Effect of Tracheal Gas Insufflation During Weaning From Prolonged Mechanical Ventilation: A Preliminary Study

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- **Background** Tracheal gas insufflation reduces inspired tidal volume and minute ventilation in spontaneously breathing patients and may facilitate weaning from mechanical ventilation.
- **Objective** To determine if tracheal gas insufflation can reduce ventilatory demand during weaning trials in patients who require prolonged mechanical ventilation.
- **Methods** A reduction in ventilatory demand was defined as a relative decrease in tidal volume, minute ventilation, and mean inspiratory flow during trials with tracheal gas insufflation compared with the values during trials without this therapy. A total of 14 subjects underwent T-piece trials with and without insufflation (flow rate 6 L/min) on 2 consecutive days; the order of insufflation was randomized. Tidal volume, minute ventilation, and mean inspiratory flow were measured at baseline (without insufflation) and 2 hours later.
- **Results** Differences in ventilatory demand were not significant when comparisons were made for condition (tracheal gas insufflation vs no flow) or time (baseline vs 2 hours) for the total group (P = .48). Subjects were classified post hoc as responders (n = 9) or nonresponders (n = 5). Comparisons between responders and nonresponders indicated a significant (P = .02) 3-way multivariate interaction for group (responder vs nonresponder), condition (tracheal gas insufflation vs no flow), and time (baseline vs 2 hours) for ventilatory demand variables.
- **Conclusion** Tracheal gas insufflation can reduce ventilatory demand during weaning trials in some patients who require mechanical ventilation. (American Journal of Critical Care. 2003:12:31-40)

Efficient weaning of patients from prolonged mechanical ventilation continues to be an elusive goal. Numerous weaning indices, protocols, and models of care (e.g., weaning teams, case management, specialized weaning units) have been tested in an effort to increase success. These strategies can improve success rates, but approximately 1% to 5% of patients receiving mechanical ventilation cannot be weaned from ventilatory support and become long-term ventilator patients. The inability to regain the capacity to breathe without ventilatory support is due to a variety of causes. However, most commonly, the cause is an imbalance between ventilatory demand and the patient's capacity to meet this demand.

Tracheal gas insufflation (TGI) is an adjunctive ventilatory technique that involves inserting a small catheter through an endotracheal or tracheostomy tube to a level just above the carina. Alternatively, a catheter
can be inserted percutaneously through the anterior wall of the trachea.11 Gas is insufflated through the catheter at various flow rates (eg, 2-10 L/min). TGI can produce an increase in exercise tolerance and a reduction in dyspnea in spontaneously breathing patients with chronic respiratory disease.11-14 Several mechanisms may contribute to this effect.

First, the catheter delivers gas lower in the airways than during normal breathing, a condition that reduces anatomic dead space (VDS).15,16 Second, part of the inspired tidal volume (VT) enters the lungs passively through the catheter, a situation that decreases the oxygen cost of breathing.17 Finally, TGI improves the efficiency of carbon dioxide elimination.18,19 During expiration, gas insufflated by the catheter flushes gas laden with carbon dioxide from the anatomic and apparatus dead space proximal to the catheter tip (Figure 1). As a result, the amount of carbon dioxide recycled to the alveoli during the next inspiration is reduced, increasing the ventilatory efficiency of each tidal breath.19 Consequently, TGI may reduce ventilatory demand.11-17,20

Most commonly, TGI has been used as an alternative to traditional oxygen delivery via nasal cannulas in patients with end-stage lung disease.11-14 TGI has also been used in conjunction with a lung-protective ventilatory strategy to improve the efficiency of alveolar ventilation and/or minimize ventilator pressure requirements in patients with acute lung injury.19,20 Use of TGI in patients during weaning from mechanical ventilation or after episodes of acute respiratory failure that necessitated mechanical ventilation has also been investigated.10,11,12,21

Bergofsky and Hurewitz19 tested the potential advantages of TGI in 5 patients with chronic respiratory failure due to obstructive or restrictive disease. VDS, VT, and minute ventilation (Vmin) were significantly less with TGI than with the no-flow condition. Two patients continued to use TGI for 12 months or longer, and both had fewer episodes of acute respiratory failure that required mechanical ventilation while using TGI than while receiving oxygen via a tracheostomy mask. Hurewitz et al20 extended this work by examining mechanisms that might explain the benefits of TGI. With TGI at flow rates of 1, 5, and 8 L/min, VDS, VT, and Vmin progressively decreased without an accompanying increase in PaCO2. The reduction in Vmin was achieved primarily via a reduction in VT, whereas respiratory rate had almost no change at any flow rate.

