

# Spontaneously Breathing Lung Model Comparison of Work of Breathing Between Automatic Tube Compensation and Pressure Support

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**INTRODUCTION:** Automatic tube compensation (ATC), a new ventilation mode that compensates for the work of breathing imposed by endotracheal tube resistance, recently became commercially available. **METHODS:** We conducted a laboratory study with a lung model and a Nellcor Puritan Bennett 840 ventilator to compare ATC and pressure-support ventilation (PSV). A bellows-in-a-box lung model simulated spontaneous breathing with the following settings: respiratory rate 10 breaths/min, inspiratory time 1.0 s, peak inspiratory flow 60 L/min without connecting to the ventilator and endotracheal tube (ETT). At each ETT size (5, 6, 7, 8 and 9 mm inner diameter) 100% ATC was compared with pressure support (PS) of 0, 2, 4, 6, 8, and 10 cm H<sub>2</sub>O at positive end-expiratory pressure (PEEP) of 0 and 5 cm H<sub>2</sub>O. The negative deflection (PI) of the “alveolar” pressure (ie, pressure inside the bellows, P<sub>alv</sub>) and the delay time were measured. The PI and total pressure-time product (PTP<sub>tot</sub>) integrated from P<sub>alv</sub> were analyzed. PTP<sub>tot</sub> was subdivided into PTP<sub>trig</sub> (the PTP from the beginning of inspiration to the minimum P<sub>alv</sub>) and PTP<sub>supp</sub> (the PTP from the minimum P<sub>alv</sub> to the return to baseline P<sub>alv</sub>). **RESULTS:** At PEEP of 0 cm H<sub>2</sub>O: with ETTs of 5, 6, and 7 mm the PI values with ATC corresponded to PS of 0–4 cm H<sub>2</sub>O; with the 8-mm ETT the PI values corresponded to PS of 0 cm H<sub>2</sub>O; with the 9-mm ETT the PI values corresponded to PS of 0–2 cm H<sub>2</sub>O. At PEEP of 5 cm H<sub>2</sub>O, with all ETT sizes the PI values corresponded to PS of 0 cm H<sub>2</sub>O. PTP<sub>tot</sub> and PTP<sub>supp</sub> of ATC corresponded to: PS of 2–4 cm H<sub>2</sub>O with the 5-mm ETT; PS of 2 cm H<sub>2</sub>O with the 6-mm ETT; PS of 0–2 cm H<sub>2</sub>O with the 7-mm ETT; and PS of 0 cm H<sub>2</sub>O with the 8- and 9-mm ETTs, at PEEP of 0 cm H<sub>2</sub>O. PEEP of 5 cm H<sub>2</sub>O was not tested for PTP. PTP<sub>trig</sub> with ATC showed comparable or greater values with each size of ETT. **CONCLUSIONS:** ATC with a Nellcor Puritan Bennett 840 ventilator provided inspiratory ventilatory support corresponding to PS of ≤ 4 cm H<sub>2</sub>O, depending on ETT size, which was not enough to compensate for the work of breathing imposed by the ETT. *Key words:* automatic tube compensation, pressure support, work of breathing, pressure-time product, imposed work, weaning. [Respir Care 2003;48(1):38–45]

## Introduction

In addition to coping with the effects of underlying disease, patients undergoing mechanical ventilation have

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to overcome additional work of breathing (WOB) imposed by resistance in the ventilator circuit, including the inspiratory and expiratory valves and the endotracheal tube (ETT). Pressure-support ventilation (PSV) is a popular mode with which to wean patients from mechanical ventilation.<sup>1,2</sup> PSV supports inspiration with a pre-set and constant inspiratory pressure. Ideally, during weaning with PSV, support pressure should be reduced to a level that does no more than compensate for the imposed additional WOB. However,

