Bench Test Comparison of VPAP ST-A and BiPAP AVAPS: Evaluating Response to Changing Breath Patterns

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Introduction

Non-invasive ventilation (NIV) is a common therapy for those with respiratory disease or afflictions needing ventilator assistance in both the hospital and home settings. As technology has advanced, the products that provide NIV have gotten smaller and the algorithms that control output have become much more sophisticated. Instead of simply setting inspiratory and expiratory pressures and/or backup rates, some NIV devices today also feature triggering and cycling settings, mask and accessory adjustments, breath tracking and automatic adjusting of output based on the user's breathing trends. For clinicians, this means there are more variables in product performance that must be understood in order to help provide effective therapy. The purpose of this bench evaluation was to determine and compare selected performance characteristics of two home NIV devices operating in their respective volume assured pressure support (VAPS) modes to note any performance differences between the products. Specifically, the units' responses to changing breath patterns were investigated in dynamic test scenarios.

Methods

NIV ventilators tested were ResMed's VPAP™ ST-A and Philips Respironics' BiPAP® AVAPS™. Both units feature and were tested in their VAPS mode. A Hans Rudolph Series 1101 Breathing Simulator was used to simulate the patient. Each unit under test was subjected to three separate 30-minute test periods controlled via a script file read by the breathing simulator (this ensured that changes in lung settings occurred consistently). Each test period featured four unique "phases". Phase 1 lasted 10 minutes, with data recording beginning at the 5-minute mark after unit output stabilization. Phases 2-4 each lasted 5 minutes, before reverting to Phase 1 for the final 5 minutes of testing/data acquisition.

Results

When presented with a change in the breath pattern/parameters (i.e., the transition from one phase to the next), the VPAP ST-A reached stable pressure/volume delivery within 5-15 breaths from the time of the change. The BiPAP AVAPS, when presented with the same changes in breath pattern, would take up to approximately one minute before making any pressure/volume adjustment, and would routinely need several minutes before tidal volume stabilized. During Phase 4 of each test, which employed very restrictive lung parameters, both units routinely missed spontaneous breaths. Adjusting the triggering sensitivity on the VPAP ST-A eliminated this issue; however, there was no trigger setting on the BiPAP AVAPS to allow the unit to be adjusted and re-tested.

Conclusions

Notable performance differences existed between the VPAP ST-A and the BiPAP AVAPS. While this bench testing scenario does not directly represent conditions that may be seen in the clinical setting, the results of these tests do suggest that these devices should not be considered identical in performance capacity and output, and that the use of one device may not yield the same results if using the other device. Clinicians and healthcare providers should be aware of performance capacity and variability when prescribing an NIV device for hospital and/or home use.

Non-invasive ventilation (NIV) is a common therapy for those with respiratory disease or afflictions needing ventilator assistance in both the hospital and home settings. Patients who have complex, yet stable, breathing disorders often require ventilation technology that can adapt to constantly changing breathing patterns. These devices must be able to provide sound therapy while still allowing the patient to initiate breathing and to comfortably ventilate as much as possible. Supporting a patient's ventilation without eliminating a patient's drive to breathe is challenging, and new technology is continually being developed to provide products that balance the patient's capabilities and needs with maintaining adequate ventilation and perfusion.

As technology has advanced, the products that can provide NIV therapy have gotten smaller and more portable, and the algorithms that control their output have become much more sophisticated. Instead of simply setting inspiratory and expiratory pressures and/or backup rates, some NIV devices today also feature triggering and cycling settings, mask and accessory adjustments, breath tracking, and automatic adjusting of their therapy settings based on the user's breathing trends.

For clinicians, this means there are more variables in product performance that must be understood in order to help provide proper and effective therapy. Unfortunately, becoming educated on each product and accessory is no easy task. In many cases the products being used are still so new to the market that there is very little literature on their performance abilities and features. Even products with a long history routinely get updated with new features and abilities that impact their performance. Only by regular testing and evaluation of the products available to patients and clinicians can there be a basis for understanding how these many devices operate and compare with one another.

This white paper has been written to discuss selected performance characteristics of two home NIV devices operating in their respective volume assured pressure support (VAPS) modes to note the performance differences between the products and to discuss what these differences may mean. Bench testing on each unit was conducted to record and analyze how the devices performed in several simulated breathing scenarios. Specifically, the units' responses to changing breath patterns was investigated to see how each product adjusts its therapy output after a change in lung conditions.

Methods and Protocol

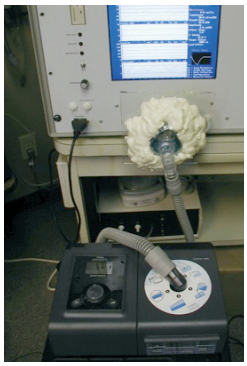
Units Tested:

VPAP™ ST-A (iVAPS) — ResMed Corp.

Non-invasive ventilation system equipped with ClimateLine$^{MAX™}$ tubing

Mask:
ResMed Mirage™ FX (Medium)

BiPAP® AVAPS™ — Respironics Inc.



Non-invasive ventilation system equipped with standard Respironics tubing

Mask:
Respironics ComfortGel 2 (Medium)

Additional Equipment:

Series 1101 Breathing Simulator–Hans Rudolph, Inc.
Data Acquisition via Remote Monitor Software
Mask Plate Fixture 3mm thick clear plastic plate
Great Stuff Foam Sealant–Dow Chemical
22mm ID/22mmOD Adapter (2)–Qosina

Pre-Test Procedures

Prior to testing, each nasal mask was sealed to a plastic plate fitted with a 22mm ID/OD adapter with foam sealant. This allowed the mask/circuit to be connected to the breathing simulator connection port for all tests. Seals were checked prior to testing to ensure minimal to no leak.