Nakos et al21 tested the effects of TGI at flow rates of 3 and 6 L/min during weaning in 12 spontaneously breathing patients with chronic obstructive pulmonary disease (COPD) who were undergoing weaning trials. In these subjects, TGI progressively decreased the ratio of VDS to VT (VDS/VT), VT, and Vmin; effects were greatest at the highest flow rates. Schönhofer et al22 found similar changes in 8 patients with COPD treated with TGI immediately after weaning from mechanical ventilation. In another study, Schönhofer et al found a 28% decrease in inspiratory work of breathing relative to Vmin when TGI was used in 6 patients with COPD who had undergone long-term mechanical ventilation. In combination, the findings of these studies21,22-23 support the notion that TGI can decrease ventilatory demand in patients with COPD when delivered during or just after weaning from mechanical ventilation.

The ability of TGI to promote weaning from mechanical ventilation was tested previously only in patients with COPD.21-23 Because it decreases VT, Vmin, and mean inspiratory flow or the ratio of VT to inspiratory time (VT/TI), TGI may also be useful in weaning patients with other types of pulmonary dysfunction from prolonged mechanical ventilation. Accordingly, we tested the ability of TGI to reduce ventilatory demand during weaning from mechanical ventilation in patients with and without COPD who required prolonged (>14 days) mechanical ventilation. A reduction in ventilatory demand was defined as a relative decrease in VT, Vmin, and VT/TI during trials with TGI compared with the values during trials without this therapy.

Materials and Methods

Sample

Subjects were 14 consecutive patients who met the following criteria: (1) required prolonged (>14 days) mechanical ventilation; (2) had a tracheostomy because they could not be weaned from mechanical ventilation; (3) were undergoing daily weaning trials ordered by the intensive care unit attending physician at the time of entry into the study; (4) had stable hemodynamic status (ie, no treatment with vasopressors, no clinical or radiological evidence of pulmonary edema, and no unstable arrhythmia); and (5) had had no evidence of infection for 3 or more days (ie, temperature <38°C [<100.4°F] and white blood cell count <15 x 109/L). The study was approved by the appropriate institutional review board, and all subjects or their legal representative gave informed consent. All work was carried out in accordance with standards set forth in the Helsinki Declaration of 1975.

Experimental Protocol

Each subject underwent a 2-hour T-piece weaning trial with and without TGI (flow rate 6 L/min) on
2 consecutive days; the order of TGI was randomized. Baseline data were collected to determine respiratory frequency, $V_t$, $V_{\text{min}}$, and $V_t/T_i$ 5 minutes after the beginning of the T-piece trial (baseline) and 2 hours later. During TGI trials, baseline data were obtained before TGI was started. Mean arterial blood pressure (cuff pressure), heart rate (standard lead II electrocardiogram), and arterial oxygen saturation (as determined by pulse oximetry; $\text{SpO}_2$) were measured at the same time points. The protocol required that data col-

Figure 1 Comparison of inspiration and expiration with and without tracheal gas insufflation (TGI) in a patient with a tracheotomy. A, Without TGI, during inspiration, all tidal volume ($V_t$) enters the airway through the tracheostomy tube, with active work by the patient. B, With TGI, during inspiration, part of the $V_t$ passively enters lower in the airway at a rate of 100 mL/s (flow rate = 6 L/min), improving the patient’s capacity to meet ventilatory demands. C, Without TGI, at the end of expiration, gas laden with carbon dioxide ($CO_2$) is present throughout the airway. With the next inspiration, the patient rebreathes this $CO_2$-laden gas as part of the $V_t$. D, With TGI, at the end of expiration, most of the $CO_2$-laden gas is “washed out” with TGI flow and replaced with gas rich in oxygen ($O_2$) before the next inspiration. The efficiency of $CO_2$ elimination is improved, and the patient’s ventilatory demand is diminished.
lection be terminated if any of the following occurred: 
SpO₂ less than 88%, heart rate greater than 120/min, 
respirations greater than 35/min or greater than a 15% 
increase from baseline, new dysrhythmia or change in baseline dysrhythmia, or request for discontinuation 
by the subject.

