIO (FEV/FVC) IS THE FEV1/FVC

10

FORCED VITAL CAPACITY



11

FVC THE TECHNIQUE

Have the patient take a few tidal breaths, then instruct them to inspire maximally and as quickly as possible then expire as forcefully and rapidly as possible – there should be no pause between the maximal inspiration and forced expiration

This technique is for FEV over time plot – which differs from a flow volume loop.

12

ATS CRITERIA FOR ACCEPTABILITY (FVC MANEUVER)

Maximal effort: no cough or glottic closure during the first second; no leaks or obstruction of the mouthpiece

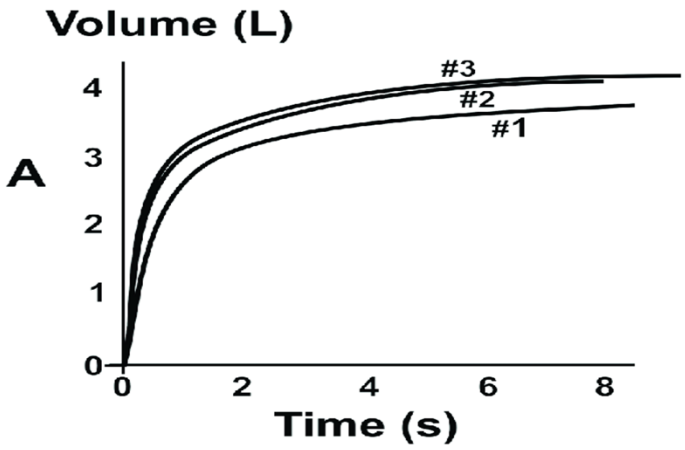
Good start of test; back-extrapolated volume less than 5% of FVC or 150mL

Tracing shows 6 seconds of exhalation or an obvious plateau; no early termination or cut off; or patient cannot continue or should not continue to exhale

Three acceptable efforts should be obtained; two largest FVC values within 200mL ; two largest FEV1 values within 200mL

13

3 ACCEPTABLE FVC EFFORTS



14

FLOW VOLUME LOOPS (CURVES)

The Flow Volume Loops generated during an FVC maneuver graphs flow against volume changes

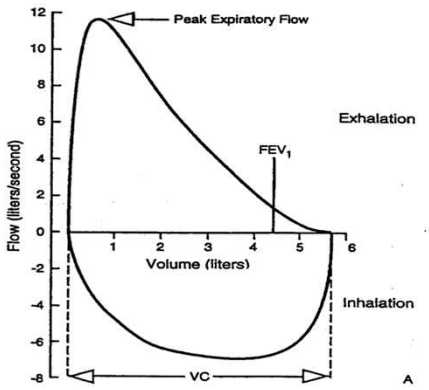
The maximal expiratory flow volume (MEFV) loop shows the patient as they exhale from maximal inspiration (TLC) to maximal expiration (RV)

The maximal inspiratory flow (MIFV) displays inspiratory flow plotted from RV to TLC

When MEFV and MIFV curves are plotted together- the result is the flow volume loop.

15

FLOW-VOLUME LOOP



The graph represents a classic example of a flow volume loop

16

FLOW VOLUME LOOP THE TECHNIQUE

The patient patient performs 3-4 tidal breaths then inspires quickly and as fully as possible. They must exhale as rapidly as possible after maximal inspiration for at least 6-8 seconds or until a visible plateau is reached. The patient must then inspire as rapidly as possible back to maximal inspiration from maximal expiration to "close the loop"

