DLCO: adjust for lung volume, standardised reporting and interpretation

To the Editor:

The American Thoracic Society (ATS) and European Respiratory Society (ERS) should be congratulated on updating standards for diffusing capacity of the lung for carbon monoxide (DLCO) [1]. I agree that “Besides varying with age, sex, height and possible ethnicity, DLCO also changes with Hb, lung volume, COHb, P\textsubscript{\text{ao}2} …, exercise and body position.” and that “adjustments for these factors be made in the predicted rather than the measured DLCO”. Reporting transfer coefficient of the lung for carbon monoxide (K\textsubscript{CO}) rather than DLCO/alveolar volume (VA) will help get away from the mistaken notion that DLCO/VA “corrects” DLCO for lung volume [2]. While the new standards describe how to adjust predicted DLCO for haemoglobin (Hb), COHb and inspired oxygen tension (P\textsubscript{\text{i}O2}), it does not discuss how to adjust predicted DLCO and K\textsubscript{CO} for lung volume.

The following equations [3] were included in the 2005 ATS/ERS DLCO standards [4], and describe how to adjust DLCO and K\textsubscript{CO} for lung volume. They were developed studying normal subjects with experimental reductions in inspired volume (V\textsubscript{I}; and thus VA) and fit the model that DLCO and K\textsubscript{CO} change in a manner expected from having DLCO reduced proportionate to the surface area for gas exchange with the capillary blood component unchanged. Mathematically, they result in DLCO % predicted for lung volume equaling K\textsubscript{CO} % predicted for lung volume when using the equation K\textsubscript{CO}(predicted)=DLCO(predicted)/VA(predicted).

\begin{align*}
\text{DLCO}_{\text{predicted for lung volume}} &= \text{DLCO}_{\text{predicted}} \times (0.58 + 0.42 \times (V_{\text{am}}/V_{\text{ap}})) \\
\text{KCO}_{\text{predicted for lung volume}} &= \text{KCO}_{\text{predicted}} \times (0.42 + 0.58/(V_{\text{am}}/V_{\text{ap}}))
\end{align*}

with \(V_{\text{am}}/V_{\text{ap}}=\text{measured VA/predicted VA.}\)

For example, at VA 50% of predicted, the DLCO predicted for lung volume is 80% and K\textsubscript{CO} is 160% of that for VA 100% of predicted.

The standards require reporting DLCO and K\textsubscript{CO} (adjusted, predicted) with specification of the adjustments. Additional reporting requirements should include DLCO (% of adjusted predicted) and VA (% predicted).

Neither the 2005 nor the current standards address how to report DLCO and K\textsubscript{CO} adjusted for lung volume, or how to interpret DLCO.

In addition to knowing % predicted DLCO and K\textsubscript{CO} adjusted for all factors except lung volume, it is also very helpful to know % predicted DLCO and K\textsubscript{CO} when also adjusted for lung volume [2]. Just as adjusting predicted DLCO and K\textsubscript{CO} for haemoglobin in an anaemic patient yields a better indication of the lung’s ability of gas exchange, adjusting DLCO and K\textsubscript{CO} for lung volume in a patient with low lung volume yields a better indication of the lung’s ability of gas exchange.

A shorter nomenclature is needed for DLCO and K\textsubscript{CO} % predicted also adjusted for lung volume.

I propose D\textsubscript{ACO} and K\textsubscript{ACO} to refer to DLCO and K\textsubscript{CO} predicted values that have been adjusted for lung volume (the “A” refers to adjusted for lung volume.)

Reporting requirements should include D\textsubscript{ACO} (adjusted, predicted), K\textsubscript{ACO} (adjusted, predicted), as well as D\textsubscript{ACO} (% of adjusted predicted) and K\textsubscript{ACO} (% of adjusted predicted).
The new standards recommend development of a standardised common report form. I propose the following, one when Hb is not measured (box 1) and a second when Hb is measured (box 2), with both including % of FVC for Vl if spirometry was done the same day.

**BOX 1** Common report form for diffusing capacity when haemoglobin measurements are not taken

<table>
<thead>
<tr>
<th>Diffusing capacity</th>
<th>Predicted range</th>
<th>Actual</th>
<th>% pred</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dlco mL·min⁻¹·mmHg⁻¹</td>
<td>xx.xx xx.xx</td>
<td>dd.dd xx</td>
<td>Predicted not adjusted for Hb</td>
</tr>
<tr>
<td>Vl (BTPS) L</td>
<td>x.x x.x</td>
<td>x.x xx</td>
<td>Predicted not adjusted for Hb</td>
</tr>
<tr>
<td>Kco mL·min⁻¹·mmHg⁻¹·L⁻¹</td>
<td>xx.xx xx.xx</td>
<td>x.x xx</td>
<td>xx% of FVC</td>
</tr>
<tr>
<td>VI (BTPS) L</td>
<td>x.x x.x</td>
<td>xx.xx</td>
<td>Predicted adjusted for lung volume</td>
</tr>
<tr>
<td>Daco mL·min⁻¹·mmHg⁻¹</td>
<td>xx.xx xx.xx</td>
<td>dd.dd yy</td>
<td>Predicted adjusted for lung volume</td>
</tr>
</tbody>
</table>

Dlco and Kco are yy% predicted, adjusted for lung volume.

