The Effects of Ethanol Ingestion on the Accuracy of Pulmonary Diffusing Capacity Measurement*

Francesco Simeone, MD; Jeffrey Wiese, MD; Henry Glindmeyer, MD; and Joseph Lasky, MD, FCCP

Background: Erroneous diffusing capacity of the lung for carbon monoxide (DLCO) values as measured by spectrophotometry were observed at our facility in ethanol-intoxicated subjects. An atypical methane curve tracing was noted in these subjects.

Study objectives: We hypothesized that ethanol intoxication interferes with DLCO measurements obtained using methane and designed a study to assess the blood ethanol level at which this occurs.

Study design: DLCO and breath ethanol levels were measured at baseline and after escalating doses of ethanol in seven healthy subjects.

Setting: Pulmonary function testing laboratory of a university hospital.

Participants: Seven healthy volunteers.

Interventions: DLCO measurement at baseline and after escalating doses of ethanol.

Measurements and results: We found no significant change in measured DLCO values for a wide range of blood ethanol levels (from 0.006 to 0.12 mg/dL). However, subsequently, an abnormal methane curve and DLCO were again observed in an intoxicated subject whose ethanol blood level was 0.22 mg/dL.

Conclusions: We conclude that interference between breath ethanol level and DLCO measurement exists only for blood ethanol levels well above the legal limit for intoxication. Based on our observations, we suggest that ethanol intoxication should be suspected when an abnormal DLCO measurement occurs along with an abnormal methane curve tracing. If intoxication is confirmed, precautions should be taken and referral for treatment of possible ethanol dependence should be offered.

Key words: diffusing capacity; diffusing capacity of the lung for carbon monoxide; ethanol

Abbreviations: CO = carbon monoxide; DLCO = diffusing capacity of the lung for carbon monoxide; VA = alveolar volume

Ingestion of ethanol (12 to 30 g) has been reported in two studies1,2 to reduce diffusing capacity of the lung for carbon monoxide (DLCO) by 11 to 15% in healthy volunteers. The existence of a carbon monoxide (CO) carrier has been postulated to explain these findings. In both studies,1,2 DLCO was measured with a modified Krogh technique using gas chromatography and a known inspiratory concentration of CO and neon. However, other methods used to measure DLCO employ helium or methane. In many centers, methane, due to its lower cost, has replaced neon or helium as the inert gas and is measured in the exhaled breath using spectrophotometry. We initially observed spuriously elevated DLCO values in two intoxicated subjects undergoing routine pulmonary function testing using spectrophotometry with methane as the inert gas. The methane curve showed an upward displacement (Fig 1, top). The measured DLCO values for the two intoxicated subjects subsequently corrected to baseline values, when the subjects were sober, and the methane curve normalized (Fig 1, bottom). In one case, there was a dramatic change in DLCO from 61% of the predicted value while intoxicated to 23% when sober. While trying to explain our observations, we found that the infrared absorbance spectra for
ethanol and methane overlap (Fig 2). Therefore, we hypothesized that the ethanol present in the breath of intoxicated subjects might be spuriously measured as methane. Our aim was to define the minimum blood ethanol concentration that interferes with DLCO measurement.

MATERIALS AND METHODS

After obtaining Institutional Review Board approval, seven healthy volunteers (five men and two women; all nonsmokers; age range, 28 to 32 years) with no known underlying lung disease were included in the study. Subjects were excluded if they had a history of GI disease (peptic ulcer disease, esophageal varices, GI bleeding), liver disease, active tuberculosis, diabetes, ethanol hypersensitivity, ethanol dependency, allergic reaction to ethanol, current pregnancy, or were receiving treatment with medications prohibiting ethanol consumption. No ethanol intake was allowed for 24 h and no food intake for 6 h prior to the study. Enrolled subjects underwent a baseline measurement of ethanol using a breath analyzer (Alco Sensor IV; Intoximeters; St. Louis, MO). After resting quietly for at least 10 min, DLCO was measured in the sitting position using a metabolic system (Vmax series 229; SensorMedics; Yorba Linda, CA) which employs the Krogh effect.
Inspired concentrations of 0.3% CO and 0.3% methane were used. Inspired and expired CO and methane concentrations were measured with a rapid-response multigas analyzer, and spectrophotometric absorbance was measured using a nondispersive infrared technique. The metabolic system, according to the manufacturer, analyzes gas concentration and volume continuously during the entire single-breath DLco maneuver. The collected sample gas concentration is measured by finding the mean gas concentration over the appropriate expired volume interval. Three DLco measurements were obtained to establish a baseline value, and the average for the two closest DLco values was recorded. DLco, expressed as a volume (standard temperature and pressure, dry) of gas (CO) uptake per unit alveolar-capillary pressure difference, was calculated according to the following formula:

\[
DLco = \left[60 \times VA\, (STPD)/(PB - 47)\right]
\times T[\ln((FECH4/FICH4)/(FICO/FECO))]
\]

where STPD = standard temperature and pressure, dry; VA = alveolar volume; PB = barometric pressure; T = temperature; \(\ln\) = natural log; FECH4 = fraction of expired methane; FICH4 = fraction of inspired methane; FICO = fraction of expired CO; FICO = fraction of inspired CO.

Because all study subjects were healthy volunteers, the hemoglobin level used to correct DLco was assumed to be normal. DLco and breath ethanol levels were measured at baseline and after escalating doses of ethanol. Each ethanol dose consisted of two ounces of gin (24 g of ethanol) in a mixed drink (with tonic). Seven subjects received a total of 24 g of ethanol, six subjects received 48 g, five subjects received 72 g, and two subjects received 96 g. Ethanol levels were measured every 10 to 15 min using the breath analyzer to define the plateau phase after each dose, so that DLco could be measured again when ethanol levels reached a plateau.