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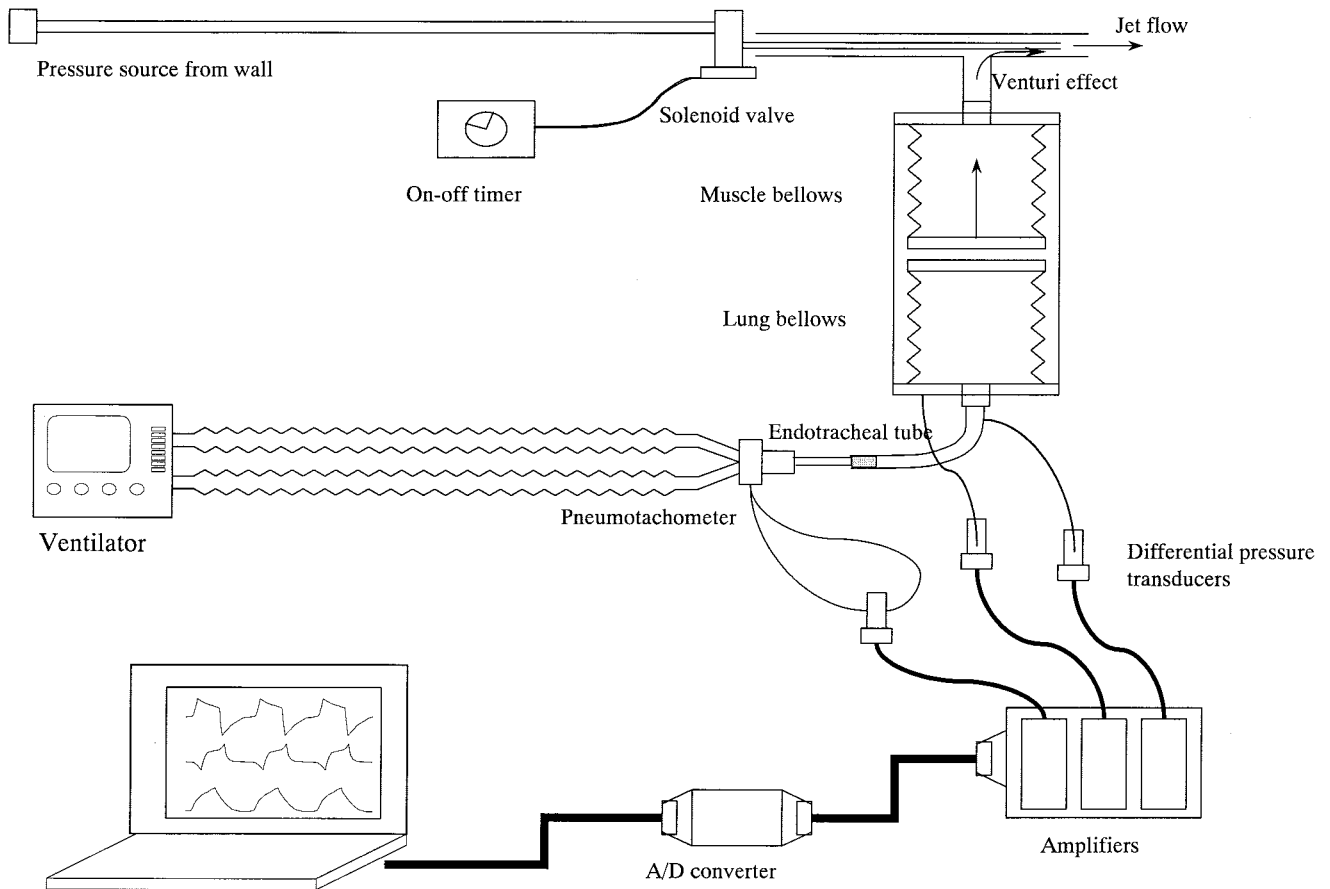


Fig. 1. Experimental setup. A/D = analog-to-digital.

the WOB is highly variable, depending on inspiratory effort, because the pressure drop across the ETT is flow-dependent in a nonlinear way.<sup>3</sup> Fiastro et al evaluated the pressure support level required to eliminate the extra WOB (2–20 cm H<sub>2</sub>O).<sup>4</sup> Haberthür et al showed that the imposed additional WOB related to the ETT can be more than 50% of total WOB in ventilator-dependent patients.<sup>5</sup>

Automatic tube compensation (ATC), a new technology that compensates for the ETT-imposed WOB, recently became commercially available.<sup>5–9</sup> ATC was designed to increase airway pressure by continuously calculating pressure drop across the ETT during inspiration and to decrease airway pressure during expiration to maintain constant alveolar pressure.<sup>3</sup> The prototype ATC mode used subatmospheric pressure to provide tube compensation during expiration.<sup>5–8</sup> A subsequent study used a ventilator that compensated during expiration by reducing airway pressure, but not to subatmospheric pressure.<sup>9</sup> Other manufacturers implemented inspiratory-only ATC. In Europe a pilot clinical study recently compared PSV with T-piece and ATC as a weaning mode.<sup>10</sup>

Ventilator performance can affect the results of a clinical study. In laboratory studies using a lung model we

evaluated the performance characteristics<sup>11,12</sup> of ATC delivered by a Nellcor Puritan Bennett (NPB) 840 ventilator for alleviating the inspiratory WOB imposed by the ETT and triggering function, in comparison with PSV.

## Methods

### Lung Model

A custom-made bellows-in-a-box lung model was used to simulate spontaneous breathing (Fig. 1).<sup>11</sup> The space between the rigid box and the bellows simulates the pleural space. The lower bellows simulates the lung. The upper bellows, which simulates the diaphragm, was connected to a metal T-tube through which gas was injected to create negative pressure in the pleural space, owing to the Venturi effect. Source gas (air at 50 psi) was connected to a custom-made pressure regulator and a proportional solenoid valve (SMC 315, SMC, Tokyo, Japan) controlled by a function generator (H3BF, Omron, Tokyo, Japan). Inspiratory flow demand, inspiratory time, and respiratory rate were controlled by setting the pressure regulator and function generator. This lung model generates inspiratory flow with a decelerating