**BOX 2** Common report form for diffusing capacity when haemoglobin measurements are taken

<table>
<thead>
<tr>
<th>Diffusing capacity</th>
<th>Predicted range</th>
<th>Actual</th>
<th>% pred</th>
<th>Hb xx.x from D-MON-YYYY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dlco mL·min⁻¹·mmHg⁻¹</td>
<td>xx.xx xx.xx</td>
<td>dd.dd xx</td>
<td>Predicted not adjusted for Hb</td>
<td></td>
</tr>
<tr>
<td>Dlco mL·min⁻¹·mmHg⁻¹</td>
<td>xx.xx xx.xx</td>
<td>dd.dd xx</td>
<td>Predicted adjusted for Hb</td>
<td></td>
</tr>
<tr>
<td>Vl (BTPS) L</td>
<td>x.x x.x</td>
<td>x.x xx</td>
<td>Predicted adjusted for Hb</td>
<td></td>
</tr>
<tr>
<td>Kco mL·min⁻¹·mmHg⁻¹·L⁻¹</td>
<td>xx.xx xx.xx</td>
<td>x.x xx</td>
<td>xx% of FVC</td>
<td></td>
</tr>
<tr>
<td>VI (BTPS) L</td>
<td>x.x x.x</td>
<td>xx.xx</td>
<td>Predicted adjusted for lung volume and Hb</td>
<td></td>
</tr>
<tr>
<td>Daco mL·min⁻¹·mmHg⁻¹</td>
<td>xx.xx xx.xx</td>
<td>dd.dd yy</td>
<td>Predicted adjusted for lung volume and Hb</td>
<td></td>
</tr>
</tbody>
</table>

Dlco and Kco are yy% predicted, adjusted for lung volume and Hb.

For both reports, if Dlco and Kco predicted were also adjusted for COHb and/or PIO2, then a line saying “Predicted Dlco and Kco also adjusted for …” should appear at the end, which includes the data used to make the adjustment, such as “COHb of 2.6% and altitude of 2000m.” The 95% values are the lower limit of normal (LLN), with Daco[LLN]=Daco[adjusted,predicted]×DLCO[LLN]/DLCO[predicted].

There is not a clear consensus on interpretation of Dlco. I recommend the following algorithm to interpret Dlco, with Dlco % predicted, adjusted and LLN the lower limit of normal (box 3).

**BOX 3** Interpretation of diffusing capacity values

- Dlco ≥80% and ≥LLN: Dlco is normal
- Dlco <80% but ≥LLN: Dlco is near lower limit of normal
- Dlco ≥60%, <80%, and <LLN: Dlco is mildly reduced
- Dlco ≥40%, <60%, and <LLN: Dlco is moderately reduced
- Dlco <40%: Dlco is severely reduced

If Dlco is not normal, and Dlco adjusted for lung volume (Daco) is above the LLN as % predicted, then add phrase “due to low lung volume”.

If Dlco is not normal, and Dlco adjusted for lung volume is below the LLN as % predicted but more than 10% predicted greater than Dlco, then add phrase “in part due to low lung volume”.

As a co-author of the 2005 ERS/ATS Dlco standards, I believe including adjustments of Dlco for lung volume and standardised reports and interpretation would improve the clinical value of Dlco.
From the authors:

D.C. Johnson proposed that an adjustment of the predicted value for the diffusing capacity of the lung for carbon monoxide (DLCO) based on the measured and predicted lung volume be included in the report of DLCO test results. An interpretation algorithm is also proposed.

The rationale is based on the observation that a decreased inspired volume in normal subjects reduces DLCO and that this reduction can be predicted using a linear function of the measured alveolar lung volume (VA) divided by the predicted VA. While this formula may be applicable for normal, healthy lungs and may potentially adjust for effects of reductions in VA due to weakness, chest wall deformities or reduced effort, it is unlikely to be applicable in patients with reduced VA due to pathological processes that also impact the distribution of ventilation, the distribution of perfusion and the development of heterogeneous parenchymal changes in the lung. As Hughes and Pride [1] noted, “any ‘correction’ of the DLCO for volume must take into account the reason for the volume deficit.” Volume adjustment equations for DLCO developed from submaximal inhalation manoeuvres in normal subjects do not consider other mechanisms for a reduced VA.

The 2017 European Respiratory Society (ERS)/American Thoracic Society (ATS) standards for single-breath carbon monoxide uptake in the lung [2] describe technical standards for the measurement of DLCO. The interpretation of DLCO was not included in the mandate of the ERS/ATS task force in the development of these standards. Nevertheless, the reporting of the results must provide all of the necessary information for their interpretation.

The standards address the need for the subject to achieve maximal inhalation of test gas. A failure to reach full inflation to total lung capacity is a reason to repeat the manoeuvre rather than applying a volume correction to the predicted DLCO. Reporting the VA and its z-score together with the DLCO allows the reviewer to interpret the DLCO in the context of whether the VA is reduced, normal or increased. It continues to be the opinion of the ERS/ATS DLCO task force that this information is sufficient for the interpretation of DLCO.

Brian L. Graham1, Vito Brusasco2, Felip Burgos3, Brendan G. Cooper4, Robert Jensen5, Adrian Kendrick6, Neil R. MacIntyre7, Bruce R. Thompson8 and Jack Wanger9

@ERSpublications
A correction of the predicted value for DLCO based on the measured lung volume is not recommended
http://ow.ly/KFn730cPJ9n

Correspondence: Brian L. Graham, University of Saskatchewan, Respirology, Critical Care and Sleep Medicine, 5th Floor, Ellis Hall, Saskatoon, Saskatchewan S7N 0W8, Canada. E-mail: brian.graham@usask.ca

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Conflict of interest: Disclosures can be found alongside this article at erj.ersjournals.com

References

1 Hughes M, Pride N. Examination of the carbon monoxide diffusing capacity (DLCO) in relation to its KCO and V\textsubscript{A} components. *Am J Respir Crit Care Med* 2012; 186: 132–139.


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