Understanding A Less Commonly Used, But Important, Pulmonary Function Test: DLCO

Al Heuer, PhD, MBA, RRT-ACCS, RPFT, FAARC

Rutgers--School of Health Professions

Co-Owner A & T Lectures

Objectives

- Identify the steps for performing the single-breath DL_{CO} technique
- List the criteria for an acceptable single-breath DL_{CO} test
- Identify abnormal DL_{CO} values and its causes
- Evaluate D_L/V_A to distinguish between obstructive lung disease and restrictive lung disease as causes of decreases DLCO
- Compare diffusion limitation due to membranes and pulmonary capillary blood volume

Introduction

- Diffusion is defined as the flow of particles from an area of higher concentration to an area of lower concentration.
- Diffusing capacity (DL_{CO}) test provides information about the transfer of gas between the alveoli and the pulmonary capillary blood

Introduction (cont.)

- The measurement of DLCO can be performed using three general techniques
  - Steady state
  - Rebreathing
  - Single breath
- Single-breath technique is most common

Physiology, Terms and Definitions

- The two major gases involved in lung diffusion (O_2 and CO_2) must move through two barriers
  - The alveolar-capillary (A-C) membrane
  - The blood plasma-red blood cell barrier
- The rate of diffusion across these primarily liquid barriers is limited by
  - the surface area for diffusion
  - the distance the gas molecules must travel
  - the solubility coefficient of the gases in liquid
  - the partial pressure difference (gradient) between air and blood for each gas
  - the density of each gas

Physiology (cont.)

- CO is more suitable to measure diffusing capacity than other gases because:
  - It has a great affinity for Hb (210 times that of O_2)
  - It is soluble in blood
  - Its concentration in venous blood is insignificant
- The measurement of DL_{CO} involves the rate of consumption (uptake) of CO by the blood from the alveoli.

Conditions that Decrease DLCO

- Respiratory muscle weakness or deformity preventing maximal inflation
- Reduced Hb
- Pulmonary emboli
- Increased CO or inspired O_2 concentration
- Lung resection
- Emphysema
- Interstitial lung disease

Conditions that Increase DLCO

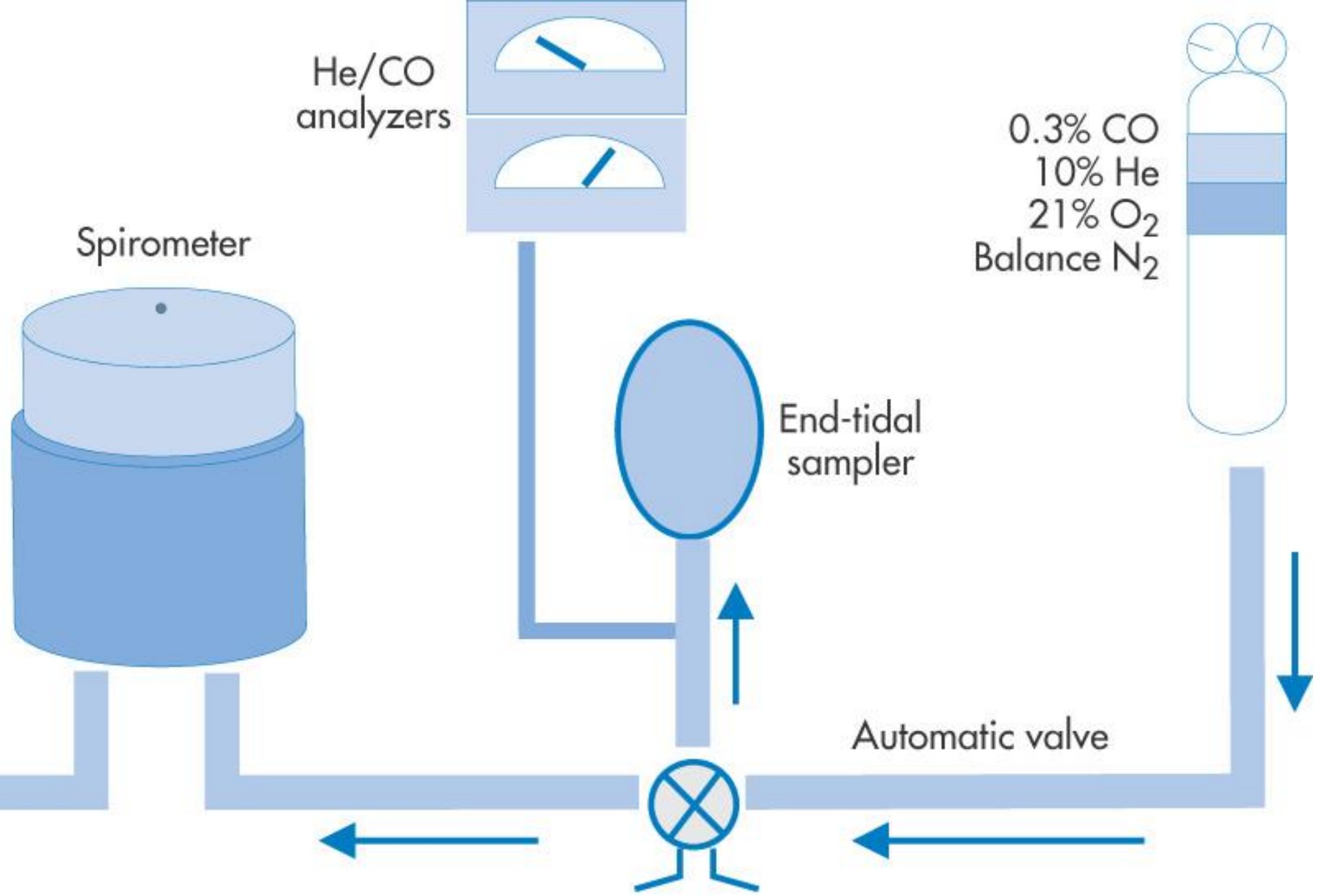
- Increased Hb (polycythemia)
- Decreased Intrathoracic pressure (resistance breathing)
- Exercise
- Asthma
- Supine position