**TGI Apparatus**

A single distal-lumen catheter (internal diameter 
1.67 mm) was inserted through a jet-ventilator adapter 
(model 600101, Concord/Portex, Keene, NH) for TGI 
(Figure 2). Before the catheter was inserted, a recent 
chest radiograph was assessed to determine the position 
of the tracheal tube in relationship to the carina. 
The catheter was then passed ex vivo through a tra-
cheal tube of the same size and model as that used in 
the patient to a position that would place the catheter 
tip approximately 1 cm above the carina and was 
locked in position by using the jet-ventilator adapter. 
The catheter and adapter were then inserted into the 
patient’s tracheal tube. Gas was delivered through a 
calibrated flow generator (Bellofram, Newell, WV) at 
a flow rate of 6 L/min with the same fraction of inspired 
oxygen (0.40-0.50) as that ordered for the weaning trial 
(Air/O₂ Microblender, Bird Products Corp, Palm 
Springs, Calif). No humidification of the insufflated gas 
was used because of the short duration of the study.

During no-flow conditions, the TGI catheter was 
positioned in the tracheostomy tube in the same man-
nner as during the TGI condition, but no gas was deliv-
ered. This practice ensured that patients experienced 
equal resistance to air flow during both conditions 
(TGI vs no TGI).

**Respiratory Inductive Plethysmography**

Respiratory inductive plethysmography bands 
were positioned and secured around the patient’s rib 
cage and abdomen. The plethysmography device 
(RespiTrace Plus, Nims, Miami Beach, Fla) was cali-
ibrated by using the semiquantitative single-position 
calibration method, with the patient receiving breaths 
of consistent volume from the ventilator.24 Subjects 
were placed in the same position after the bands were 
positioned and were maintained in this position 
throughout calibration and the experimental protocol 
on both days. Respiratory inductive plethysmography 
was used to directly measure all gas entering the pa-
tients’ lungs, because total inspired Vt included gas 
from spontaneous inspiration and TGI-derived gas. In 
addition, respiratory inductive plethysmography was 
used to measure respirations and Vt/Ti. Signals from 
the RespiTrace were imported for 5 minutes at each 
data collection point and were stored in a computer 
(Colorbook DX2-50, Gateway 2000, N Sioux City, SD) 
by using RespiEvents software (Version 4.1, Nims, 
Miami Beach, Fla). A minimum of 1 minute of contin-
uous respiratory inductive plethysmography data was 
used for analysis.

**Data Analysis**

Data were analyzed for the total group and for 
responders and nonresponders to TGI by using multi-
variate and univariate analyses of variance. Subjects 
were classified as responders or nonresponders post 
hoc by using change scores calculated by subtracting 
the baseline values for Vt, Vₘₐₓ and Vₜ/ₖ from the 
2-hour values. Responders were defined as subjects 
who had a minimum of 20% difference (decrease or 
less of an increase) with TGI than without TGI in at 
least 2 of the 3 parameters measured. Subjects who 
did not fulfill these criteria were defined as nonrespon-
ders. Demographic data and data on medical conditions 
were analyzed by using the Fisher exact test (diagnosis, 
sex) and the Mann-Whitney test (age, ventilator days, 
pretrial PaCO₂ from an arterial blood gas analysis) with
a Bonferroni correction for multiple comparisons. Differences were considered significant at $P < .05$.

**Results**

**Characteristics of the Sample**

The subjects consisted of 8 men and 6 women 36 to 73 years old (Table 1). They had been receiving mechanical ventilation for a mean of 36.0 days (SD = 15.1 days, range = 15-65 days) and were receiving a mean fraction of inspired oxygen of 0.46 (SD = 0.05) at the time of data collection. Samples for arterial blood gas analysis were obtained with the patients off mechanical ventilation within 3 days of data collection for 12 subjects (mean $\text{PaCO}_2$ = 51.5 mm Hg, SD = 11.6 mm Hg). All subjects completed the 2-hour trial with no adverse effects.