17

ATS ACCEPTABILITY CRITERIA FOR THE FLOW VOLUME LOOP

Rapid rise from maximal inspiration to PEF

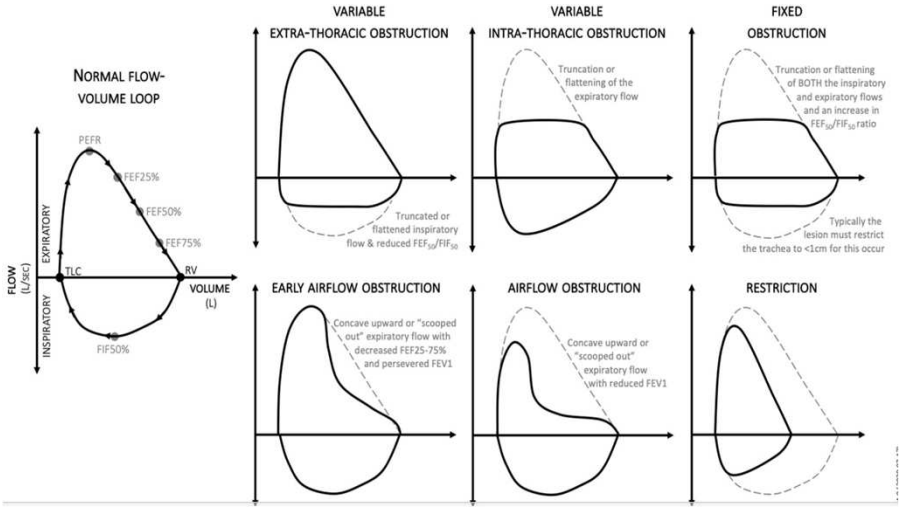
Maximal effort until flow returns to zero baseline; no glottic closure or abrupt end of flow

Maximal inspiratory effort with return of volume to point of maximal inspiration (failure to close loop indicates that effort was not started from maximal inspiration, inspiratory effort was submaximal, or spirometer error)

At least three acceptable loops recorded, superimposed or side by side loops should be reproducible, unless bronchospasm occurs (no more than 8 attempts should be made)

18

INTERPRETIVE STRATEGIES FVC MANEUVER



19

INTERPRETIVE STRATEGIES –FVC MANEUVER

1. Were there at least 3 acceptable efforts performed? Are the FVC and FEV1 reproducible with 150mL (2019 update)

2. Are reference values appropriate? Age? Sex? Height? Race?

3. Is FEV1% less than predicted? If so, obstruction is present
   A. is FVC also reduced? If so, is it caused by obstruction or restriction?
   B. If FVC is less than 80% lung volumes may be indicated
   C. Is the obstruction reversible? Bronchodilators may be indicated

20

INTERPRETATIVE STRATEGIES – FVC MANEUVER

4. Is the FEV1% equal to or greater than expected?

A. Are FVC and FEV1 both reduced proportionately? If so, restriction may be present; lung volumes may be indicated.

B. Are FVC and FEV1 within normal limits? If so spirometry is likely normal.

5. IS FEF25-75% LESS THAN 65% OF PREDICTED? IS FEV1% OR FEV1 BORDERLINE NORMAL? IF SO, AIRWAY OBSTRUCTION MAY BE PRESENT

6. ARE THE SPIROMETRY FINDINGS CONSISTENT WITH THE PATIENT HISTORY AND PHYSICAL FINDINGS? IS BRONCHIAL PROVACATION TESTING INDICATED TO REVEAL OBSTRUCTION? IS EXERCISE TESTING INDICATED TO REVEAL OBSTRUCTION?

21

DLCO- DIFFUSING CAPACITY FOR CARBON MONOXIDE

Diffusing Capacity is measured (in the lungs) by using small volumes of carbon monoxide and is referred to as DLco.

DLco is used to assess the gas exchange ability of the lungs, specifically oxygenation of mixed venous blood.

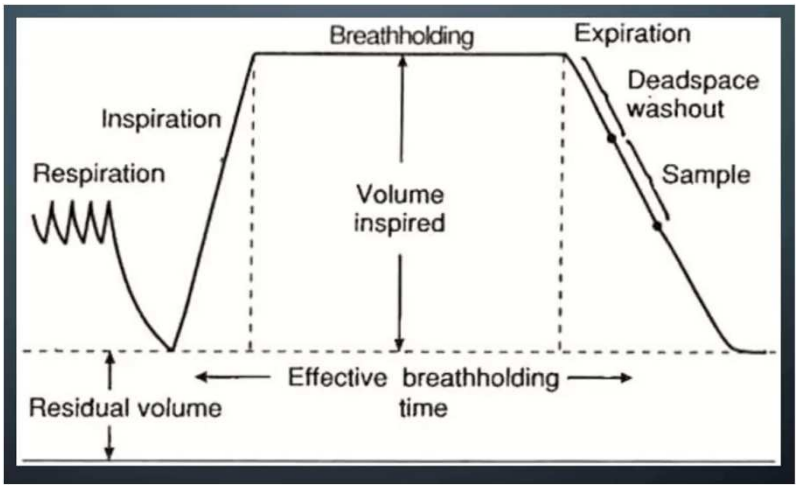
There are a number of different methods that are used, but by far the most common method is the single breath technique.

