Single-Breath Carbon Monoxide Diffusing Capacity

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Introduction:

Single-breath diffusing capacity for carbon monoxide (DLCO-sb). This test is also sometimes referred to as the Transfer Factor for Carbon Monoxide. It reflects the ability of the lung to transfer gas across the alveolar / capillary interface.

Definition:

Diffusing capacity is a test in which the subject inspires a gas containing carbon monoxide and one or more tracer gases in order to determine the gas exchange capacity of the lungs. CO is used because:

- It is a non-physiological gas.
- It is readily absorbed by hemoglobin.
- Unlike oxygen, it does not diffuse in both ways, therefore it is easier to quantify.

Two different techniques can be used for this test. If the single-breath or breath-holding technique is used, you will take a breath of air containing a very small amount of carbon monoxide from a container while measurements are taken. In the steady-state technique, you will breathe air containing a very small amount of carbon monoxide from a container. The amount of carbon monoxide in your arterial blood will then measured. Diffusing capacity provides an estimate of how well a gas is able to move from your lungs into your blood.

Although several different methods of measuring DLCO have been described, the most commonly used technique is the single-breath maneuver or DLCO-sb. Many of these standards apply indirectly to other methods of measuring diffusing capacity:

- DLCO is usually expressed in mL CO min⁻¹ torr⁻¹ (STPD).
- The alveolar volume (VA) at which the DLCO-sb is measured is also commonly reported; the units for the VA are liters at body temperature and pressure, saturated with water vapor (BTPS).

- The ratio of DLCO to VA is also commonly reported as the DL/VA or simply D/VA. This is also known as KCO or Carbon monoxide transfer coefficient.

Indications:

Tests of diffusing capacity may be indicated in:

1. Evaluation and follow-up of parenchymal lung diseases including: Idiopathic pulmonary fibrosis and bronchiolitis obliterans organizing pneumonia, diseases associated with dusts such as asbestos, or drug reactions (amiodarone) or related to sarcoidosis; and for quantification of disability associated with interstitial lung disease.

2. Evaluation and follow-up of emphysema and cystic fibrosis; and differentiating among chronic bronchitis, emphysema, and asthma in patients with obstructive patterns; and for quantification of impairment and disability.

3. Evaluation of cardiovascular diseases (primary pulmonary hypertension, acute or recurrent thromboembolism, or pulmonary edema).


5. Evaluation of the effects of chemotherapy agents or other drugs (amiodarone, bleomycin) known to induce pulmonary dysfunction.


7. As an early indication of certain pulmonary infections (pneumocystis pneumonia); in patients with AIDS DLCO is a highly sensitive (but not specific) test for the presence of pulmonary disease especially PCP. A normal DLCO in a patient with AIDS is strong evidence against PCP.

8. Prediction of arterial desaturation during exercise in some...
patients with lung disease.

**Contraindications:**

*Absolute contraindications* to performing a diffusing capacity test are:

1. The presence of carbon monoxide toxicity.
2. Dangerous levels of oxyhemoglobin desaturation without supplemental oxygen.

*Relative contraindications* to performing a diffusing capacity test are:

1. Mental confusion or muscular incoordination preventing the subject from adequately performing the maneuver or inability to obtain or maintain an adequate lip seal on the instrument mouthpiece.
2. A large meal or vigorous exercise immediately before the test.
3. Smoking within 24 hours of test administration (smoking may have a direct effect on DLCO independent of the effect of COHb).
4. Decreased lung volumes that would not yield valid test results.
5. Devices that are improperly calibrated or maintained or the unavailability of a qualified operator.

**Complications:**

- DLCO requires breath holding at total lung capacity (TLC); some patients may perform either a Valsalva (higher than normal intrathoracic pressure) or Müller (lower than normal intrathoracic pressure) maneuver. Either of these can result in alteration of venous return to the heart and pulmonary capillary blood volume.
- Interruption of supplemental oxygen may result in oxyhemoglobin desaturation.
- Transmission of infection is possible via improperly cleaned mouthpieces or as a consequence of the inadvertent spread of droplet nuclei or body fluids (patient-to-patient or patient-to-technologist).

**Limitations in Performing DLCO**

- Limitations of the typical methods used for DLCO include:
  - DLCO should be corrected for hemoglobin level.
  - DLCO should be corrected for the effects of COHb present in the subject’s blood for purpose of interpretation.
  - DLCO increases with increasing altitude and appropriate correction for the alveolar or inspired oxygen pressures are recommended.
  - A 4-minute minimum interval should elapse between subsequent maneuvers to allow test gas to be eliminated from the lungs.
  - DLCO varies with body position; the upright seated position is recommended.
  - Abnormal breath holding maneuvers (Valsalva or Müller) alter DLCO.
  - Other factors that may alter measurement of DLCO include recent alcohol consumption, vigorous exercise, smoking, diurnal variation, and bronchodilators.
  - Pregnancy (1st trimester only) is associated with an increase in DLCO. Menstruation may also influence DLCO.
  - Breath-hold time should be calculated using different methods.