The VPAP ST-A was fitted with the included ClimateLineMax tubing and connected to the Mirage FX Nasal Mask/plate fixture. The unit was set to "Nasal" for the mask setting (there is no tubing setting; ClimateLineMax tubing is automatically detected by the unit).

The BiPAP AVAPS was fitted with the included 22mm CPAP tubing and connected to the ComfortGel 2 Nasal Mask/plate fixture. The unit was set to 22mm for the tubing setting (there is no mask setting).

Humidification settings on both units were set to "off". No water was placed in either chamber.

For data acquisition purposes, the Breathing Simulator was connected to a PC running the Remote Monitor Software. The software records select real-time data in 50ms intervals (20 Hz) as well as breath-by-breath results.

Recorded signals included:

Remote Monitor Real Time (sample rate fixed at 50ms):
Flow (ATPD), Pressure, Volume, Effort

Remote Monitor Post-Breath (data written to file after each breath):
Peak Inhale Flow, Peak Exhale Flow, Peak Pressure, End-Exhale Pressure, End-Exhale Absolute Pressure, Auto PEEP, Rate, I:E, Vt, Pt WOB, Vent WOB, Air Temperature

Each unit was set to the following fixed settings for all tests:

VPAP ST-A Settings		BiPAP AVAPS Settings	
Mode:	iVAPS	Mode:	S/T
EPAP:	5.0	AVAPS:	On
Min PS:	5.0	IPAP Max:	25
Max PS:	20.0	IPAP Min:	10
Ti Max:	2.0	EPAP:	5
Ti Min:	0.3	Ti:	0.5
RT:	300ms	Rise Time:	On
Trig:	Med	Rise Time Setting:	2
Max Ramp:	Off	Ramp Time:	Off

Test Procedures

Each unit under test was subjected to three separate 30-minute test periods controlled via a script file read by the breathing simulator (this ensured that changes in lung settings occurred consistently). Each test period featured four unique "phases". Phase 1 lasted 10 minutes, with data recording beginning at the 5-minute mark after unit stabilization (labeled in report/graphics as Phase 1a). Phases 2-4 each lasted 5 minutes, before reverting to Phase 1 (labeled as Phase 1b) for the final 5 minutes of testing. Note that a total of 25 minutes of data were recorded.

A description of the ventilator settings and script process for each test is shown in the tables below. Note that the only ventilator settings that change between tests are the tidal volume*, backup rate settings and, in the case of the VPAP ST-A, the patient height. Also note that the only changes in breathing simulator parameters between individual test phases are Resistance, Compliance, and Breath Rate.

*Tidal volume is directly set on the BiPAP AVAPS. The tidal volume setting value on the VPAP ST-A is achieved by adjusting three parameters to yield a tidal volume at or near the desired value: patient height, backup rate, and target alveolar.

TEST 1 PARAMETERS

Device Settings

	iVAPS	AVAPS	
Rate (bpm)	15	13	Rate
Vt (ml)	*353*	350	Vte
EPAP (cmH_2O)	5	5	EPAP
Min PS (cmH_2O)	5	10	IPAP Min
Max PS (cmH_2O)	20	25	IPAP Max
Height	5' 6" (66")		
Alveolar Min. Vol.	3.8		

Lung Settings

	phase 1	phase 2	phase 3	phase 4
R (cmH_2O/LPS)	10	15	8	20
C (ml/cmH_2O)	40	30	50	20
Rate (bpm)	17	20	16	27
Amplitude (cmH_2O)	4	4	4	4
Slope	5	5	5	5
I:E	1:2	1:2	1:2	1:2

TEST 2 PARAMETERS

Device settings

	iVAPS	AVAPS	
Rate (bpm)	13	11	Rate
Vt (ml)	*504*	500	Vte
EPAP (cmH_2O)	5	5	EPAP
Min PS (cmH_2O)	5	10	IPAP Min
Max PS (cmH_2O)	20	25	IPAP Max
Height	5' 10" (70")		
Alveolar Min. Vol.	5.0		

Lung settings

	phase 1	phase 2	phase 3	phase 4
R (cmH_2O/LPS)	10	15	8	20
C (ml/cmH_2O)	50	30	70	25
Rate (bpm)	15	18	14	25
Amplitude (cmH_2O)	4	4	4	4
Slope	5	5	5	5
I:E	1:2	1:2	1:2	1:2

TEST 3 PARAMETERS

Device Settings

	iVAPS	AVAPS	
Rate (bpm)	10	8	Rate
Vt (ml)	*750*	750	Vte
EPAP (cmH_2O)	5	5	EPAP
Min PS (cmH_2O)	5	10	IPAP Min
Max PS (cmH_2O)	20	25	IPAP Max
Height	6' (72")		
Alveolar Min. Vol.	6.2		

Lung settings

	phase 1	phase 2	phase 3	phase 4
R (cmH_2O/LPS)	10	15	8	20
C (ml/cmH_2O)	60	40	80	35
Rate (bpm)	12	15	11	22
Amplitude (cmH_2O)	4	4	4	4
Slope	5	5	5	5
I:E	1:2	1:2	1:2	1:2

Protocol For Each Test

- Device settings set (note fixed settings on prev. page).
- Breathing Simulator script file initiated (the script file institutes timed, automated changes to lung parameters).
- Simulator set to phase 1 settings.
- Vent turned on. System allowed to stabilize for 5 minutes.
- Remote Monitor data acquisition started. 5 minutes allowed to pass.
- Simulator set to phase 2 settings. 5 minutes allowed to pass.
- Simulator set to phase 3 settings. 5 minutes allowed to pass.
- Simulator set to phase 4 settings. 5 minutes allowed to pass.
- Simulator set to phase 1 settings. 5 minutes allowed to pass.
- Remote Monitor data acquisition stopped. Unit powered off.