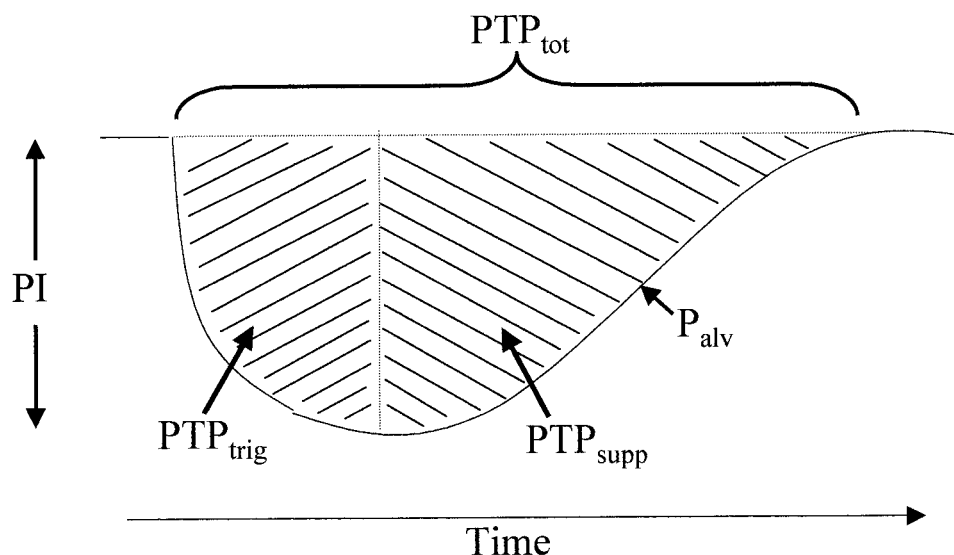


Fig. 2. Data analysis. The negative deflection (PI) of the “alveolar” pressure (ie, pressure inside the bellows,  $P_{alv}$ ) is the maximum pressure drop from baseline during inspiratory triggering, and is reported as a positive value. The total pressure-time product ( $PTP_{tot}$ ) is calculated as the integral of the negative deflection from the point where  $P_{alv}$  began to decrease from baseline to the point where  $P_{alv}$  returned to baseline.  $PTP_{tot}$  is subdivided into  $PTP_{trig}$  (the pressure-time product required for triggering) and  $PTP_{supp}$  (the pressure-time product during assist by the ventilator). Delay time is the time interval between the beginning of  $P_{alv}$  decline and the minimum  $P_{alv}$  value.

waveform, and expiration is passive. The lung model compliance was set at 46.8 mL/cm H<sub>2</sub>O. The ETT was connected between the lung model and ventilator. When attached to the ventilator, using the ventilator’s standard circuit, without a humidifier, the lung model was set as follows: spontaneous breathing rate 10 breaths/min, inspiratory time 1.0 s, peak inspiratory flow 60 L/min without connecting to the ventilator and endotracheal tube (ETT).

### Measurements

A pneumotachometer (model 4700 [0–160 L/min], Hans Rudolph, Kansas City, Missouri) calibrated using a precision flow meter, was placed at the airway opening of the lung model. Pressure transducers (Model TP603T [ $\pm 50$  cm H<sub>2</sub>O], Nihon Kohden, Tokyo, Japan), which had been calibrated at 20 cm H<sub>2</sub>O using a water manometer, measured the pressure differential across the pneumotachometer, the pressure at the airway opening, and the “alveolar” pressure (the pressure inside the lower bellows,  $P_{alv}$ ). The data signals from these devices were amplified, digitized, and recorded at 100 Hz signal resolution using data acquisition software (WINDAQ, Dataq Instruments, Akron, Ohio). Each 3 breaths were analyzed, and average values from these were used.

### Experimental Protocol

Using an NPB840 ventilator (Nellcor Puritan Bennett/Mallinckrodt, Pleasanton, California), with each size of

ETT and with positive end-expiratory pressure (PEEP) of 0 or 5 cm H<sub>2</sub>O, ATC was compared with pressure support (PS) of 0, 2, 4, 6, 8, and 10 cm H<sub>2</sub>O. The NPB840 is designed to deliver ATC only during inspiration, and ATC is set by setting the ETT size. We studied ETTs with inner-diameters of 5, 6, 7, 8, and 9 mm. ATC was set at 100%. For ATC and PSV, inspiratory trigger sensitivity was set at 1.0 L/min and expiratory sensitivity was set at 30%. The PSV inspiratory flow acceleration was set at 50%. The fraction of inspired oxygen was set at 0.21 throughout the study.

### Data Analysis and Statistics

$P_{alv}$  was considered equivalent to in vivo pleural pressure. The negative deflection (PI) of  $P_{alv}$  was defined as the maximum pressure drop from baseline during inspiratory triggering and is presented in positive values. The total pressure-time product ( $PTP_{tot}$ ) was calculated as the integral of PI with time from the point where  $P_{alv}$  began to decrease from baseline to the point where  $P_{alv}$  returned to baseline, which was used as an index of WOB during inspiration (Fig. 2).<sup>13,14</sup>  $PTP_{tot}$  was subdivided into  $PTP_{trig}$  (the PTP from the beginning of inspiration to the minimum  $P_{alv}$ ) and  $PTP_{supp}$  (the PTP from the minimum  $P_{alv}$  to the return to baseline  $P_{alv}$ ). Delay time (DT) was defined as the time between the beginning of  $P_{alv}$  decline and the minimum  $P_{alv}$  value. Data are expressed as mean  $\pm$  SD. Two-way analysis of variance (ANOVA) was performed to