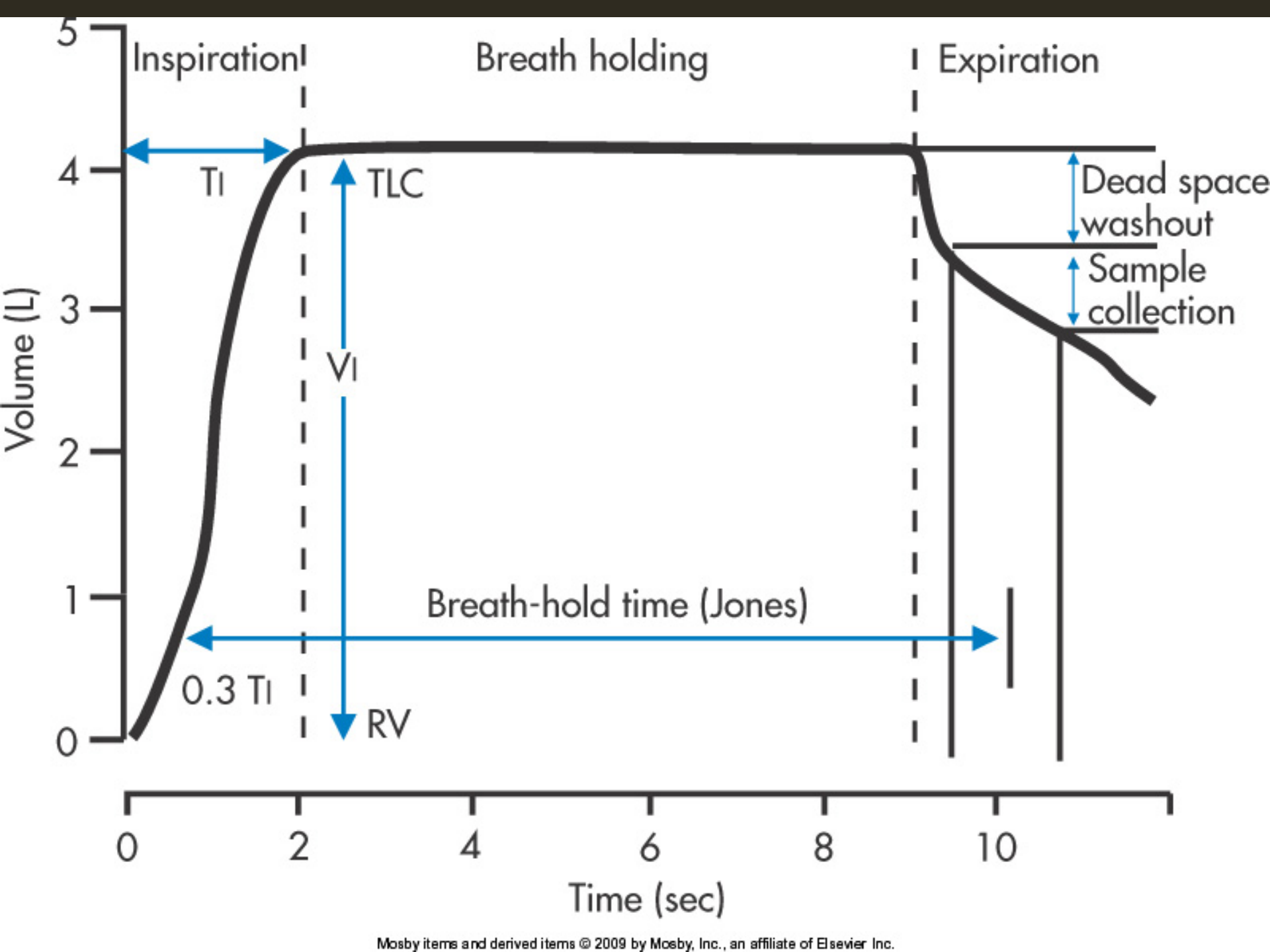
Instrumentation

- Gas analyzers for
  - CO
  - Tracer gas (e.g., He, neon, methane)
- Volume measurement device
  - Volume-displacement spirometer
  - Flow-sensing spirometer
- Gas analyzers must be zeroed and checked for linearity
- Volume measurement device must have calibration check

DLCOsb

- Most commonly done
- Sensitive to V/Q mismatch
- 10 sec breath hold required
- Gas mix: 0.3% CO, R/A, N_2
- 0.75 to 1 L discarded
- Corrections must be done for anatomic dead space (VD) & equipment dead space
- All gas volumes must be corrected from ATPS to BTPS





Testing Technique

- Patient preparation
  - Supplemental O_2 should be discontinued > 10 minutes before the test - if this is not appropriate, note the patient's O_2 use in the comments.
  - The patient should be seated for approximately 5 minutes before the test is performed to assure that the patient has had time to recover from any walking around or other testing. The patient should remain seated throughout the test.
  - Smoking should be stopped on the day of the test. The time of the last cigarette smoked should be recorded.