During the automated test process, unit performance was monitored via the simulator's display screen as well as the Remote Monitor Software interface on the attached PC.

One minute after each Phase transition, screenshots of the Remote Monitor Software were taken to show the unit's response to the change in lung settings. The resulting images show waveforms of the volume flow (ATPD), airway pressure, lung volume, and patient effort for one minute pre- and post-change in lung conditions.

At the conclusion of data acquisition, a screenshot of the trend graph for the 25-minute data acquisition period was taken. Resulting images show trends for peak positive and negative patient flows, peak and end-exhalation pressures, tidal volumes and breath rate.

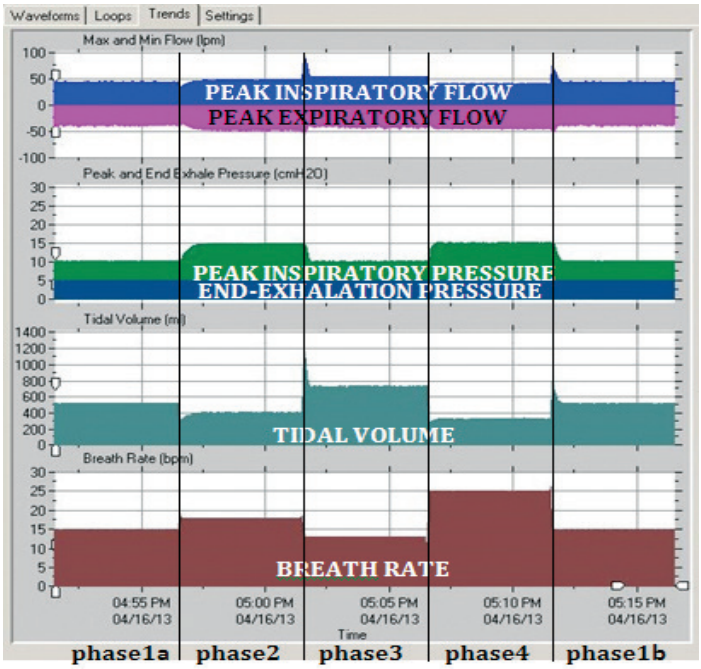
Additional Testing

After completion of the testing described above, the VPAP ST-A was re-tested in all three test cases with the Trigger setting set to "High" (initial tests had the unit set to "Medium"), with no other adjustments or modifications made. There was no adjustable trigger or equivalent settings on the BiPAP AVAPS, so the unit was not similarly re-tested. Results from these re-tests are shown alongside results from the initial testing.

Descriptions of Results Graphics

Device response to changes in breath patterns is most clear when observing the trend graph for each test. Screenshots of the trend graphs show peak inspiratory and expiratory flows, peak inspiratory and end-expiratory pressures, delivered tidal volume and breath rate for each recorded breath over the duration of the test (25 minutes total). By viewing these graphs, the units' output in response to the change in breath pattern can be evaluated.

TREND GRAPH



Peak inspiratory flow readings show the simulated patients' maximum inspiratory flow rate, which is largely driven by the pressure support supplied by the ventilator. It follows that changes in peak inspiratory flow are related to changes in the pressure support supplied by the ventilator, which can be seen by viewing the peak inspiratory pressure section of the graph. When the patient conditions change, resulting in automatic adjustments by the ventilator to the delivered pressure support, the trend graph shows how quickly the ventilator makes these changes in both the peak inspiratory flow and peak inspiratory pressure sections of the graph.

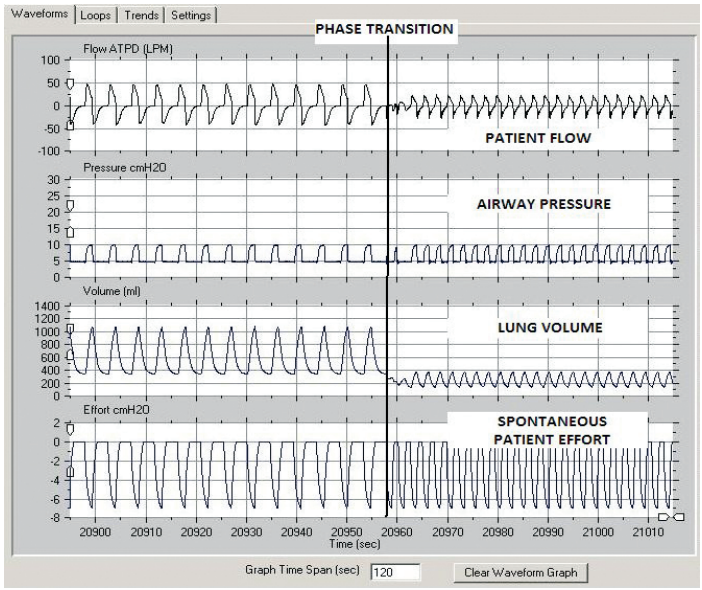
Other graphs of interest include the real-time plots of the simulated patient's volume flow, airway pressure, lung volume, and patient effort patterns before and after the lung simulator transitioned to a new phase. Each of these breath-to-breath profiles can help to illustrate how each ventilator's output is immediately affected by the sudden change in lung conditions, as well as any adjustments the ventilators may make in that time. Each graph represents two minutes of breathing, with the transition from one phase to the next phase occurring around the one-minute mark (typically spotted by noting abrupt changes in the peak flow and pressure profiles).