**Total Group Response**

No significant differences in ventilatory demand ($V_T$, $V_{min}$, $V_T/T_I$) were detected when multivariate comparisons were made for condition (TGI vs no flow), time (baseline vs 2 hours), or the interaction of condition and time for the total group. Furthermore, multivariate analysis indicated no significant differences in heart rate, mean arterial pressure, and $\text{SpO}_2$ for condition, time, or the interaction of condition and time. Univariate analysis revealed a statistically significant ($P = .01$), but clinically unimportant, increase in heart rate from a mean of 97.6/min (SD = 15.6/min) at baseline to a mean of 100.9/min (SD = 14.9/min) at 2 hours without TGI.

**Responders and Nonresponders**

On the basis of change scores, 9 subjects were classified as responders and 5 subjects as nonresponders. Comparisons between responders and nonresponders indicated a significant ($P = .02$) 3-way multivariate interaction for group (responder vs nonresponder), condition (TGI vs no flow), and time (baseline vs 2 hours) for ventilatory demand variables (Table 2).

### Table 1 Characteristics of the sample

<table>
<thead>
<tr>
<th>Primary diagnosis or condition</th>
<th>Pulmonary diagnosis or condition</th>
<th>Age, years</th>
<th>Sex</th>
<th>Days of mechanical ventilation</th>
<th>Weaning fraction of inspired oxygen</th>
<th>Pretrial $\text{PaCO}_2$ off mechanical ventilation, mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acute respiratory failure</td>
<td>Obstructive lung disease</td>
<td>60</td>
<td>Male</td>
<td>49</td>
<td>0.5</td>
<td>60</td>
</tr>
<tr>
<td>Neurodegenerative disease</td>
<td>Aspiration pneumonia</td>
<td>60</td>
<td>Male</td>
<td>35</td>
<td>0.4</td>
<td>40</td>
</tr>
<tr>
<td>Lung cancer</td>
<td>Obstructive lung disease</td>
<td>59</td>
<td>Male</td>
<td>26</td>
<td>0.5</td>
<td>66</td>
</tr>
<tr>
<td>Sepsis</td>
<td>Obstructive lung disease</td>
<td>49</td>
<td>Male</td>
<td>15</td>
<td>0.5</td>
<td>52</td>
</tr>
<tr>
<td>Liver transplantation</td>
<td>Obstructive lung disease</td>
<td>47</td>
<td>Male</td>
<td>20</td>
<td>0.5</td>
<td>58</td>
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<tr>
<td>Acute respiratory failure</td>
<td>Restrictive lung disease</td>
<td>70</td>
<td>Male</td>
<td>24</td>
<td>0.4</td>
<td>68</td>
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<tr>
<td>Pneumonia</td>
<td>$\alpha_1$-Antitrypsin deficiency</td>
<td>54</td>
<td>Male</td>
<td>18</td>
<td>0.4</td>
<td>50</td>
</tr>
<tr>
<td>Hemicolecotomy</td>
<td>Obstructive lung disease</td>
<td>73</td>
<td>Female</td>
<td>31</td>
<td>0.5</td>
<td>60</td>
</tr>
<tr>
<td>Multivisceral transplantation/sepsis</td>
<td>Pneumonia</td>
<td>36</td>
<td>Female</td>
<td>33</td>
<td>0.4</td>
<td>ND</td>
</tr>
<tr>
<td><strong>Mean (SD)</strong></td>
<td><strong>56.4 (11.5)</strong></td>
<td><strong>27.9 (10.5)</strong></td>
<td><strong>0.46 (0.05)</strong></td>
<td><strong>56.8 (9.1)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonresponders</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver transplantation</td>
<td>Postoperative complications</td>
<td>45</td>
<td>Male</td>
<td>51</td>
<td>0.4</td>
<td>30</td>
</tr>
<tr>
<td>Heart-bilateral lung transplantation</td>
<td>Diffuse alveolar disease</td>
<td>41</td>
<td>Female</td>
<td>39</td>
<td>0.5</td>
<td>52</td>
</tr>
<tr>
<td>Sepsis</td>
<td>Acute respiratory failure</td>
<td>40</td>
<td>Female</td>
<td>43</td>
<td>0.5</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>Acute respiratory distress syndrome</td>
<td>53</td>
<td>Female</td>
<td>55</td>
<td>0.5</td>
<td>41</td>
</tr>
<tr>
<td>Liver transplantation</td>
<td>Postoperative complications</td>
<td>48</td>
<td>Female</td>
<td>65</td>
<td>0.4</td>
<td>ND</td>
</tr>
<tr>
<td><strong>Mean (SD)</strong></td>
<td><strong>42.4 (15.0)</strong></td>
<td><strong>NA</strong></td>
<td><strong>50.6 (10.2)</strong></td>
<td><strong>0.46 (0.05)</strong></td>
<td><strong>41.0 (9.0)</strong></td>
<td></td>
</tr>
<tr>
<td>Responders plus nonresponders</td>
<td><strong>Mean (SD)</strong></td>
<td><strong>52.5 (11.0)</strong></td>
<td><strong>NA</strong></td>
<td><strong>36.0 (15.1)</strong></td>
<td><strong>0.46 (0.05)</strong></td>
<td><strong>51.5 (11.6)</strong></td>
</tr>
</tbody>
</table>