**Assessment of Test Quality**

- Individual test maneuvers and results, should be evaluated according to the ATS recommendations. In particular,
  - The inspiratory volume should exceed 90% of the largest previously measured vital capacity (FVC or VC).
  - Breath-hold time should be between 9 and 11 seconds, with a rapid inspiration.
  - The washout volume (dead space) should be 0.75 to 1.00 L, or 0.50 L if the subject’s VC is less than 2.0 L. If a washout volume other than 0.75-1.00 is used, it should be noted.
  - Two or more acceptable tests should be averaged; the maneuvers should be reproducible to within 10% or 3 mL CO • min⁻¹ • torr⁻¹, whichever is greater.
  - The subject should have refrained from smoking for 24 hours prior to the test.
  - Corrections for Hb and COHb should be included in the calculations.

**Physiological Factors which Alter DLCO**

- Position (more capillaries are open in supine position).
- Hematocrit (must correct values for anemia or polycythemia).
- Exercise (as more capillaries open).
- Body size.
- Body temperature.

**Pathological Conditions in which DLCO is Normal**

- Asthma
- Chronic Bronchitis
- Chest Wall Abnormalities
Factors that Result in a Decrease in DLCO

<table>
<thead>
<tr>
<th>Factor</th>
<th>Condition Giving Rise to Factor</th>
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<tbody>
<tr>
<td>Deficiency in red blood cells</td>
<td>Anemia</td>
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<tr>
<td>Loss of pulmonary capillary bed with relatively normal lung volume</td>
<td>Multiple pulmonary emboli, early collagen-vascular disease, early sarcoidosis, miliary tuberculosis</td>
</tr>
<tr>
<td>Loss of functioning alveolar-capillary (A-C) bed with increased lung volume</td>
<td>Emphysema</td>
</tr>
<tr>
<td>Loss of functioning A-C bed with lung volume</td>
<td>Parenchymal restrictive processes including decreased pulmonary resection, idiopathic interstitial fibrosis, asbestosis, scleroderma lung disease, histiocytosis-X, sarcoidosis, pneumonia</td>
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<tr>
<td>Failure of inspired air to reach alveoli, or poor distribution of ventilation with low, normal or increased lung volume</td>
<td>Seen occasionally with severe obstruction during asthmatic or bronchitic attack; seen frequently with emphysema and poor effort</td>
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Factors that Result in an Increase in DLCO

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<tr>
<td>Increase in pulmonary capillary blood volume</td>
<td>Increase in red blood cells</td>
</tr>
<tr>
<td>Left heart failure, left-to-right shunt (atrial septal defect, anomalous pulmonary venous return), exercise</td>
<td>Early polycythemia</td>
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Specific Abnormalities Leading to an Increase in DLCO

<table>
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<th>Abnormality</th>
<th>Precipitation Condition</th>
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<td>Lung compression</td>
<td>Scoliosis, obesity, pectus excavatum</td>
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<tr>
<td>Increased airway resistance</td>
<td>Asthma, cystic fibrosis, central airway lesions</td>
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<tr>
<td>Pulmonary vascular congestion</td>
<td>Congestive heart failure, regurgitative valvular disease</td>
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<tr>
<td>Intrapulmonic hemorrhage</td>
<td>Pulmonary hemosiderosis, Goodpasture’s syndrome, hemoptorax</td>
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<tr>
<td>‘Physiologic’ leaks</td>
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* The clinician should be suspicious if a patient with any of the abnormalities and/or precipitating condition listed proves to have a normal diffusing capacity.

Summary of Variables that Affect Oxygen Diffusion

A. Partial Pressure

High altitude can reduce alveolar $P_{O_2}$ so that it may limit oxygen diffusion, especially during exercise when red cell transit times in the capillaries are much reduced.

B. Length of Diffusion Path

This path may increase in disease to produce a physical barrier-alveolo-capillary block:

1. Thickening of alveolar wall (fibrous tissue or cells).
2. Thickening of capillary endothelium.
3. Separation of membranes by interstitial edema or fibrous tissues.
4. Capillary dilation.
5. Alveolar collapse into large air sacs.
C. Area for Diffusion

1. Total area of functioning alveoli in contact with capillaries with flowing blood (normally ~ 70 m²).
2. Pathological changes which decrease surface area:
   a) Decrease in ventilation of some alveoli (bronchiolar obstruction or alveolar edema).
   b) Destruction of alveolar and capillary membranes (emphysema).

D. Temperature

- In metabolically active tissues, such as skeletal muscle during exercise, temperature can be elevated by several degrees celsius. This could facilitate transfer of O₂ and CO₂.

Synonyms:

Transfer factor (TL, mmol/min/kilopascal, Europe); DLCO; diffusing capacity of lung (DL, mL/min/mmHg); diffusing capacity of lung/alveolar volume (DL/VA); rate of carbon monoxide (CO) uptake (KCO), which is equivalent to the DL/VA; and alveolar volume (VA, L), which is the single-breath estimate of the TLC determined by the dilution of the helium concentration.

References:

1. AARC and Respiratory Care Journal; Respiratory Care (Respir Care 1999; 44(5): 539-546).

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