Spontaneous breaths that did not trigger pressure support delivery from the device can be seen as part of a sawtooth-like pattern that appears in all sections of the trend graph (except breath rate, where the breathing simulator continued to breathe "spontaneously" regardless of any ventilatory support provided). Phase 4 of each test scenario featured the most restrictive lung conditions, and both ventilators under test failed to trigger consistently during this phase. As a result, breath-to-breath flows, pressures, and tidal volumes varied, resulting in the sawtooth-like pattern described above.

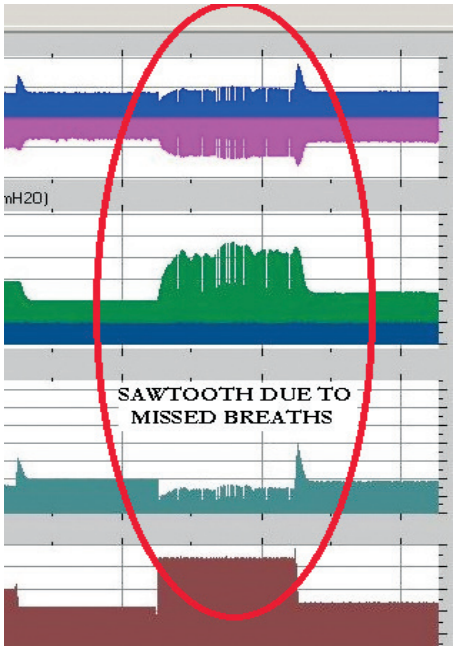
In the transition graphs, missed breaths by the ventilator can be noted where spontaneous effort occurs, but there is no change in pressure, and peak flow and lung volume is notably less than breaths where pressure support occurs.

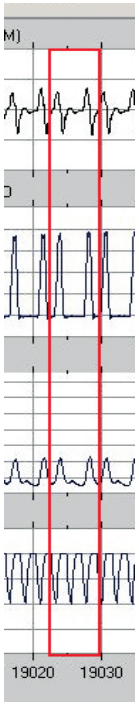
Since the ResMed VPAP ST-A featured additional trigger sensitivity settings, the unit was re-tested with the device set to "High" for trigger sensitivity. These results are displayed alongside the initial results to show that adjusting the setting gave the unit the ability to deliver pressure support on each spontaneous breath during the most restrictive phase of the test. The Respironics BiPAP AVAPS does not feature adjustable trigger sensitivity, so that unit could not be similarly re-tested.

TRANSITION GRAPH



HIGHLIGHTED TREND AND TRANSITION GRAPHS: MISSED SPONTANEOUS BREATHS

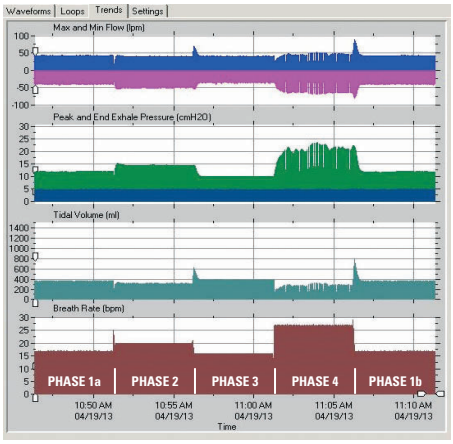




Test 1 Results

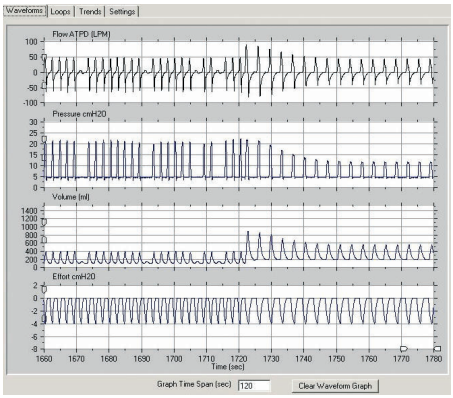
ResMed VPAP ST-A:

Trigger Setting "Medium"



Responses to phases 1a-2, 2-3, and 4-1b transitions show ventilation stabilization within approximately 10-12 breaths or less. Ventilator performance during phase 4, with the most restrictive lung conditions, showed numerous missed spontaneous breaths. Stabilized peak flows were generally similar regardless of the phase and stabilized tidal volumes increased/decreased inversely to increases/decreases in patient breath rates as expected.

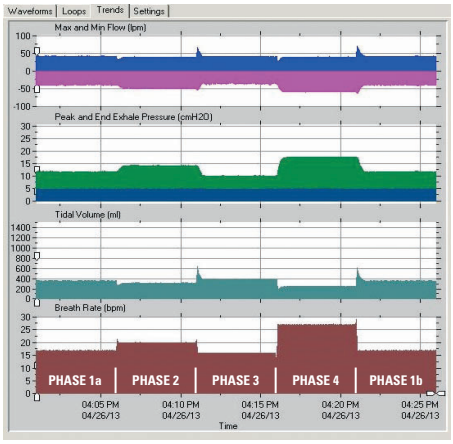
Transition: Phase 4 to Phase 1b



During phase 4, the ventilator routinely did not trigger. Immediately after phase 4 transitioned to phase 1b, peak inspiratory flow and lung volume sharply increased, though pressure support remained stable. The unit began to adjust pressure support delivery within the first three breaths of the phase transition, and the breath pattern was stabilized within eight breaths of the transition, with no missed breaths occurring during phase 1b at all.