Carbon Monoxide combines with Hb approximately 210X more readily than oxygen.

In the presence of normal amount of Hb and normal ventilatory function, the primary limiting factor is the status of the alveolocapillary membrane

22

DLCO – SINGLE BREATH



23

ATS ACCEPTABILITY CRITERIA FOR DLCO

Volume time tracing should show a smooth, rapid inspiration from RV to TLC.

Inspiration should be rapid but not forced; less than 2.5 seconds in healthy subjects and less than 4 seconds in patients with a known obstruction

Dead space washout should be 0.75-1.00L (0.5L if the VC is less than 2.0L) If continuous analysis of expired gas is used visual inspection of dead space washout should be made.

Alveolar volume should be 0.5- 1.0L unless continuous analysis is used.

The Vi should be at least 90% of the previously recorded best VC.

Breath hold time should be within 9 to 11 seconds, using Jones Method (single breath)

The average of two or more acceptable tests should be reported. Duplicate determinations should be within 10% of 3ml CO/min/mmHg.

24

DLCO-SINGLE BREATH- THE TECHNIQUE

The patient is instructed to place their mouth on the mouth piece in which there is a demand valve for the CO

The patient tidal breaths until stabilization is detected, then the patient is asked to exhale to RV or plateau (not with force)

At RV the patient is instructed to inspire rapidly to TLC (from RV) and hold their breath for at least 10 seconds.

At the end of the breath hold time the patient should then exhale normally and remove mouth from mouthpiece when instructed-

There is a 4 minute time interval between each effort, which allows for washout.

25

INTERPRETIVE STRATEGIES- DLCO- SINGLE BREATH

1. WERE THE TEST MANUEVERS PERFORMED ACCEPTABLY? WHERE THE TESTS REPRODUCIBLE WITHIN 10% OR 3ML CO/MIN/MMHG OF THE MEAN?

2. WERE ALL THE APPROPRIATE CORRECTIONS MADE? HB? COHB? ALTITUDE?

3. ARE REFERENCE VALUES APPROPRIATE? AGE? SEX? HEIGHT? WEIGHT?

4. IS THE DLCO LESS THAN THE LOWER LIMITS OF NORMAL? IF NOT EXPLAINED BY ABNORMAL HB OR COHB, CHECK DL/VA (SPECIFIC DIFFUSION PER UNIT OF LUNG VOLUME)

5. IS THE DL/VA RATIO WITHIN NORMAL LIMITS? IF SO, SUSPECT REDUCED DIFFUSING CAPACITY RELATED TO DECREASED LUNG VOLUMES OR PARENCHYMAL CHANGES- CONSIDER CLINICAL CORRELATION

26

INTERPRETITIVE STRATEGIES-DLCO-SINGLE BREATH

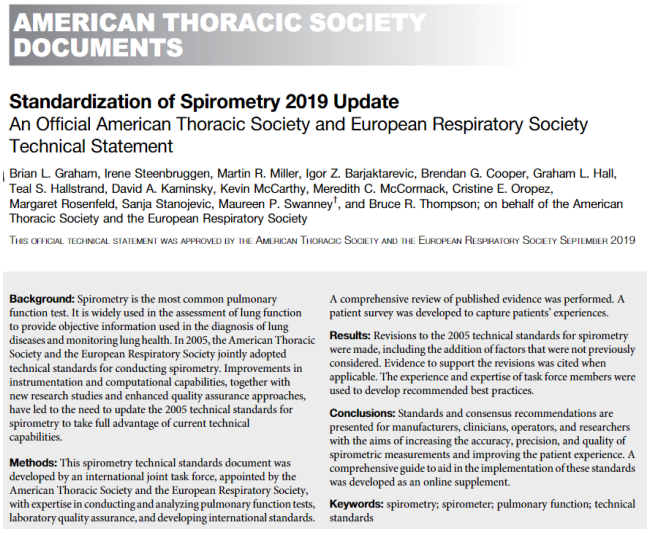
6. IS THE DL/VA RATION REDUCED? IF SO, SUSPECT REDUCED DIFFUSING CAPACTIY RELATED TO OBSTRUCTION OF INCREASED DEAD SPACE. LOOK FOR CLINICAL CORRELATION