**RESULTS**

As shown in Table 1, the two subjects who received 96 g of ethanol achieved a mean blood...
ethanol level of 0.103 mg/dL (range, 0.087 to 0.12 mg/dL). Even though this is above the 0.08 mg/dL legal limit for intoxication, there was no significant change in the DLCO (average DLCO, 101 ± 7.07% of baseline). The five subjects who received 72 g of ethanol had a mean ethanol level of 0.072 mg/dL (range, 0.047 to 0.096 mg/dL) and a mean DLCO measurement of 102.2 ± 8.58 mg/dL at baseline. Six subjects received 48 g of ethanol and had a mean ethanol level of 0.051 mg/dL (range, 0.021 to 0.078 mg/dL) along with a mean DLCO value of 101.17 ± 4.88% of baseline. The mean ethanol level was 0.029 mg/dL (range, 0.006 to 0.055 mg/dL) and the mean DLCO was 101.86 ± 3.89% of baseline in the seven subjects who ingested 24 g of ethanol. The measured DLCO did not vary by > 5% in any subject over a wide range of blood ethanol levels (Fig 3). DLCO/VA also did not change significantly.

Before conducting the study, we observed abnormal DLCO values and methane exhalation curves in two intoxicated subjects, but blood ethanol levels were not measured. After completing the study on healthy volunteers, we encountered a third patient in whom the DLCO could not be measured due to inability of the instrument to provide a numeric value. The methane exhalation curve graphic displayed the same type of abnormality (upward displacement of the methane curve) we had previously observed in the two other intoxicated subjects (Fig 1, top). The patient admitted that he had ingested ethanol and gave consent to have his blood ethanol level measured by a breath analyzer. His blood ethanol level was 0.22 mg/dL. This patient appeared only slightly euphoric and had a deceptively balanced

<table>
<thead>
<tr>
<th>Dose of Ethanol, g</th>
<th>Subjects, No.</th>
<th>Mean Ethanol Level (Range), mg/dL</th>
<th>Mean ± SD DLCO, % of Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>7</td>
<td>0.029 (0.006-0.055)</td>
<td>101.86 ± 3.89</td>
</tr>
<tr>
<td>48</td>
<td>6</td>
<td>0.051 (0.021-0.078)</td>
<td>101.17 ± 4.88</td>
</tr>
<tr>
<td>72</td>
<td>5</td>
<td>0.072 (0.047-0.096)</td>
<td>102.20 ± 8.58</td>
</tr>
<tr>
<td>96</td>
<td>2</td>
<td>0.103 (0.087-0.12)</td>
<td>101 ± 7.07</td>
</tr>
</tbody>
</table>

Table 1—Ethanol Levels and DLCO in Subjects Studied

Figure 3. DLCO values in seven different subjects (S1 to S7) after administration of escalating doses of ethanol.
gait. The intoxicated patient agreed to return the following day to repeat the study. Repeat testing when he was sober, as documented by breath analyzer (0 mg/dL), demonstrated that the methane curve had reverted to a normal appearance (Fig 1, bottom).

Discussion

Previous studies1,2 using a modified Krogh technique with neon and gas chromatography have shown an 11 to 15% decrease in DLCO after ingestion of small-to-moderate doses of ethanol (12 to 30 g). While ethanol levels achieved in these earlier studies were not measured, we accurately documented ethanol levels in our study subjects using a breath analyzer. In contrast to these earlier reports that used different methods, when using methane as the inert gas we found no significant change in DLCO measurements over a wide range of ethanol doses (24 to 96 g), and with blood ethanol levels up to 0.12 mg/dL, which are well above the legal limit for intoxication. Methane has replaced neon to assess Vlco, and an abnormal DLCO measurement using methane when blood ethanol levels, and we report spurious clinical observations in three heavily intoxicated subjects. But we were not able to study the effects of higher doses of ethanol in volunteers because of ethical concerns due to the risk of inducing harm in our study subjects.

Conclusion

We have shown that up to a blood ethanol level of 0.12 mg/dL, there is no change in DLCO measured employing methane as the inert gas, while there is an artifact in DLCO measurement for a level of 0.22 mg/dL. Blood ethanol levels within the legal limit of intoxication do not affect the DLCO measurement with the method that employs methane, while heavy ethanol intoxication causes an upward displacement of the methane curve, and an erroneous DLCO measurement, probably by interfering with methane detection in the exhaled breath. This interference can be explained by the overlapping infrared absorbance spectra for ethanol and methane. Ethanol dependence is common, with a prevalence of 6% in men and 2% in women in the United States,7 and is difficult to detect because ethanol-dependent sub-
Objects tend to conceal their habit. Awareness of the findings that we report will avoid misinterpretation of DLCO measurements in ethanol-intoxicated patients and might help identify patients who may benefit from referral to a chemical dependency program. The appearance of subjects intoxicated with ethanol may be deceptive, as it was in the three cases we observed. When an abnormal DLCO, with the typical upward displacement in the methane curve that we report (Fig 1, top) is observed, ethanol intoxication should be suspected and consideration given to document blood ethanol levels. If ethanol intoxication is confirmed, measures should be taken to ensure the patient’s safety, such as preventing driving while intoxicated, and referral for treatment of possible ethanol dependence should be offered.

REFERENCES

1 Peavy H, Summer W, Gurtner G. The effects of acute ethanol ingestion on pulmonary diffusing capacity. Chest 1980; 77: 488–492