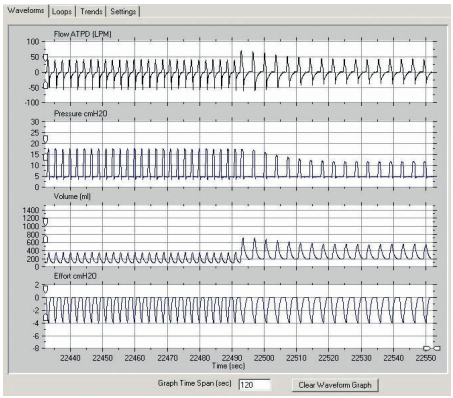
ResMed VPAP ST-A:

Trigger Setting "High"



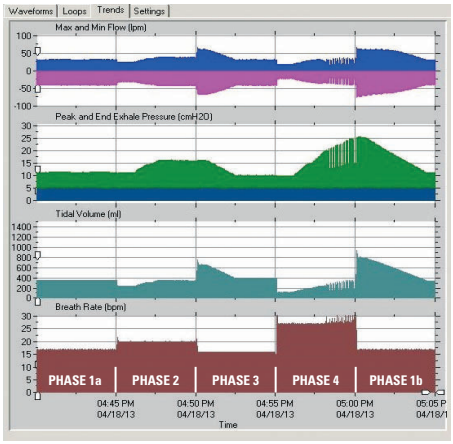
Responses to all phase transitions show ventilation stabilization within approximately 10-12 breaths or less. The transition to phase 4, with the most restrictive lung conditions, did not result in missed spontaneous breaths as seen when the unit was set to "Medium" triggering. Stabilized peak inspiratory flows were generally similar regardless of the phase and stabilized tidal volumes increased/decreased inversely to increases/decreases in patient breath rates, as expected.

Transition: Phase 4 to Phase 1b



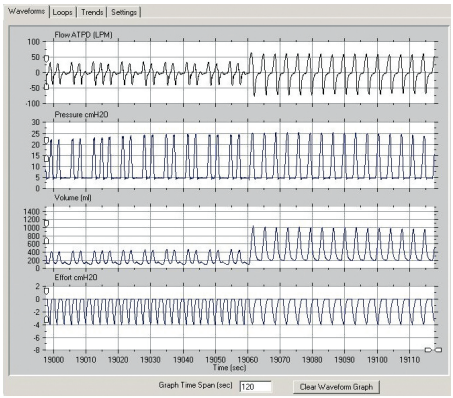
During phase 4, the ventilator routinely triggered and did not miss a single breath. Immediately after phase 4 transitioned to phase 1b, peak inspiratory flow and lung volume sharply increased, though pressure support remained stable. The unit began to adjust pressure support delivery within the first three breaths of the phase transition, and the breath pattern was stabilized within eight breaths of the transition, similar to when the unit was set to the "Medium" trigger setting.

Respironics BiPAP AVAPS



Responses to all phase transitions show ventilation adjustment does not begin until approximately one minute or more after the change in lung conditions. Tidal volumes during the first breaths of phase 4 were around 120 mL, about 1/3 of the set volume. Tidal volumes during the first breaths of phases 3 and 1b were significantly greater than the set volume of 350 mL before adjusting downward. During the latter half of phase 4, the phase with most restrictive lung settings, the unit began to regularly miss spontaneous breaths as it continued to adjust to the lung conditions.

Transition: Phase 4 to Phase 1b

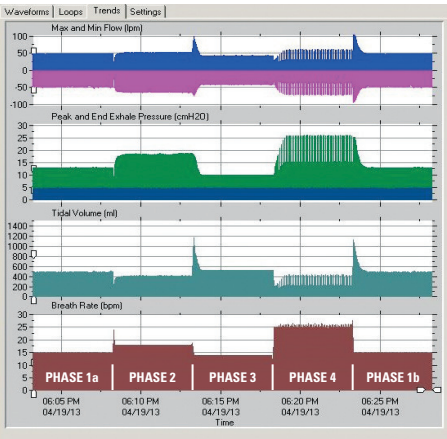


During phase 4, the ventilator routinely did not trigger, missing a spontaneous breath every 3-4 breaths. Immediately after phase 4 transitioned to phase 1b, peak inspiratory flow and lung volume sharply increased, though pressure support remained stable. Pressure support continued to remain stable for about one minute, with peak flows and lung volume remaining at increased levels during that time as well. There were no missed breaths occurring during phase 1b at all.

Test 2 Results

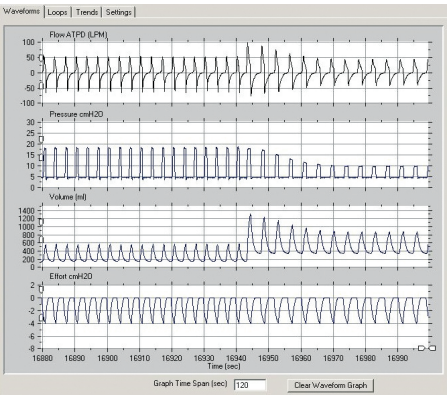
ResMed VPAP ST-A:

Trigger Setting "Medium"



Responses in phase 1a-2, 2-3, and 4-1b transitions show ventilation stabilization within approximately one minute or less. Ventilator performance during phase 4 showed numerous missed spontaneous breaths throughout the phase. Initial tidal volumes in phases 3 and 1b were significantly greater than 500 mL, between 1100 to 1180 mL, but were reduced by a large amount on each consecutive breath until stabilization.

