AGORA
CORRESPONDENCE

D_{LCO}: 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 (D_{LCO}) [1]. I agree that "Besides varying with age, sex, height and possible ethnicity, D_{LCO} also changes with Hb, lung volume, COHb, PIO_2 …, exercise and body position." and that "adjustments for these factors be made in the predicted rather than the measured D_{LCO}". Reporting transfer coefficient of the lung for carbon monoxide (K_{CO}) rather than D_{LCO}/alveolar volume (V_A) will help get away from the mistaken notion that D_{LCO}/V_A "corrects" D_{LCO} for lung volume [2]. While the new standards describe how to adjust predicted D_{LCO} for haemoglobin (Hb), COHb and inspired oxygen tension (P_{IO_2}), it does not discuss how to adjust predicted D_{LCO} and K_{CO} for lung volume.

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

$$D_{LCO}[\text{predicted for lung volume}]=D_{LCO}[\text{predicted}]\times(0.58+0.42\times(V_{Am}/V_{Ap}))$$

$$K_{CO}[\text{predicted for lung volume}]=K_{CO}[\text{predicted}]\times(0.42+0.58/(V_{Am}/V_{Ap}))$$

with V_{Am}/V_{Ap}=measured V_A/predicted V_A.

For example, at V_A 50% of predicted, the D_{LCO} predicted for lung volume is 80% and K_{CO} is 160% of that for V_A 100% of predicted.

The standards require reporting D_{LCO} and K_{CO} (adjusted, predicted) with specification of the adjustments. Additional reporting requirements should include D_{LCO} (% of adjusted predicted) and V_A (% predicted).

Neither the 2005 nor the current standards address how to report D_{LCO} and K_{CO} adjusted for lung volume, or how to interpret D_{LCO}.

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

I propose D_{ACO} and K_{ACO} to refer to D_{LCO} and K_{CO} predicted values that have been adjusted for lung volume (the "A" refers to adjusted for lung volume.)

Reporting requirements should include D_{ACO} (adjusted, predicted), K_{ACO} (adjusted, predicted), as well as D_{ACO} (% of adjusted predicted) and K_{ACO} (% of adjusted predicted).

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D_{LCO} reports and interpretation should be standardised and include adjusting predicted D_{LCO} and K_{CO} for lung volume http://ow.ly/ywTA30cOh44

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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 *V*I if spirometry was done the same day

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

Diffusing capacity	Predicted range		Actual	% pred	
	Mean	95%			
***D*LCO mL·min^{-1}·mmHg^{-1}**	xx.xx	xx.xx	dd.dd	xx	Predicted not adjusted for Hb
***V*A (BTPS) L**	x.xx	x.xx	x.xx	xx	
***K*CO mL·min^{-1}·mmHg^{-1}·L^{-1}**	xx.xx	xx.xx	x.xx	xx	Predicted not adjusted for Hb
***V*I (BTPS) L**	x.xx	x.xx	xx.xx	xx	xx% of FVC
***D*ACO mL·min^{-1}·mmHg^{-1}**	xx.xx	xx.xx	dd.dd	yy	Predicted adjusted for lung volume

*D*LCO and *K*CO are yy% predicted, adjusted for lung volume.

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

Diffusing capacity	Predicted range		Actual	% pred	Hb xx.x from D-MON-YYYY
	Mean	95%			
***D*LCO mL·min^{-1}·mmHg^{-1}**	xx.xx	xx.xx	dd.dd	xx	Predicted not adjusted for Hb
***D*LCO mL·min^{-1}·mmHg^{-1}**	xx.xx	xx.xx	dd.dd	xx	Predicted adjusted for Hb
***V*A (BTPS) L**	x.xx	x.xx	x.xx	xx	
***K*CO mL·min^{-1}·mmHg^{-1}·L^{-1}**	xx.xx	xx.xx	x.xx	xx	Predicted adjusted for Hb
***V*I (BTPS) L**	x.xx	x.xx	x.xx	xx	xx% of FVC
***D*ACO mL·min^{-1}·mmHg^{-1}**	xx.xx	xx.xx	dd.dd	yy	Predicted adjusted for lung volume and Hb

*D*LCO and *K*CO are yy% predicted, adjusted for lung volume and Hb.

For both reports, if *D*LCO and *K*CO predicted were also adjusted for COHb and/or PIO2, then a line saying "Predicted *D*LCO and *K*CO 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 *D*ACO[LLN]=*D*ACO[adjusted,predicted]×*D*LCO[LLN]/*D*LCO[predicted].

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

BOX 3 Interpretation of diffusing capacity values

***D*LCO ⩾80% and ⩾LLN**	*D*LCO is normal
***D*LCO <80% but ⩾LLN**	*D*LCO is near lower limit of normal
***D*LCO ⩾60%, <80%, and <LLN**	*D*LCO is mildly reduced
***D*LCO ⩾40%, <60%, and <LLN**	*D*LCO is moderately reduced
***D*LCO <40%**	*D*LCO is severely reduced

If *D*LCO is not normal, and *D*LCO adjusted for lung volume (*D*ACO) is above the LLN as % predicted, then add phrase "due to low lung volume".

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

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

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From the authors:

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

The rationale is based on the observation that a decreased inspired volume in normal subjects reduces *D*LCO and that this reduction can be predicted using a linear function of the measured alveolar lung volume (*V*A) divided by the predicted *V*A. While this formula may be applicable for normal, healthy lungs and may potentially adjust for effects of reductions in *V*A due to weakness, chest wall deformities or reduced effort, it is unlikely to be applicable in patients with reduced *V*A 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 *D*LCO for volume must take into account the reason for the volume deficit." Volume adjustment equations for *D*LCO developed from submaximal inhalation manoeuvres in normal subjects do not consider other mechanisms for a reduced *V*A.

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 *D*LCO. The interpretation of *D*LCO 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 *D*LCO. Reporting the *V*A and its z-score together with the *D*LCO allows the reviewer to interpret the *D*LCO in the context of whether the *V*A is reduced, normal or increased. It continues to be the opinion of the ERS/ATS *D*LCO task force that this information is sufficient for the interpretation of *D*LCO.

Brian L. Graham[1], Vito Brusasco[2], Felip Burgos[3], Brendan G. Cooper[4], Robert Jensen[5], Adrian Kendrick[6], Neil R. MacIntyre[7], Bruce R. Thompson[8] and Jack Wanger[9]

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

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