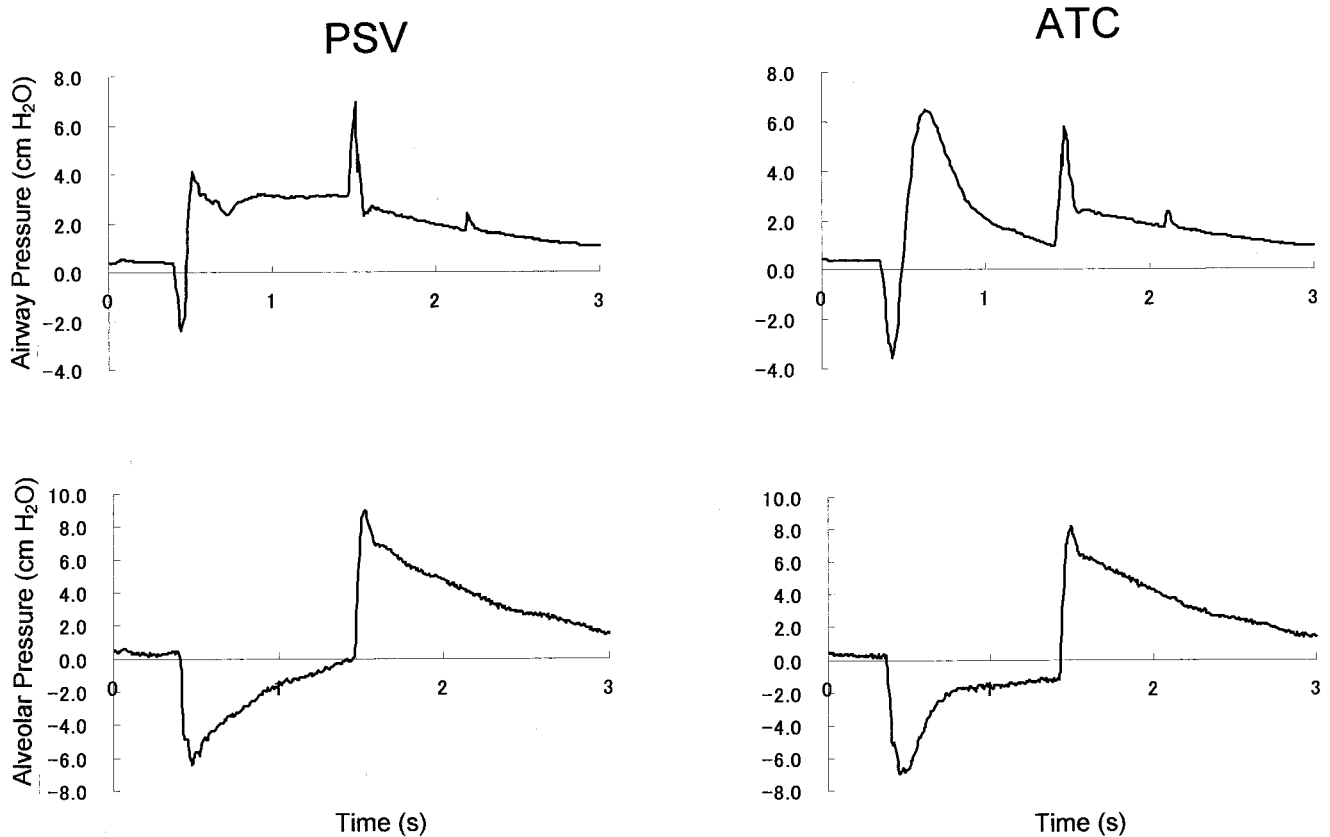


Fig. 3. Waveforms of airway and alveolar pressures during pressure-support ventilation (PSV) with pressure support of 4 cm H<sub>2</sub>O and automatic tube compensation (ATC) with a 5 mm inner-diameter endotracheal tube and zero positive end-expiratory pressure. Alveolar pressure with ATC increased after triggering, but it did not reach end-expiratory pressure. At the end of inspiration, airway pressure rose sharply with both ATC and PSV.

compare each variable at each PS setting and ATC between PEEP of 0 and 5 cm H<sub>2</sub>O. Scheffé's test was performed as a post hoc test for multiple comparisons. Differences were considered statistically significant when  $p < 0.05$ .

### Results

Figure 3 shows the airway and alveolar pressure waveforms with PS of 4 cm H<sub>2</sub>O and ATC with the 5-mm ETT and PEEP of 0 cm H<sub>2</sub>O. Alveolar pressure with ATC increased after triggering, but it did not reach end-expiratory airway pressure. At the end of inspiration, airway pressure rose sharply with both ATC and PSV. Supported pressure with ATC decreased as tube size increased. With the 8- and 9-mm ETTs the average supported pressures were  $< 1$  cm H<sub>2</sub>O (Fig. 4).