NA indicates not applicable; ND, not determined.
addition, analysis revealed significant 3-way univariate interactions (group, condition, time) for VT (P = .006), Vmin (P = .008), and VT/TI (P < .001).

Responders had a 13% decrease in VT, a 10% decrease in Vmin, and a 19% decrease in VT/TI when comparisons were made between baseline and 2 hours during TGI (Figure 3). The respiratory rate remained unchanged. During the no-TGI condition, responders’ respirations increased 19%; VT, 26%; Vmin, 57%; and VT/TI, 39%.

For nonresponders, comparisons between baseline and 2-hour values during TGI indicated a 24% increase in VT, a 42% increase in Vmin, and a 43% increase in VT/TI (Figure 4). Without TGI, changes in these variables were minimal.

Analysis of demographic data and data on medical conditions indicated that responders were more likely than nonresponders to have a history of obstructive or restrictive lung disease and that nonresponders were more likely than responders to have an acute pulmonary problem (P = .02). In addition, responders received mechanical ventilation for fewer days than did nonresponders (mean = 27.9 days; SD = 10.5 days vs mean = 50.6 days; SD = 10.2 days, respectively; P = .002). After Bonferroni correction was used, differences in sex, age, and pretrial PaCO2 were not significant. However, analysis indicated a trend toward a higher pretrial PaCO2 in the responders than in the nonresponders (P = .05).

Discussion

We found that adding TGI during a T-piece trial in patients being weaned from prolonged mechanical ventilation produced changes consistent with a decrease in ventilatory demand in some but not all patients. Those patients most likely to benefit from TGI had a history of obstructive or restrictive lung disease and tended to be hypercapnic, whereas those with an acute pulmonary process tended to have an adverse response to TGI during weaning trials. In addition, duration of mechanical ventilation differed in the 2 groups; responders received ventilatory support for fewer days than nonresponders did.

For a given level of ventilation, increasing respiratory rate, although simultaneously limiting the VT of each breath, can minimize energy output. The consequence (ie, rapid, shallow breathing) can be considered an adaptation to reduce fatigue. Unfortunately, as VT decreases, VDS increases, and this increase reduces ventilatory efficiency. Therefore, Vmin must be increased or hypercapnia will develop. In this situation, TGI might confer unique benefits because it can reduce VDS/VT and inspired VT and enhance the efficiency of carbon dioxide elimination, thus decreasing the imbalance between ventilatory demand and capacity. Our findings suggest that use of TGI may reduce ventilatory demand, but only in patients with underlying obstructive or restrictive pulmonary dysfunction.