Testing Technique
Basic Maneuver

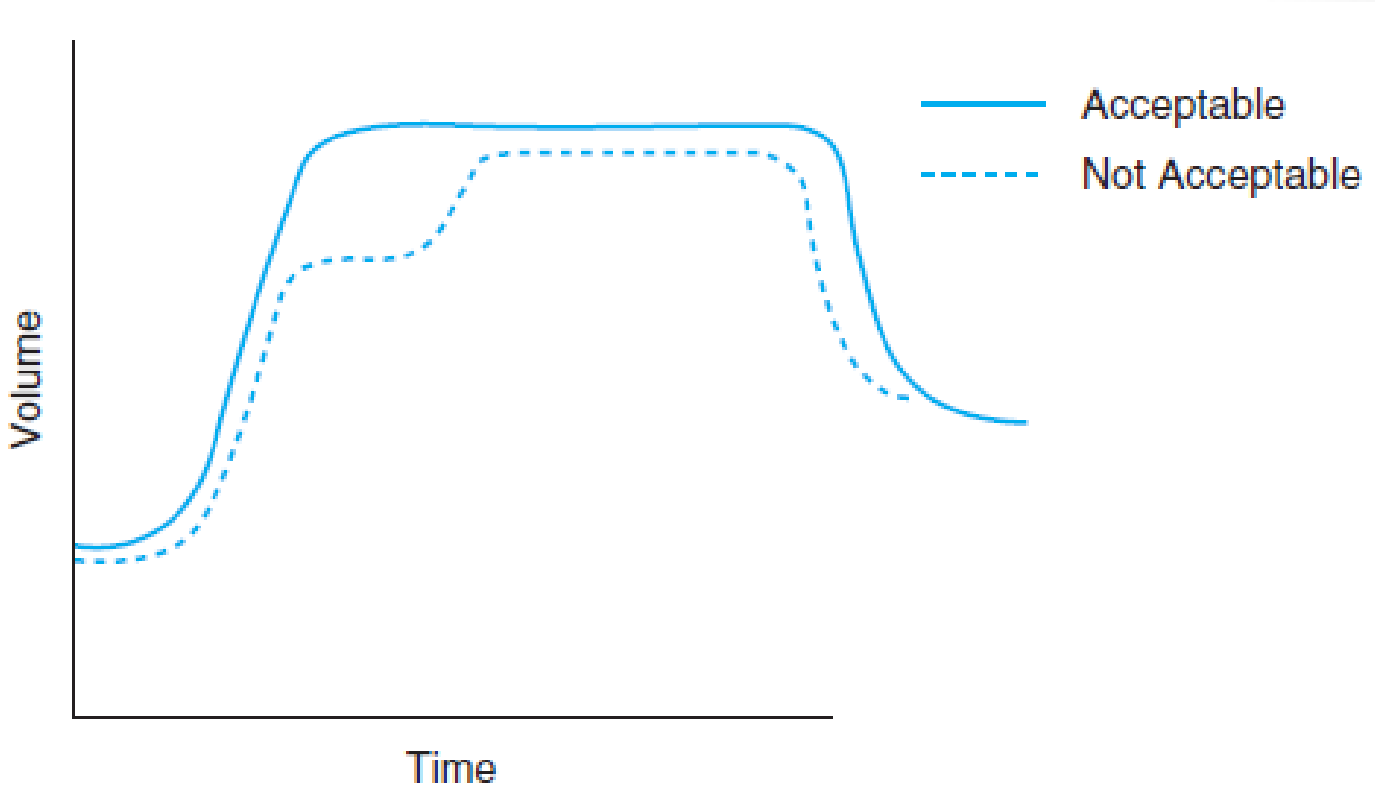
- Have patient
  - Attach to mouthpiece, apply nose clip and breathe normal tidal breaths
  - Slowly exhale to maximum expiratory level (i.e., RV).
  - Upon signal, quickly inhale the test gas to maximum inhalation level (i.e., TLC)
  - Hold the breath for approximately 10 seconds.
  - Exhale at a moderate speed

Testing Technique-Basic Maneuver (cont.)

- Have patient
  - Continue exhaling while a sample of exhaled gas (called alveolar gas sample) is collected
  - Come off the mouthpiece and remove the nose clip while the alveolar gas sample is analyzed
  - Repeat the procedure after waiting at least 4 minutes.

Testing Technique- Recommendations

- Inspiratory maneuver
  - 85% of the inspired volume should be inspired within 4 seconds. If longer times are needed, this should be noted.
  - The inspiratory volume should be from RV to TLC (i.e., an inspiratory vital capacity [IVC]).
  - The IVC at body temperature, ambient pressure, and saturated with water vapor (BTPS) conditions should be ≥ 85% of the largest previously measured VC at BTPS conditions
  - No stepwise changes should be made in inspiration
- Expiratory manuever
  - Exhalation must be smooth in ≤ 4 sec



Graphic illustration of an acceptable and unacceptable inspiratory maneuver. The unacceptable maneuver shows a pause in inspiration resulting in a step-like pattern. The inspirations should be rapid and performed in less than 4 seconds without a stepwise appearance.

Testing Technique-Recommendations

- Breath hold
  - Patient should not create excessive positive or negative intrathoracic pressures during the breath hold (i.e., keep intrathoracic pressure close to atmospheric levels)
    - Increases in intrathoracic pressure above atmospheric levels may decrease the DLCO value, and decreases in intrathoracic pressure below atmospheric levels may increase the DLCO value.
  - The breath hold must last 8 to 12 seconds.