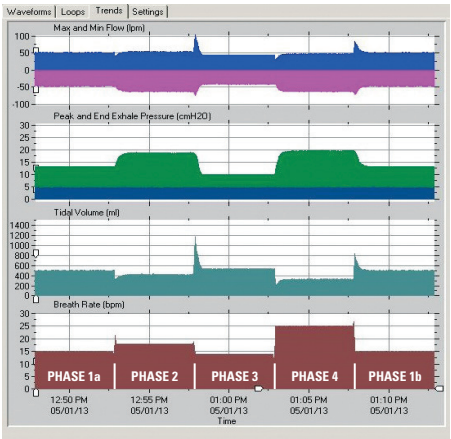
Transition: Phase 2 to Phase 3



Immediately after phase 2 transitioned to phase 3, peak inspiratory flow and lung volume sharply increased, though pressure support remained stable. The unit began to reduce the amount of pressure support within the first three breaths of the phase transition, and the breath pattern was stabilized within eight breaths of the transition, with no missed breaths occurring during either phase, or the phase transition.

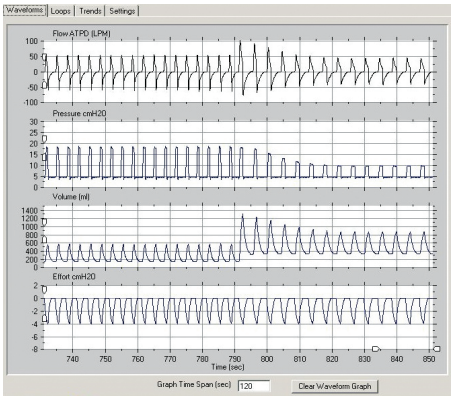
ResMed VPAP ST-A:

Trigger Setting "High"



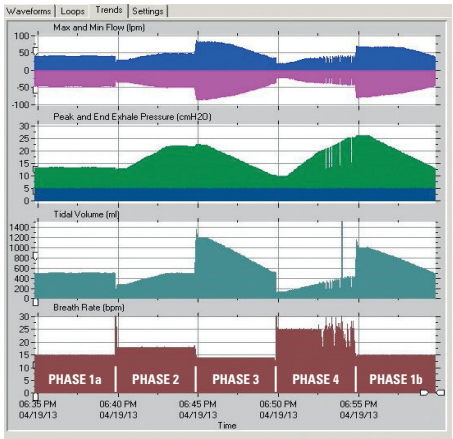
Responses to all phase transitions show ventilation stabilization within approximately one minute or less. The transition to phase 4, with the most restrictive lung conditions, did not result in missed spontaneous breaths as seen when the unit was set to "Medium" triggering. Initial tidal volumes in phases 3 and 1b were significantly greater than 500 mL but were reduced by a large amount with each consecutive breath until stabilization.

Transition: Phase 2 to Phase 3



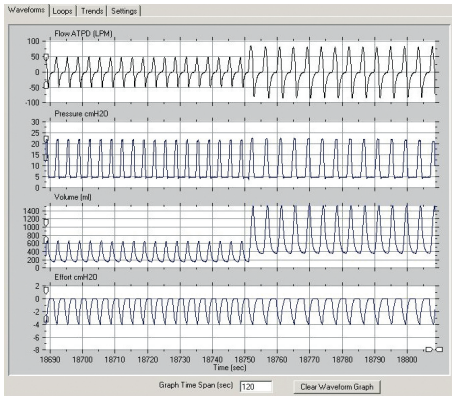
Ventilator performance was nearly identical to when the VPAP was set to "Medium" trigger. Immediately after phase 2 transitioned to phase 3, peak inspiratory flow and lung volume sharply increased, though pressure support remained stable. The unit began to reduce the amount of pressure support within the first three breaths of the phase transition, and the breath pattern was stabilized within eight breaths of the transition, with no missed breaths occurring during either phase, or the phase transition.

Respironics BiPAP AVAPS



During the latter half of phase 4, the phase with the most restrictive lung settings, the unit began to regularly miss spontaneous breaths as it continued to adjust to the lung conditions. Tidal volumes during the first breaths of phases 2 (230 mL) and 4 (170 mL) were significantly less than the set volume of 500 mL. Similarly, tidal volumes during the first breath of phases 3 (1350 mL) and 1b (1140 mL) were significantly greater than the set tidal volume, and the unit had not adjusted to stabilization by the end of the phase.

Transition: Phase 2 to Phase 3

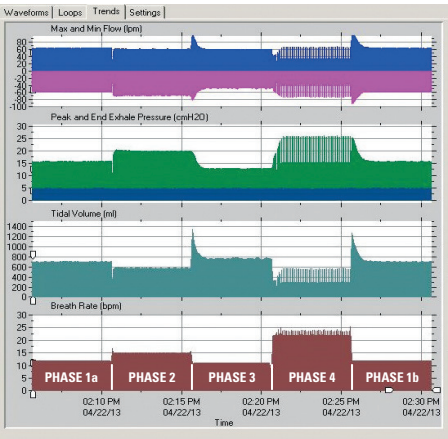


Immediately after phase 2 transitioned to phase 3, peak inspiratory flow and lung volume sharply increased, though pressure support continued to remain stable for about one minute, with peak flows and lung volume remaining at increased levels during that time as well. There were no missed breaths occurring during either phase or the phase transition.