Table 2 Ventilatory and cardiopulmonary responses to tracheal gas insufflation (TGI) during weaning from mechanical ventilation at baseline and 2 hours later with and without TGI*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Responders</th>
<th>No TGI</th>
<th>Responders</th>
<th>No TGI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TGI</td>
<td>2 hours</td>
<td>Baseline</td>
<td>2 hours</td>
</tr>
<tr>
<td>Respirations, breaths/minute</td>
<td>22 (6)</td>
<td>22 (8)</td>
<td>21 (6)</td>
<td>25 (11)</td>
</tr>
<tr>
<td>Tidal volume, mL/kg</td>
<td>478 (255)</td>
<td>418 (181)</td>
<td>415 (172)</td>
<td>524 (213)</td>
</tr>
<tr>
<td>Minute ventilation, L/min</td>
<td>9.4 (3.5)</td>
<td>8.5 (4.3)</td>
<td>8.3 (3.1)</td>
<td>13.0 (8.8)</td>
</tr>
<tr>
<td>Mean inspiratory flow, mL/sec</td>
<td>520 (427)</td>
<td>423 (285)</td>
<td>375 (170)</td>
<td>521 (312)</td>
</tr>
<tr>
<td>Mean arterial pressure, mm Hg</td>
<td>82 (9)</td>
<td>81 (8)</td>
<td>80 (15)</td>
<td>89 (13)</td>
</tr>
<tr>
<td>Heart rate, beats per minute</td>
<td>97 (14)</td>
<td>93 (16)</td>
<td>94 (14)</td>
<td>97 (17)</td>
</tr>
<tr>
<td>Oxygen saturation, %</td>
<td>98 (2)</td>
<td>99 (1)</td>
<td>98 (2)</td>
<td>98 (2)</td>
</tr>
</tbody>
</table>

*Values are mean (SD). Mean inspiratory flow = tidal volume/inspiratory time.
Nakos et al evaluated the effect of TGI in 12 spontaneously breathing patients with COPD who were undergoing weaning from mechanical ventilation; 7 of the 12 had an endotracheal tube in place, and 5 had a tracheostomy tube. During TGI, VT, V\text{min}, PaCO\textsubscript{2}, and V\text{DS}/VT were reduced in a flow-dependent manner when gas was delivered through the endotracheal tube at flow rates of 3 and 6 L/min. The patients with tracheostomy tubes had a similar response, but significant changes occurred only during the higher flow rate (ie, 6 L/min), presumably because the tracheostomy reduced V\text{DS}. In our study, we used a single flow rate (6 L/min), and the responder group, predominately patients with obstructive lung disease, had similar changes in VT and V\text{min}.

The group we characterized as nonresponders had different changes. Without TGI, nonresponders increased respiratory rate 16% but had minimal increases in VT (2%) and V\text{min} (5%), as would be anticipated during a weaning trial. During TGI, respirations changed minimally (8%), but marked increases occurred in VT (24%) and V\text{min} (42%). Consequently, the ventilatory pattern in nonresponders did not change despite tracheal gas flow. Thus, the patients realized a 100-mL increase in VT equivalent to the gas flow delivered by the catheter during inspiration. The reason neither respiratory rate nor VT decreased during TGI is unknown, but it might have been an overriding increase in respiratory drive. All patients characterized as nonresponders experienced acute respiratory failure due to an acute pulmonary process and, except for 1 patient, were normocapnic. Notably, the nonresponder who was hypercapnic was a heart-lung transplant recipient. Presumably, the consequences of pulmonary denervation precluded a similar response in this patient, as in other patients with hypercapnia. The ventilatory response to TGI in hypercapnic patients with obstructive and restrictive lung disease in our study was similar to that reported in patients receiving transtracheal oxygen therapy. Like our patients, those patients consistently had a substantial reduction in inspired VT and V\text{min}. Further, airway insufflation via a transtracheal catheter reduces the oxygen cost of breathing and shifts the diaphragm to a less demanding pattern. The changes in responders to TGI might facilitate the ability to tolerate a longer weaning trial; however, we did not evaluate this potential.

