Effect of Automatic Tubing Compensation on Tidal Volume during a Spontaneous Breathing Trial using an Electronic Lung Simulator

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ABSTRACT:
Background: Automatic Tubing Compensation (ATC) is a feature used to compensate for the Work of Breathing (WOB) imposed by the endotracheal tube (ETT). When the initial problem that created the need for ventilatory support has resolved and decision is made to begin weaning trials, the clinician must determine if the patient meets criteria for a Spontaneous Breathing Trial (SBT). Recently, there has been research conducted that indicates ATC may either over-compensate (provide more pressure than is needed to overcome the WOB imposed by the ETT) or under-compensate (doesn't provide enough pressure to adequately overcome the WOB). If the machine over-compensates, additional pressure, and subsequently additional volume, will be delivered to the patient, which could cause the patient to be prematurely extubated. The purpose of our study is to determine if patient effort, the size of the ETT, or the ventilator itself impact the delivered volume.

Methods: The Hans Rudolph HR 1101 Electronic Lung Simulator was interfaced using 4 ETTs sized 7.0, 7.5, 8.0 and 8.5 by the Viasys Aava, the PB 840, and the Dräger XL. We tested at 100% compensation as well as the manufacturer recommended 80% compensation setting. Data was collected by the HR 1101 at intervals of 20 seconds. The Hans Rudolph HR 1101 was set to deliver tidal volumes at 3000 mL, a rate of 20 breaths per minute, and an increase in tidal volume of 79 mL per breath, and an additional minute ventilation of 1580 mL at a rate of 20 breaths per minute.

Results: As the internal diameter of the ETT decreased, there was a linear increase in delivered tidal volume with the Dräger and the PB 840. The most significant increase in tidal volume was using the Dräger with a size 7.0 ETT with a set amplitude of 20. The 17% increase is an increase in volume of 79 mL, per breath, and an additional minute ventilation of 1580 mL at a rate of 20 breaths per minute.

Conclusion: The findings in this study suggest that ATC does affect the tidal volume in an electronic lung simulator as amplitude (similar to patient effort) change. Therefore, clinicians must realize that ATC may augment the patient's spontaneous tidal volume and may provide additional support. This support, being insufficient to greatest pressure, is beneficial and may prevent exultation. The use of ATC during an SBT requires further evaluation in clinical settings.

Background: When clinicians assess a patient’s readiness to be weaned from ventilatory support, one of the tools available to evaluate their pulmonary status is to conduct a spontaneous breathing trial (SBT). The ventilator is placed in CPAP mode with minimal support and the Rapid Shallow Breathing Index (RSBI) is measured. The RSBI is calculated by dividing the respiratory rate by the tidal volume (measured in liters). Under ideal circumstances, clinicians do a spontaneous breathing trial with minimal support to best replicated how the patient will be able to breathe without the ventilator and endotracheal tube. We commonly give a low level of PEEP, because the normal physiologic PEEP is reduced by insertion of the endotracheal tube (ETT).

One of the recent debates among respiratory care practitioners has been the addition of automatic tube compensation (ATC) to overcome the imposed work of breathing due to the ETT. If the ventilator does not provide enough support to overcome this resistance, the patient may have an increased work of breathing, delaying extubation. If the ventilator provides more support than is needed, the patient may falsely pass the SBT, which could increase the risk of a failed extubation, necessitating the need for re-intubation. The purpose of this study is to determine how ATC, patient effort, the size of the ETT or the ventilator itself, impact the delivered volume during an SBT.

Methods: The Hans Rudolph HR 1101 Electronic Lung Simulator was interfaced using a 7.0, 7.5, 8.0 and 8.5 ETT, to the Viasys Aava, the Puritan Bennett 840, and the Dräger XL (at both 100% compensation and the manufacturer recommended 80% compensation). Data was exported to Microsoft Excel by the HR 1101 at intervals of 0.05 seconds. Settings on the HR 1101 were: Resistance 25 cm H2O/L/sec, Compliance 60 mL/cm H2O, Rate 20/minute, Slope 1, 20% Inhale, Target volume 3000 mL, Effort type SHORTIE.

The HR 1101 amplitude (similar to patient effort) was set at 5, 10, 15, and 20 for each ETT size and for each ventilator. The ventilators were set on CPAP mode, 5 cm H2O PEEP, pressure support off, and apnea override at the upper limit. Test conditions: each ETT, at each amplitude setting, with ATC on and off, over a series of 20 breaths. Tidal volumes were averaged in Microsoft Excel comparing each ETT size at amplitudes of 5, 10, 15, and 20, with ATC on and off.

Results: As ETT size decreased and amplitude (similar to patient effort) increased, tidal volume increased with the Dräger (at ATC 80% and 100% compensation) and the PB 840. The largest percentage increase occurred with an ETT size 7.0 and amplitude 20 on the Dräger (at 80% and 100%) and the PB 840, with an increase in tidal volume of 15% 17% and 12%, respectively. The 17% increase amounted to an increase in delivered volume of 79 mL per breath, and an additional minute ventilation of 1580 mL at a rate of 20 breaths per minute. It should be noted that the Viasys Aava delivered tidal volumes that were variable or not measurable using ETT sizes 7.5, 8.0, and 8.5, with an amplitude of 5, due to inconsistent triggering of breaths.

Conclusion: The findings in this study demonstrate that ATC does affect the tidal volume, when using an electronic lung simulator, as amplitude (similar to patient effort) and ETT size change. Therefore, clinicians must realize that ATC may augment the patient’s spontaneous tidal volume and may provide additional support that is removed once the patient is extubated. The use of ATC during an SBT requires further evaluation in clinical settings, particularly comparing the effects of ATC during an SBT. Clinicians must realize that the level of support provided varies based upon the ETT, patient effort and the specific ventilator being used.

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