7. IS DLCO INCREASED? IF NOT EXPLAINED BY ABNORMAL HB, CONSIDER INCREASED PULMONARY BLOOD VOLUME OR HEMORRHAGE. LOOK FOR CLINICAL CORRELATION

8. IS THE DLCO LESS THAN 50% OF PREDICATED? IF SO, CONSIDER ADDITIONAL TESTS (BLOOD GASES, EXERCISE DESATURATION STUDY.)

27

2019 UPDATE ATS/ERS



AMERICAN THORACIC SOCIETY DOCUMENTS

Standardization of Spirometry 2019 Update
An Official American Thoracic Society and European Respiratory Society Technical Statement

Brian L. Graham, Irene Steenbruggen, Martin R. Miller, Igor Z. Barjaktarevic, Brendan G. Cooper, Graham L. Hall, Teal S. Hallstrand, David A. Kaminsky, Kevin McCarthy, Meredith C. McCormack, Cristine E. Oropez, Margaret Rosenfeld, Sanja Stanojevic, Maureen P. Swanney[†], and Bruce R. Thompson; on behalf of the American Thoracic Society and the European Respiratory Society

THIS OFFICIAL TECHNICAL STATEMENT WAS APPROVED BY THE AMERICAN THORACIC SOCIETY AND THE EUROPEAN RESPIRATORY SOCIETY SEPTEMBER 2019

Background: Spirometry is the most common pulmonary function test. It is widely used in the assessment of lung function to provide objective information used in the diagnosis of lung diseases and monitoring lung health. In 2005, the American Thoracic Society and the European Respiratory Society jointly adopted technical standards for conducting spirometry. Improvements in instrumentation and computational capabilities, together with new research studies and enhanced quality assurance approaches, have led to the need to update the 2005 technical standards for spirometry to take full advantage of current technical capabilities.

Methods: This spirometry technical standards document was developed by an international joint task force, appointed by the American Thoracic Society and the European Respiratory Society, with expertise in conducting and analyzing pulmonary function tests, laboratory quality assurance, and developing international standards. A comprehensive review of published evidence was performed. A patient survey was developed to capture patients' experiences.

Results: Revisions to the 2005 technical standards for spirometry were made, including the addition of factors that were not previously considered. Evidence to support the revisions was cited when applicable. The experience and expertise of task force members were used to develop recommended best practices.

Conclusions: Standards and consensus recommendations are presented for manufacturers, clinicians, operators, and researchers with the aims of increasing the accuracy, precision, and quality of spirometric measurements and improving the patient experience. A comprehensive guide to aid in the implementation of these standards was developed as an online supplement.

Keywords: spirometry; spirometer; pulmonary function; technical standards

28

ATS/ERS STANDARDIZATION OF SPIROMETRY 2019 UPDATE

Background:

The ATS and ERS jointly adopted technical standards for conducting spirometry. Improvements is instrumentation and computational capabilities, together with new research studies, enhanced quality assurance approaches led for a need to update the 2005 technical standards for spirometry to take full advantage of current technical capabilities.

29

KEY UPDATES !

New list of Relative Contraindications

Spirometers are required to meet International Organization Standardization (ISO) 26782 standards but with a max. permissible accuracy error of $\pm$ 2.5%

Device quality assurance procedures were updated

*Operator training as well as attainment and maintenance of competency were addressed

*The list of activities the patient should avoid before testing was updated

*There is a focus of the use of devices that measure both expiration and inspiration

*Maneuver acceptability and repeatability criteria were updated. The end of forced expiration (EOFE) was redefined

30

KEY UPDATES!