Table 1 shows the PI and DT values at each setting. As the tube diameter increased, PI decreased significantly at all settings ( $p < 0.001$  by ANOVA) and DT decreased significantly at PS of 2, 4, 8, and 10 cm H<sub>2</sub>O ( $p < 0.05$  by ANOVA). With the 8-mm ETT the PI at PS of 10 cm H<sub>2</sub>O and PEEP of 0 cm H<sub>2</sub>O was significantly less than that at

PEEP of 5 cm H<sub>2</sub>O ( $p < 0.05$ ). With the 9-mm ETT the PI at PS of 8 and 10 cm H<sub>2</sub>O and PEEP of 0 cm H<sub>2</sub>O was significantly less than that at PEEP of 5 cm H<sub>2</sub>O. The DT at PS of 10 cm H<sub>2</sub>O and PEEP of 0 cm H<sub>2</sub>O was significantly shorter than that with PEEP of 5 cm H<sub>2</sub>O.

At PEEP of 0 cm H<sub>2</sub>O, the PI values for ATC were not significantly different from those for PS of 0–4 cm H<sub>2</sub>O with ETTs of 5, 6, or 7 mm, PS of 0 with the 8-mm ETT, or PS of 0–2 cm H<sub>2</sub>O with the 9-mm ETT. At PEEP of 5 cm H<sub>2</sub>O, the PI values for ATC were greater than those at all PSV settings with ETTs of 5, 6, 7, and 9 mm ( $p < 0.05$ ). The PI value for ATC with the 8-mm ETT and PEEP of 5 cm H<sub>2</sub>O was not significantly different than that for PS of 0 cm H<sub>2</sub>O (see Table 1).

PTP was only assessed with PEEP of 0 cm H<sub>2</sub>O. With the 5-mm ETT, PTP<sub>tot</sub> and PTP<sub>supp</sub> of ATC corresponded to PS of 2–4 cm H<sub>2</sub>O, with the 6-mm ETT to PS of 2 cm H<sub>2</sub>O, with the 7-mm ETT to PS of 0–2 cm H<sub>2</sub>O, and with ETTs of 8, and 9 mm to PS of 0 cm H<sub>2</sub>O. At each ETT size, PTP<sub>trig</sub> with ATC showed comparable or greater values (Fig. 5).

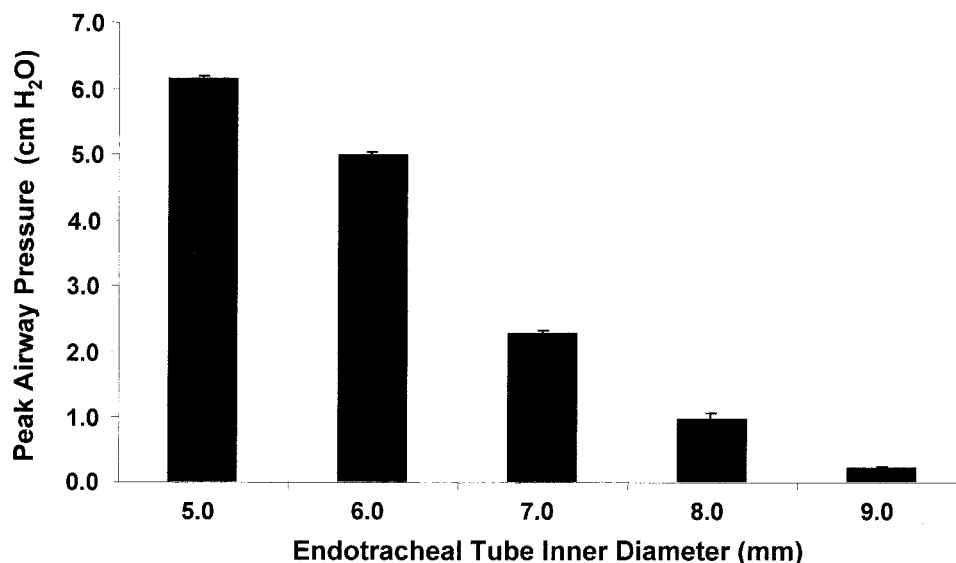


Fig. 4. Peak airway pressure above the set positive end-expiratory pressure during automatic tube compensation with each size of endotracheal tube.

### Discussion

The major findings of this study are:

1. With the NPB840, with PEEP of 0 cm H<sub>2</sub>O the ATC support corresponds to PS of  $\leq 4$  cm H<sub>2</sub>O (with the NPB840), but with PEEP of 5 cm H<sub>2</sub>O the support was less.
2. With each size of ETT, PTP<sub>trig</sub> with ATC showed similar or greater values than with PSV.
3. ATC undercompensates the ETT-imposed WOB because of the work of triggering.