Testing Technique- Recommendations

- Washout Volume
  - Washout volume is volume of gas that must be expired and discarded to clear anatomic and mechanical dead space before the alveolar sample is collected.
  - If the alveolar sample is contaminated with dead space gas, the resulting DLCO will likely be underestimated.
  - The washout volume should be 0.75 to 1.00 liter.
    - For patients with a VC < 2.00 liters, use a washout volume of 0.50 liter.

Testing Technique- Recommendations

- Alveolar Sample
  - An alveolar sample volume of 0.5 to 1.00 liter should be collected for analysis.
- Number of maneuvers and repeatability
  - Perform at least two acceptable maneuvers that agree within ± 10% or 3 mL/min/mmHg, whichever is larger.
  - More than five maneuvers is not recommended.

Testing Technique-Recommendations

- Reporting Values
  - The average of at least two acceptable maneuvers should be reported with outliers excluded
  - The report should always include
    - Unadjusted measured DLCO,
    - Adjusted DLCO (e.g., DLCO Hbcorr) if an adjustment is made,
    - Predicted and percent predicted DLCO,
    - Predicted and percent predicted DLCO /VA.
    - Including the lower limit of normal is also valuable.
  - If adjustments are made to the DLCO value (e.g., for Hb or COHb) the Hb or COHb value used for the adjustment should be reported.
  - The average VA should be reported.

Calculation Recommendations

- Inspired Volume (VI)
  - Instrument dead space (including filters) will vary and should be reported by the manufacturer and subtracted from VI.
  - Anatomic dead space (2.2 mL/kg of body weight) should also be subtracted from VI.
    - It seems reasonable to limit the anatomic dead space to 150 mL or to use an ideal body weight in overweight individuals.
    - Or, in obese patients use the following formula:

Anatomic dead space = 24 X height in inches X height in inches / 703

5ft 4in = 64 inches

= 24 (64)(64)/703

Anatomic dead space = 140

Calculation Recommendations

- Carboxyhemoglobin (COHb)
  - COHb levels of less than 2% from ordinary environmental exposures are already incorporated into reference values based on healthy nonsmoking individuals.
  - If an adjustment for increased levels of COHb is made, the recommendation is that DLCO be increased by approximately 1% for each 1% of COHb.
    - Predicted DLCO, corrected for COHb = Predicted DL,CO X (102% - COHb%)

Quality Control

- Gas analyzers daily zeroing
- Gas analyzers linearity check (every three months
- DLCO with 3-liter syringe
- Biological controls
- DLCO simulator

Quality Control

- DLCO Simulator

Figure 3-5: Hans Rudolph 5560 Series DL,CO simulator.

Source: Printed with permission from: Hans Rudolph, Inc.

DLCO Interpretation

- Normal value: 25 mL CO/min/mm Hg (STDP)
- It varies directly with the patient's lung volumes
- Increases during exercise
- Decrease in restrictive lung diseases and emphysema
- DLCO is directly related to lung volumes (V_A)
- Normal DL/V_A ratio is 4-5 mL CO

DLCO Interpretation (cont.)

- Increased DLCO values:
  - Increased pulmonary capillary blood volume
  - Exercise
  - Left-to-right intracardiac shunts
  - Left heart failure
  - Supine position
  - Polycythemia
  - Asthma

DLCO Interpretation (cont.)

- Decreased DLCO values
  - Caused by:
    - Small lung volume (e.g., lung resection)
    - Diffusion defects
  - Pulmonary fibrosis
  - Emphysema
  - Pulmonary vascular and cardiovascular diseases
  - Anemia
  - Renal failure
  - Marijuana and/or cigarette smoking

Take Home Points

- DLCO testing can be a valuable component of PFTs
- Should only be done when a index of suspicion exists for a disease state involving a diffusion defect.
  - Emphysema
  - Pulmonary Fibrosis
- Proper technique is the key to avoiding inaccurate results
- Results can be viewed as a single test or done in a series to trend disease progression.

Selected Sources & References

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