Delivering elevated PEEP for ARDS patients using the VORTRAN $GO_2VENT^{®}$ disposable ventilator

Previous studies have shown the VORTRAN GO_2VENT® to automatically respond to changes in compliance, as seen in Acute Respiratory Distress Syndrome (ARDS) patients, by self-adjusting to increase respiratory rate (RR) and decreasing tidal volume (TV) to deliver stable minute ventilation (MV).[1] With the use of VORTRAN Medical's new inline resistance valve, PEEP can be elevated to levels recommended by the U.S Department of Defense and the NHLBI ARDS Network.[2] [3] PEEP can be increased further by increasing the flow to create a higher respiratory rate (RR). In doing so, tidal volume (TV) will automatically decrease to ensure stable minute ventilation (MV).

INTRODUCTION

VORTRAN Medical's GO_2VENT is designed for MRI ventilation, transport ventilation, and emergency use during natural disasters or disease outbreaks such as the COVID-19 pandemic. It is an FDA approved device that meets ISO guidelines for gas-powered emergency resuscitators.[4] Within seconds, it can be set up to provide ventilatory support via a secure airway and powered using a compressor, oxygen source, or air source with a minimum of 10 LPM flow rates. A unique ability of the GO2VENT is its ability to create intrinsic positive end-expiratory pressure (PEEP) that is approximately 20% of the set peak inspiratory pressure (PIP). With the use of VORTRAN's inline parabolic resistor valve, PEEP can increase to 40% (or higher) of the set PIP.

METHODS

A Training & Test Lung Simulator (TTL Model 3600i, manufactured by Michigan Instruments) with PneuView Test Lung Simulation Software was used in the benchtop evaluation of the GO_2VENT Model 6123. VORTRAN's new inline parabolic resistor valve was placed within the GO_2VENT's exhalation pathway in order to elevate PEEP without increasing PIP. At a set lung compliance, the PEEP and resulting tidal volume (TV) were measured across a typical range of PIP values (20, 25, 30, and 35 cm-H_2O) for respiratory rates (RR) of 10, 15, 20, 25, and 30 breaths-per-minute (BPM). This process was repeated for lung compliances of 0.01, 0.02, 0.03, 0.04, and 0.05 L/cm-H_2O. For all tests, the I:E ratio was kept at 1:2 ± 20% as per ISO guidelines for gas-powered emergency resuscitators.[4]

RESULTS

VORTRAN's inline parabolic resistor valve was shown to substantially increase the given PEEP value for any given PIP, respiratory rate, and lung compliance compared to the use of the GO_2VENT without the resistor valve. For patients with extremely stiff lungs that have a compliance of 0.01 L/cm-H_2O, PEEP ranged from a low of 6 cm-H_2O at a PIP of 20 cm-H_2O and respiratory rate of 10 BPM, to a high PEEP of 17 cm-H_2O at a PIP of 35 cm-H_2O and respiratory rate of 30 BPM. Tidal volumes for a lung compliance of 0.01 L/cm-H_2O ranged from 103 mL to 243 mL, which was dependent on the set PIP and respiratory rate as expected. Results for a lung compliance of 0.01 L/cm-H_2O are presented in Table 1. The inline parabolic resistor's ability to increase PEEP for a given PIP value was more pronounced as lung compliance was increased, while still providing the high tidal volumes that are necessitated by higher lung compliance. This is indicated by values that were measured for a lung compliance of 0.05 cm-H_2O, where PEEP ranged from a low of 11 cm-H_2O at a

Table 1. PEEP and Tidal Volume for Various PIP Values with Lung Compliance of 0.01 L/cm-H2O

RR ± 2 BPM	10		15		20		25		30	
Set PIP	PEEP	TV	PEEP	TV	PEEP	TV	PEEP	TV	PEEP	TV
20	6	132	6	127	7	121	7	114	9	103
25	7	171	8	162	9	151	10	144	11	130
30	8	211	9	196	11	182	12	181	14	158
35	10	243	11	233	13	209	14	210	17	174