In mechanically ventilated patients the WOB imposed by the ETT and by the underlying lung disease must be compensated. The ETT-imposed WOB can exceed 50% of the total WOB.<sup>5</sup> The pressure-support required to offset that WOB is highly variable.<sup>4,15</sup> The pressure drop across the ETT ( $\Delta P_{\text{tube}}$ ) can be approximated with a Rohrer's equation:

$$\Delta P_{\text{tube}} = K_1 \cdot \dot{V} + K_2 \cdot \dot{V}^2$$

in which  $K_1$  and  $K_2$  are the tube-specific coefficients and  $\dot{V}$  is the flow.<sup>3</sup>  $\dot{V}$  can vary by inspiratory effort and is not constant even within each breath. Therefore it is impossible to offset the ETT-imposed WOB by a pre-set constant pressure. ATC is a new option to offset the ETT-imposed WOB. ATC was originally implemented to increase airway pressure by continuously calculating pressure drop across the ETT, using the equation described above during inspiration, and to decrease airway pressure during expiration to maintain constant tracheal pressure.

Using a modified Evita-1 ventilator with 2 groups of patients (normal minute ventilation and increased ventila-

tory demand), Fabry et al compared the effects of ATC and PS at 5, 10, and 15 cm H<sub>2</sub>O on breathing pattern and additional WOB (WOB<sub>add</sub>) due to ETT and demand valve resistance. They concluded that ATC was suitable for compensating WOB<sub>add</sub> in patients who have increased ventilatory demand.<sup>6</sup> Guttman et al similarly reported that, for 10 healthy volunteers, ATC provided more respiratory comfort than PSV.<sup>7</sup> In 10 tracheotomized patients, after evaluating WOB<sub>add</sub> while comparing ATC to PS of 5, 10, and 15 cm H<sub>2</sub>O, Haberthür et al concluded that ATC suitably compensated for WOB<sub>add</sub>, whatever the patient's ventilatory effort.<sup>8</sup> Haberthür et al measured total WOB in addition to the tube-imposed WOB in ventilator-dependent patients and compared ATC, continuous positive airway pressure, and PS of 5, 10, and 15 cm H<sub>2</sub>O. They concluded that ATC gave the best compensation of ETT-imposed resistance.<sup>5</sup> Mols et al, using volunteers, compared breathing comfort during ATC and PSV with 2 different rise times. They concluded that ATC was perceived as most comfortable during both inspiration and expiration.<sup>9</sup>

Whereas in the latter studies the investigators used customized ventilators that could compensate for the ETT resistance during both inspiration and expiration, we used an NPB840 ventilator that compensates only the inspiratory ETT-imposed resistance. Comparison of results is further complicated because the ventilator triggering function in our study was probably different from those in the previous studies.

In our study PTP<sub>trig</sub> values during ATC were similar to or greater than those during some PSV settings. We speculate that this difference was mainly due to the longer delay time of ATC (see Table 1), which may be attribut-

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Table 1. Delay Time and Negative Deflection of Alveolar Pressure with Various Endotracheal Tubes and Ventilation Settings

			Endotracheal Tube Inner Diameter				
			5 mm	6 mm	7 mm	8 mm	9 mm
PS 0 cm H <sub>2</sub> O	PI	0	6.82 ± 0.11	6.39 ± 0.25	6.28 ± 0.15	5.98 ± 0.12	5.37 ± 0.22
		5	6.77 ± 0.10*	6.37 ± 0.20*	5.98 ± 0.22*	5.91 ± 0.15	5.53 ± 0.20*
	DT	0	90 ± 10	80 ± 0	80 ± 0	77 ± 6	80 ± 0
		5	83 ± 6	80 ± 0*	87 ± 6	80 ± 0	83 ± 6
PS 2 cm H <sub>2</sub> O	PI	0	6.99 ± 0.18	6.32 ± 0.14	6.12 ± 0.07	5.63 ± 0.12*	5.44 ± 0.08
		5	6.90 ± 0.10*	6.43 ± 0.14*	6.00 ± 0.07*	5.83 ± 0.05*	5.21 ± 0.21*
	DT	0	83 ± 6	80 ± 0	80 ± 0	80 ± 0	73 ± 6
		5	80 ± 0	80 ± 0*	80 ± 0	80 ± 0	77 ± 6
PS 4 cm H <sub>2</sub> O	PI	0	6.79 ± 0.09	6.31 ± 0.09	6.11 ± 0.31	5.62 ± 0.23*	5.30 ± 0.30
		5	6.79 ± 0.15*	6.27 ± 0.12*	5.93 ± 0.12*	5.85 ± 0.16*	5.24 ± 0.35*
	DT	0	87 ± 6	80 ± 0	77 ± 6	73 ± 6	77 ± 6
		5	87 ± 6	80 ± 0*	80 ± 0	73 ± 6	77 ± 6
PS 6 cm H <sub>2</sub> O	PI	0	6.65 ± 0.13*	6.26 ± 0.05*	5.83 ± 0.09*	5.37 ± 0.33*	5.51 ± 0.55
		5	6.61 ± 0.17*	6.13 ± 0.05*	6.01 ± 0.16*	5.80 ± 0.22*	5.38 ± 0.06*
	DT	0	80 ± 0	80 ± 0	90 ± 10	77 ± 6	73 ± 6
		5	80 ± 0	80 ± 0*	77 ± 6	80 ± 10	77 ± 6
PS 8 cm H <sub>2</sub> O	PI	0	6.55 ± 0.22*	5.98 ± 0.15*	5.61 ± 0.13*	5.26 ± 0.17*	5.01 ± 0.14*†
		5	6.61 ± 0.18*	6.06 ± 0.06*	5.87 ± 0.04*	5.53 ± 0.08*	5.51 ± 0.20*
	DT	0	87 ± 6	80 ± 0	80 ± 0	73 ± 12	60 ± 10*
		5	77 ± 12	87 ± 6	73 ± 6	80 ± 10	70 ± 0*
PS 10 cm H <sub>2</sub> O	PI	0	6.50 ± 0.02*	5.88 ± 0.14*	5.44 ± 0.13*	5.14 ± 0.02*†	4.62 ± 0.05*†
		5	6.65 ± 0.14*	6.12 ± 0.10*	5.47 ± 0.14*	5.49 ± 0.04*	5.28 ± 0.23*
	DT	0	80 ± 0	80 ± 0	70 ± 0*	70 ± 10	57 ± 6*†
		5	83 ± 6	73 ± 6*	77 ± 6	73 ± 6	70 ± 0*
ATC	PI	0	7.20 ± 0.02	6.72 ± 0.12	6.63 ± 0.02	6.44 ± 0.13	6.25 ± 0.23
		5	7.42 ± 0.09	6.80 ± 0.00	6.54 ± 0.07	6.50 ± 0.31	6.37 ± 0.14
	DT	0	110 ± 17	87 ± 6	87 ± 6	87 ± 6	83 ± 6
		5	90 ± 0	97 ± 6	90 ± 10	87 ± 6	90 ± 0