Responses to TGI in patients who experienced acute respiratory failure and were successfully weaned from mechanical ventilation were evaluated in several other studies. Schönhofer et al inserted a transtracheal catheter into the tracheostomy stoma and closed the area around the stoma with a latex membrane. Thereafter, measures were taken during two 1-hour trials in which patients received TGI at a flow rate of 2 L/min or no flow. However, the long-term response was not evaluated. Bergofsky et al used a similar

Figure 3: Impact of tracheal gas insufflation (TGI) on responders. Percentage change in respirations, tidal volume (VT), minute ventilation (V\text{min}), and mean inspiratory flow (VT/TI) from baseline (before weaning trial) to 2 hours later with TGI (flow; light bars) and without TGI (no flow; dark bars).

Figure 4: Impact of tracheal gas insufflation (TGI) on nonresponders. Percentage change in respirations, tidal volume (VT), minute ventilation (V\text{min}), and mean inspiratory flow (VT/TI) from baseline (before weaning trial) to 2 hours later with TGI (flow; light bars) and without TGI (no flow; dark bars).
reported. Patients being weaned from mechanical ventilation are also likely to have a weak cough, making it more difficult to generate the glottic blast that dislodges mucous balls. Because of the risk of complications, the catheter should be removed from the tracheostomy tube every 8 to 12 hours to assess for the accumulation of mucus.

Most studies of TGI in mechanically ventilated patients were short-term, and the investigators either did not report if the TGI gas was humidified or reported that a nonheated, dry gas was used. In 2 of 12 adults treated with mechanical ventilation who used TGI for 72 or fewer hours, catheter obstruction due to a mucous plug developed (at 58 and 67 hours) despite use of humidified gas. Both events were detected on the basis of whistling sounds emitting from the pressure-release valve on the humidifier, and no adverse sequela occurred. In another study, in which humidified and warmed gas was used with TGI in 9 premature newborns for up to 31 days (mean 17 days), no problems due to formation of a mucous plug occurred. One difference between the gas-conditioning techniques used in these studies was that Danan et al used a heated humidifier, whereas Kuo et al humidified but did not heat the inspired gas.

Data on changes in the airway morphology after use of TGI are limited. Danan et al found no tracheal abnormalities at autopsy in 3 premature newborns who had received TGI for 5, 7, or 30 days. Christopher et al reported no abnormalities in 13 adults who had received transtracheal oxygen for a mean of 29 months (SD 26 months) and were subsequently treated with oxygen nocturnally at a flow rate of 10 L/min for 3 months as part of a clinical trial. Nocturnally, gas at high flow rates was provided via a high-humidity oxygen enricher. In this study, bronchoscopic examination revealed no evidence of hemorrhage, exudates, ulceration, or necrosis before or after use of the higher flow rate. On the basis of the limited data available, TGI appears to cause no untoward damage to the airway.

Our study was subject to several limitations. The sample size was small, and post hoc analysis was used to identify responders and nonresponders to TGI. Our findings are therefore preliminary and should be tested in a prospective randomized trial. The patients most likely to benefit from TGI tended to have hypercapnia, as indicated by arterial blood gas analysis of blood samples obtained within 3 days of data collection when the patients were off mechanical ventilation. Our ability to fully evaluate a potential decrease in PaCO2 with TGI was limited by the use of noninvasive measures. Patients in our protocol were being weaned from prolonged mechanical ventilation and no longer had arterial catheters in place. We chose not to reininsert
arterial catheters. To equalize airflow resistance between conditions (ie, TGI and no TGI), we positioned a catheter in the tracheostomy tube during both conditions. Therefore, we were able to analyze the effects of TGI independent of the effects due to airflow resistance. Our findings might have differed if the catheter had not been present during the no-flow condition. Finally, our study was designed to evaluate only the short-term response to TGI and therefore does not provide any information about the ability of this technique to facilitate weaning from mechanical ventilation.

In summary, use of TGI during a 2-hour T-piece trial produced changes consistent with a decrease in ventilatory demand in some but not all patients being weaned from prolonged mechanical ventilation. Responders, that is, patients most likely to benefit from TGI, were more likely than nonresponders to have a history of obstructive or restrictive lung disease and received mechanical ventilation for fewer days than nonresponders did. Nonresponders were more likely than responders to have an acute pulmonary process.

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REFERENCES

Effect of Tracheal Gas Insufflation During Weaning From Prolonged Mechanical Ventilation: A Preliminary Study

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