Table 2. PEEP and Tidal Volume for Various PIP Values with Lung Compliance of 0.05 L/cm-H2O

RR ± 2 BPM	10		15		20		25		30	
Set PIP	PEEP	TV	PEEP	TV	PEEP	TV	PEEP	TV	PEEP	TV
20	11	477	13	368	15	278	16	227	17	153
25	15	568	17	403	19	288	20	235	22	166
30	18	651	21	434	24	296	24	261	26	162
35	21	699	25	457	27	347	29	266	30	220

PIP of 20 cm-H_2O and respiratory rate of 10 BPM, to a high PEEP of 30 cm-H_2O at a PIP of 35 cm-H_2O and respiratory rate of 30 BPM. Tidal volumes for a lung compliance of 0.05 L/cm-H_2O ranged from 153 mL to 699 mL. Results for a lung compliance of 0.01 L/cm-H_2O are presented in Table 1.

The PEEP was also shown to elevate at any given PIP by increasing the respiratory rate. Increasing the respiratory rate from 10 BPM to 30 BPM at a constant PIP resulted in an average PEEP increase of 7.6 cm-H2O.

Figure 1 demonstrates the linear relationship between PIP and PEEP for various respiratory rates at a compliance of 0.01 L/cm-H_2O. PEEP was shown to increase at a higher rate when increasing PIP at higher respiratory rates, with a lower rate of increase when increasing PIP at lower respiratory rates. Figure 2 demonstrates the same linear relationship between PIP and PEEP at a compliance of 0.05 cm-H2O. However, the rate of increase of PEEP when increasing PIP was shown to be near constant across various respiratory rates.

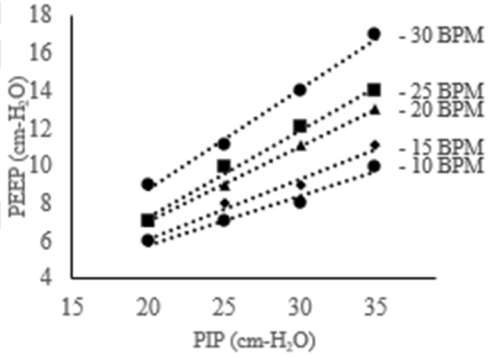

Fig. 1. Measured PEEP for a range of set PIP at various respiratory rates and a compliance of 0.01 cm-H_2O.

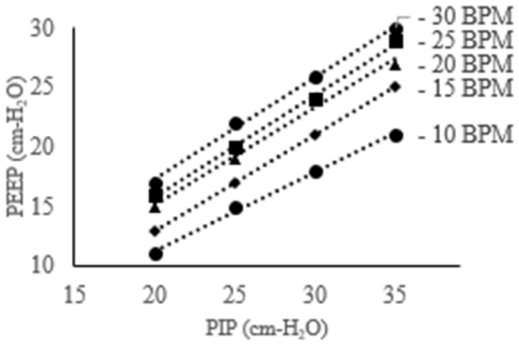

Fig. 2. Measured PEEP for a range of set PIP at various respiratory rates and a compliance of 0.05 cm-H_2O.

CONCLUSION

VORTRAN's new parabolic resistor valve placed in-line with the VORTRAN GO_2VENT Model 6123 was able to consistently provide higher PEEP values for any given PIP, lung compliance, and respiratory rate combination compared to the use of the GO_2VENT Model 6123's standard PIP to PEEP ratio, when used without any PEEP-increasing valves, of 5:1. The parabolic resistor valve allows PEEP values that encompass the entire range of PEEP as recommended in the NHLBI ARDS Network's PEEP titration protocol for ARDS patients; at no point during this study did the PEEP drop below the ARDS Network's minimum PEEP of 5 cm-H2O, while maintaining the goals of respiratory rates of less than 35 BPM and duration of inspiration less than duration of expiration.[3]

REFERENCES

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