Requirements for spirometer systems to provide uniform cues and feedback to the operator were added

New withholding times for bronchodilators before bronchodilator responsiveness testing were developed

A new grading system for assessment of spirometry quality was developed

*Standardized operator feedback options that promote synoptic reporting were developed

Preliminary findings derived from an international patient survey were presented

31

KEY UPDATES- OPERATOR DETAILS

Ruppel and Enright observed, "There are three key elements to obtain high quality pulmonary function data: accurate and precise instrumentation, a patient capable of performing acceptable and repeatable measurements, and a motivated technologist to elicit maximum performance from the patient.

Training courses for conducting quality spirometry testing are available in many countries, which has led operators to follow ATS/ERS standards, but the recommendation is for short term and follow-up supplementary training to maintain quality- and should be integrated in offices performing spirometry testing

32

KEY UPDATES: PATIENT ACTIVITIES

Smoking and/or vaping and/or water pipe use within 1h before testing

Consuming intoxicants within 8 hours before testing

Performing vigorous exercise within 1h before testing

Wearing clothing that substantially restricts full chest and abdominal expansion

33

KEY UPDATES: DEVICES THAT MEASURE BOTH INSPIRATION AND EXPIRATION

Most variability in results obtained from spirometry relates to inadequate and variable inspiration to TLC, ending the expiration prematurely and variable effort.

The operator must demonstrate the appropriate technique and follow the procedures described in Table 6-

(next slide)

34

KEY UPDATES – TABLE 6

Table 6. Procedures for FVC Maneuvers

Wash hands* (or use an approved hand sanitizer)

Prepare the patient
- Dispense hand sanitizer for the patient
- Confirm patient identification, age, birth sex, ethnicity, etc.
- Measure weight and height without shoes
- Ask about activities listed in Table 5, medication use, and any relative contraindications flagged on the requisition; note respiratory symptoms

Instruct and demonstrate the test
- Position of the mouthpiece and noseclip
- Correct posture with head slightly elevated
- Inspire rapidly until completely full
- Expire with maximal effort until completely empty
- Inspire with maximal effort until completely full
- Confirm that patient understands the instructions and is willing to comply

Perform maneuver
- Have patient assume the correct posture
- Attach noseclip, place mouthpiece in mouth, and close lips around the mouthpiece
- Breathe normally
- Inspire completely and rapidly with a pause of ≈2 s at TLC
- Expire with maximal effort until no more air can be expelled while maintaining an upright posture
- Inspire with maximal effort until completely full
- Repeat instructions as necessary, coaching vigorously
- Repeat for a minimum of three maneuvers, usually no more than eight for adults
- Check FEV_1 and FVC repeatability and perform more maneuvers as necessary

Perform maneuver (expiration-only devices)
- Have patient assume the correct posture
- Attach noseclip
- Inspire completely and rapidly with a pause of ≈2 s at TLC
- Place mouthpiece in mouth and close lips around the mouthpiece
- Expire with maximal effort until no more air can be expelled while maintaining an upright posture
- Repeat instructions as necessary, coaching vigorously
- Repeat for a minimum of three maneuvers, usually no more than eight for adults
- Check FEV_1 and FVC repeatability and perform more maneuvers as necessary

*Additional steps may be required by local infection control policies. Using disposable gloves does not eliminate the need for hand washing or sanitizing, but if gloves are used, a new pair is required for each patient.