Test 3 Results

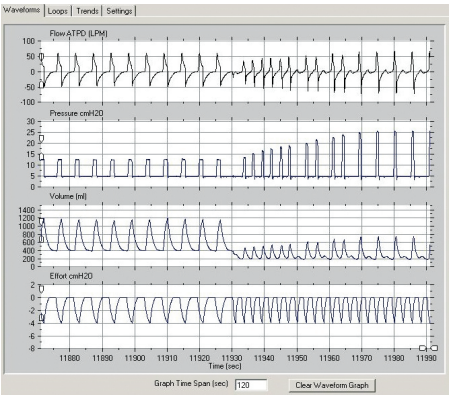
ResMed VPAP ST-A:

Trigger Setting "Medium"



Responses in phase 1a-2, 2-3, and 4-1b transitions show ventilation stabilization within approximately one minute or less. Initial tidal volumes in phases 3 and 1b were significantly greater than 750 mL, between 1240 to 1320 mL, but were reduced by a large amount on each consecutive breath until stabilization. Ventilator performance during phase 4, featuring the most restrictive lung conditions, resulted in routinely missed spontaneous breaths throughout the phase.

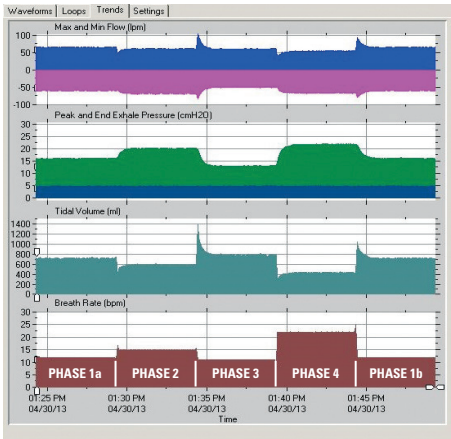
Transition: Phase 3 to Phase 4



During phase 4, the ventilator routinely did not trigger. Immediately after phase 3 transitioned to phase 4, peak inspiratory flow and lung volume sharply decreased, though pressure support remained stable. The unit began to adjust pressure support delivery within the first three breaths of the phase transition. Due to the routine missed spontaneous breaths, the breath pattern did not stabilize during phase 4, though when pressure support was provided the therapy was consistent.

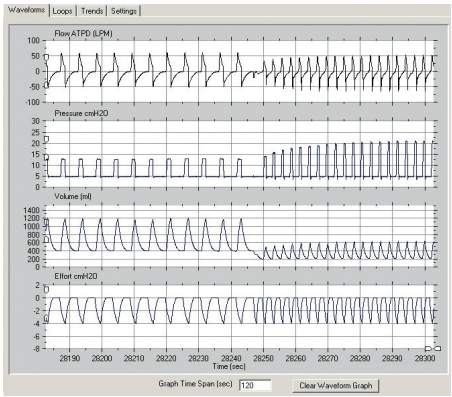
ResMed VPAP ST-A:

Trigger Setting "High"



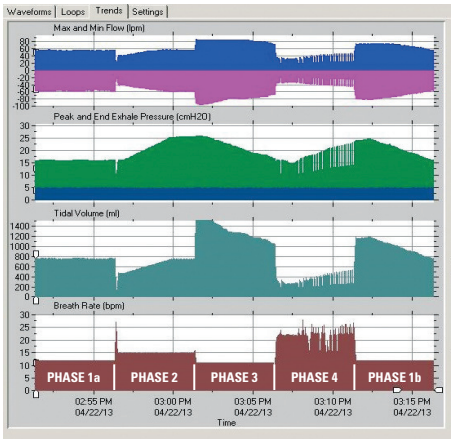
Responses to all phase transitions show ventilation stabilization within approximately one minute or less. The transition to phase 4, with the most restrictive lung conditions, did not result in missed spontaneous breaths as seen when the unit was set to "Medium" triggering. Initial tidal volumes in phases 3 and 1b were significantly greater than 750 mL- 1390 mL and 1030 mL, respectively—but were reduced by a large amount on each consecutive breath until stabilization.

Transition: Phase 3 to Phase 4



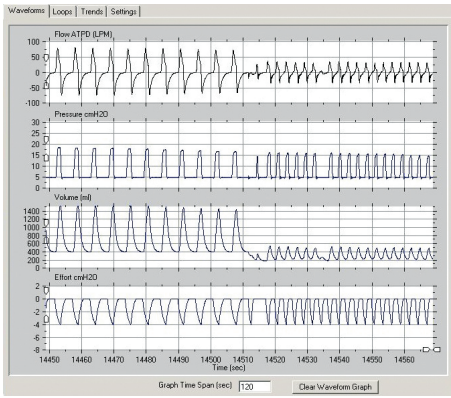
During phase 4, the ventilator routinely triggered and did not miss a breath. Immediately after phase 3 transitioned to phase 4, peak inspiratory flow and lung volume sharply decreased, though pressure support remained stable. The unit began to adjust pressure support delivery within the first three breaths of the phase transition, and the breath pattern was stabilized within one minute of the phase transition.

Respironics BiPAP AVAPS



During the latter stages of phase 4, the phase with the most restrictive lung settings, the unit began to regularly miss spontaneous breaths as it continued to adjust to the lung conditions. Tidal volumes during the first breaths of phases 2 (470 mL) and 4 (270 mL) were significantly less than the set volume of 750 mL. Similarly, tidal volumes during the first breaths of phases 3 (1590 mL) and 1b (1180 mL) were significantly greater than the set tidal volume and did not stabilize by the end of the phase despite a continual lowering of delivered volume.