PEEP = positive end-expiratory pressure  
 PS = pressure support  
 PI = negative deflection of alveolar pressure (cm H<sub>2</sub>O)  
 DT = delay time (ms)  
 ATC = automatic tube compensation

Values are mean ± standard deviation  
 Only the results of post-hoc tests comparing each tube size are given.  
 \*p < 0.05 versus ATC  
 †p < 0.05 versus PEEP of 5 cm H<sub>2</sub>O

able to a difference in inspiratory flow regulation in the NPB840 ventilator during ATC and PSV. As described in a previous report, the inspiratory flow acceleration during ATC is relatively slow,<sup>9</sup> which resulted in a greater triggering work with ATC.

As shown in Figure 3, P<sub>alv</sub> during ATC did not reach the baseline. This may be because of the pressure drop caused by the resistance of the pneumotachometer attached between the ventilator circuit and ETT (see Fig. 1). There is a possibility that PI and PTP were overestimated, but we compared between PSV and ATC instead of evaluating these absolute values, so our conclusion would not be affected. At the end of the inspiration a sharp rise of airway pressure was observed with both ATC and PSV. We speculate that that pressure rise is due to the mismatch of

the setting of cycling, as reported previously in studies that used the same lung model.<sup>11,12</sup> We cannot speculate as to the effect of ATC during expiration on this end-inspiratory pressure rise, because the NPB840 ventilator only delivers ATC during inspiration.

During weaning with PSV it is hard to determine the PSV level that compensates for the WOB imposed by the ETT and the demand valve of the ventilator. Our findings show that the WOB due to the time delay from the initiation of inspiration to the beginning of support by the ventilator still remains and can affect respiration during ATC. Fiastro et al found that the pressure support required to completely compensate for that WOB<sub>add</sub> is 2–20 cm H<sub>2</sub>O.<sup>4</sup> Although our study was not intended to evaluate the pressure support required to completely compensate for