35

KEY UPDATES- ACCEPTABILITY, USABILITY, AND REPEATABILITY CRITERIA FOR FEV1 AND FVC

Table 7. Summary of Acceptability, Usability, and Repeatability Criteria for FEV_1 and FVC

Acceptability and Usability Criterion	Required for Acceptability		Required for Usability	
	FEV_1	FVC	FEV_1	FVC
Must have BEV ≤5% of FVC or 0.100 L, whichever is greater	Yes	Yes	Yes	Yes
Must have no evidence of a faulty zero-flow setting	Yes	Yes	Yes	Yes
Must have no cough in the first second of expiration*	Yes	No	Yes	No
Must have no glottic closure in the first second of expiration*	Yes	Yes	Yes	Yes
Must have no glottic closure after 1 s of expiration	No	Yes	No	No
Must achieve one of these three EOFE indicators:	No	Yes	No	No
1. Expiratory plateau (≤0.025 L in the last 1 s of expiration)				
2. Expiratory time ≥15 s				
3. FVC is within the repeatability tolerance of or is greater than the largest prior observed FVC†				
Must have no evidence of obstructed mouthpiece or spirometer	Yes	Yes	No	No
Must have no evidence of a leak	Yes	Yes	No	No
If the maximal inspiration after EOFE is greater than FVC, then FIVC − FVC must be ≤0.100 L or 5% of FVC, whichever is greater‡	Yes	Yes	No	No

Repeatability criteria (applied to acceptable FVC and FEV_1 values)

Age >6 yr: The difference between the two largest FVC values must be ≤0.150 L, and the difference between the two largest FEV_1 values must be ≤0.150 L

Age ≤6 yr: The difference between the two largest FVC values must be ≤0.100 L or 10% of the highest value, whichever is greater, and the difference between the two largest FEV_1 values must be ≤0.100 L or 10% of the highest value, whichever is greater

36

KEY UPDATES – OPERATOR FEEDBACK

The spirometry software must provide explicit feedback to the operator indicating FEV1 and FVC acceptability at the completion of each maneuver

Sample warning messages and suggested corrections are provided (in Section E8 of document)

The operator must have the ability to override the acceptability designation, because the operator may note a leak, a cough, inadequate inspiration or expiration or a faulty zero-flow that was not detected by the software

Records of all maneuvers with FEV1 and/or FVC that are acceptable or usable must be retained because, for some patients, their best performance may yield only usable data that does not meet acceptability criteria. Examples of acceptable and unacceptable volume time curves are provided. (in the document)

37

2023 ATS/ERS GLOBAL INITIATIVE ON ETHNICITY AND RACE IN PULMONARY FUNCTION

The Global Lung Function Initiative (GLI) average equation, published as GLI Global, is a recommended race-neutral average reference equation. There are important limitations and considerations to an implementation of GLI Global that we expect ongoing research to address:

GLI Global represents a weighted average of the data included in the original GLI ethnicity-specific equations. The self-identified, or researcher-allocated, racial or ethnic group was used to inform the sample weights, and many of the world's populations are still not included in this equation. Therefore, the GLI Global equation is a race composite and not truly race agnostic. "Race neutral" refers to the equations not requiring the selection of race for application.

As in the construction of other reference equations, the participants contributing data to GLI Global have a variety of exposures throughout life, despite meeting a limited definition of healthy. Therefore, GLI Global is not immune from norming the effects of modifiable risk factors for reduced pulmonary function.

38

CONCLUSION

Performance of acceptable and reproducible pulmonary diagnostic testing is critical in the diagnosis and treatment of pulmonary disease

A trained respiratory therapist plays a key role in not only engaging with and coaching the patient, but in the evaluation and performance of all forms of pulmonary function testing.

As technology changes and additional research is performed, we can anticipate additional changes and updates regarding testing and interpretation criteria for our diagnostic labs.

39

REFERENCES

Ruppel's Manual of Pulmonary Function Testing, 12th Edition, Carl Mottram, BA, RRT, RPFT, FAARC

Standardization of Spirometry 2019 Update. An Official American Thoracic Society and European Respiratory Society Technical Statement, https://www.atsjournals.org accessed 4/6/2024

Effect of Race and Ethnicity on Pulmonary ,Function Testing Interpretation :An American College of Chest Physicians (CHEST), American Association for Respiratory Care (AARC), American Thoracic Society (ATS), and Canadian Thoracic Society (CTS) Evidence Review and Research Statement Darcy D. Marciniuk, MD; Ellen A. Becker, PhD, et al. American College of Chest Physicians https://doi.org/10.1016/j.chest.2023.03.026 , accessed 4/6/2024

40

QUESTIONS?

41