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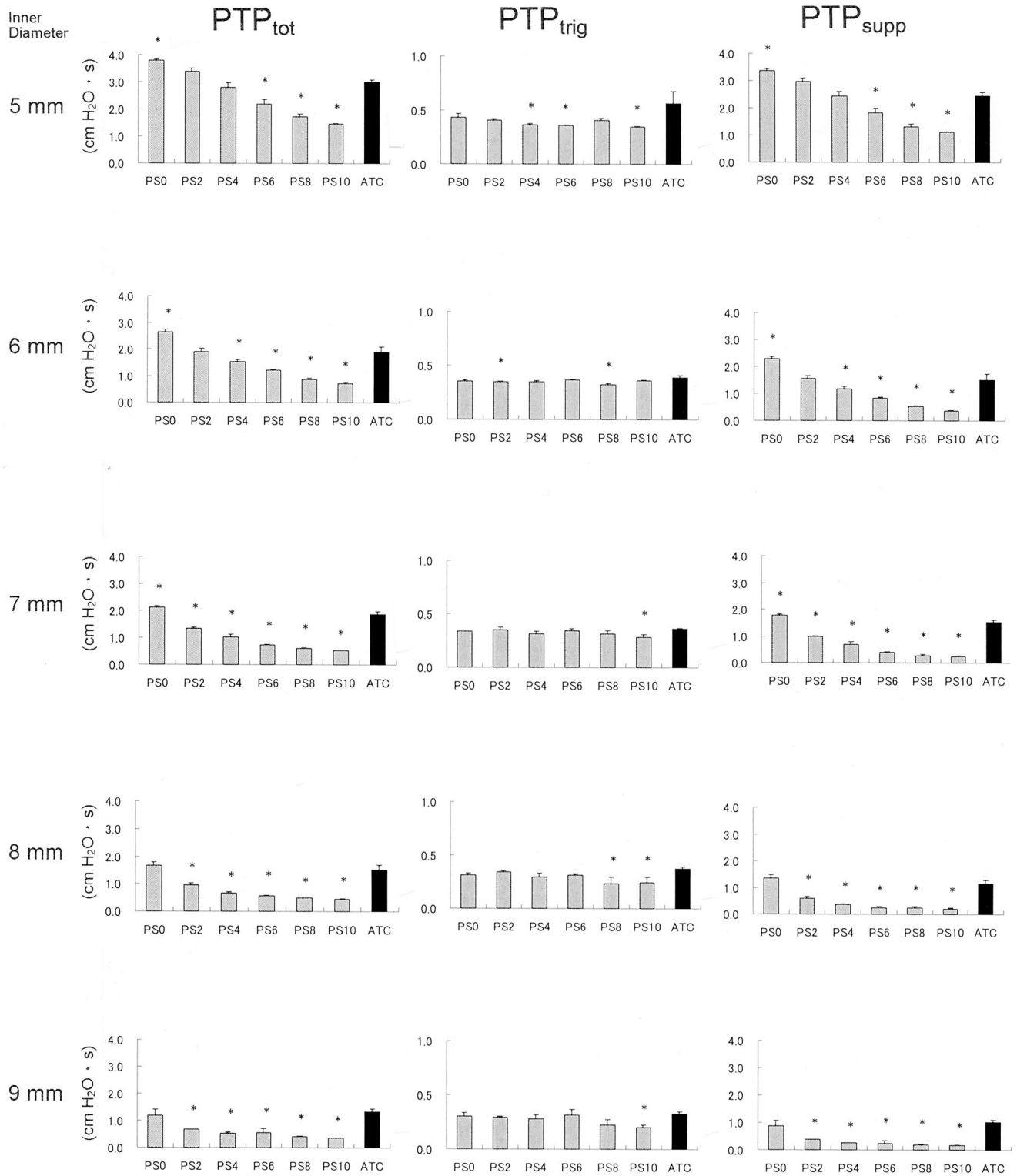


Fig. 5. Total pressure-time product ( $PTP_{tot}$ ), the pressure-time product required for triggering ( $PTP_{trig}$ ), and the pressure-time product during pressure support from the ventilator ( $PTP_{supp}$ ) at zero positive end-expiratory pressure (PEEP = 0  $cm\ H_2O$ ) with each endotracheal tube size. \* Post-hoc  $p < 0.05$  versus automatic tube compensation (ATC). PS = pressure support (0, 2, 4, 6, 8, or 10  $cm\ H_2O$ ).

the ETT-imposed WOB,  $PTP_{\text{trig}}$  during ATC was equivalent to or more than that of PSV. This may explain why the PSV levels corresponding to ATC remained relatively low. As shown in Figure 4, ventilatory support during ATC depended on ETT diameter. However, PSV levels corresponding to the support by ATC were relatively constant and independent of ETT diameter. This may also show that in our experimental setup the majority of WOB during ATC was to trigger the ventilator.

The present study is limited mainly by the characteristics of the lung model. In clinical conditions a patient's inspiratory flow is influenced by ventilatory assistance, rather than being a constant value as in the present study's experiments. It is therefore likely that the performance of ATC is underestimated in the present study. In addition, although we used the most conservative method (Scheffé's test) as a post-hoc test, it was difficult to determine the meaning of the statistical differences, because of the small standard deviation at each setting. Our results are also machine-dependent and could well be different if we used another type of ventilator, such as the Evita 4, which also offers ATC. The ATC function of the NPB840 is different than the original prototype developed by Guttman et al.<sup>5-9</sup> The prototypes were designed to compensate ETT-imposed WOB during both inspiration and expiration (by applying negative airway pressure). The Evita 4 is also designed to compensate both inspiratory and expiratory WOB, although it does not use negative pressure during expiration. The NPB840 compensates only for inspiratory WOB, so the present study focused only on inspiratory WOB. It will probably be necessary to compare the ATC functions of other ventilators.

In a T-piece trial the only  $WOB_{\text{add}}$  is that from the ETT, which is flow-dependent and thus mainly a function of tube diameter. On the other hand, the advantages of T-piece trials are that they are easy to apply and that the results are comparable with available data from patients during weaning.<sup>16,17</sup> The clinical usefulness of ATC is difficult to determine. The ATC delivered by the NPB840 does not compensate the work needed for triggering, and so its suitability during weaning is as uncertain as the suitability of PSV. A recent pilot clinical study compared PSV, T-piece, and ATC as methods for weaning from mechanical ventilation, using the same rapid shallow breathing index.<sup>10</sup> The study found no significant differences between the groups, though that result may be attributable to the small number of patients. We speculate from our results that the implementation of ATC by a manufacturer may affect the results of a clinical trial.

### Conclusion

At most experimental settings ATC with the NPB840 provided inspiratory ventilatory support corresponding to

PS of  $\leq 4$  cm H<sub>2</sub>O, which was not enough to compensate for the ETT-imposed WOB.

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