Transition: Phase 3 to Phase 4



Immediately after phase 3 transitioned to phase 4, peak inspiratory flow and lung volume sharply decreased, though pressure support remained stable. With the exception of one missed breath, pressure support continued to remain stable for about one minute, with peak flows and lung volume remaining at decreased levels during that time as well. Due in part to the routine missed spontaneous breaths that occur later in the phase as the unit continues to adjust therapy, the breath pattern did not stabilize during phase 4.

Discussion

Volume assured pressure support (VAPS) is a ventilation mode that combines aspects of pressure support ventilation (PS) with volume-controlled (VC) ventilation. By ensuring a set volume to be delivered during pressure support ventilation, changes in patient effort and/or lung conditions that may yield undesirable under- or over-ventilation and/or comfort issues in PS can be mitigated. However, by ensuring a tidal volume, changes in breath rate will impact minute volume just as they do in standard VC, and there may yet be issues with comfort. Products that feature a VAPS mode include advanced algorithms that attempt to adjust to the patient's changing breathing patterns to deliver appropriate, balanced, and comfortable ventilation therapy. However, these algorithms are often proprietary to the manufacturer, which leads to a variety of devices available to the market that have varying performance abilities and features, as well as product-specific terminology.

Two products that feature a VAPS mode and are currently available in the market are ResMed's VPAP ST-A and Philips Respironics' BiPAP AVAPS. The VPAP ST-A's VAPS mode is called "iVAPS", or "intelligent volume assured pressure support", while the BiPAP AVAPS VAPS mode is referred to as "average volume assured pressure support". The first question one might ask about these devices' VAPS modes is, "Are they any different?" What is apparent from the bench testing results presented earlier in this paper is that each device has unique methods of responding to a change in a simulated patient's respiratory conditions. So the answer to that question should be, "Yes."

Part of the differences in performance of the VPAP ST-A and BiPAP AVAPS can be attributed to how they are designed to operate when set to their respective VAPS modes. The BiPAP AVAPS goal is to maintain the set tidal volume, while the goal of the VPAP ST-A is to maintain set alveolar minute volume. The justification for maintaining alveolar minute volume as opposed to a standard tidal volume or minute volume is that by setting alveolar minute volume, the volume of the patient's anatomical dead space is accounted for, lessening the effect of breath rate changes on volume ventilation.

The difference in the products' volume delivery goals is borne out in the settings available to the clinician on each device. While both units feature standard pressure support and backup rate settings, only the BiPAP AVAPS unit features an actual tidal volume setting, whereas the VPAP ST-A requires patient height, backup rate, and alveolar minute volume settings to be adjusted in conjunction with each other to determine what the tidal volume setting will be at the set backup rate.

Illustration of the BiPAP AVAPS unit's goal of maintaining tidal volume can be seen in the trend graphs highlighted earlier in this paper. Looking at the trend results from Test 1 on the BiPAP AVAPS, which had the unit set to a tidal volume of 350 mL, during each of the phases 1a, 2, 3, and 1b, once the unit's pressure/volume output stabilized, the tidal volume was at or around 350 mL. Similarly, in Test 2, tidal volume stabilized at or around 500 mL during phases 1a, 2 and 3; in Test 3 stable tidal volumes were around 750 mL during phases 1a and 2, with the unit needing more than the 5-minute period in phases 3 and 1b to reach tidal volume stability.

Across all three tests there were several instances where the BiPAP AVAPS delivered significantly higher or lower tidal volumes than what was set on the device, and this would occur for several minutes at a time. In Test 2, for example, the transition from phase 2 to phase 3 resulted in tidal volumes jumping from approximately 500 mL to 1200 mL, where tidal volume remained stable for around one minute before the unit began to adjust its output and tidal volumes gradually decreased—with the breath rates of each phase factored in, there was a 7.8L/min jump in minute volume in that phase transition, from 9.0 L/min to 16.8 L/min. It took nearly the entirety of phase 3's 5-minute period before tidal volume delivery stabilized around 500 mL, which also means the delivered minute volume remained above the eventual stabilized 7.0 L/min minute volume for the majority of that time.

For the VPAP ST-A, viewing the trend graphs of each test illustrates that the unit does not adjust pressure/volume to meet a specific tidal volume, rather the patient's breath rate becomes a determining factor of whether the delivered tidal volume stabilizes above or below the "set" tidal volume (which itself is a product of the patient height, backup rate, and alveolar minute volume settings). With Phase 1a acting as the "baseline" conditions in each test, it is easy to see in the associated trend graph that if the patient breath rate was higher than the baseline, delivered tidal volumes were lower. Conversely, if the patient rate was lower than the baseline, delivered tidal volumes were higher.

In Test 3, for example, the "set" tidal volume was 750 mL at a backup rate of 10 BPM, a result of the patient height being set to 72" and the target alveolar minute volume being set to 6.2 L/min. The VPAP ST-A delivered tidal volumes during phase 1 of Test 3 (with a rate of 12 BPM) that were around 700 mL, then decreased to a stable 575 mL during phase 2 (15 BPM), before increasing to a stable 770 mL during phase 3 (11 BPM). Consequently, stabilized minute volumes during these phases went from 8.4 L/min to 8.6 L/min to 8.5 L/min. If the unit were to deliver a fixed tidal volume of 750 mL in these cases, then stabilized minute volumes would have gone from 9.0 L/min to 11.3 L/min to 8.3 L/min in that same sequence. So, while delivered tidal volumes during each of the first three phases of Test 3 varied, the minute volumes in each phase did not.

Another significant difference in features between the two products is the presence of triggering and cycling settings on the VPAP ST-A, whereas the BiPAP AVAPS does not have this capability. Many of Philips Respironics' ventilator devices feature what is termed Digital Auto-Trak Sensitivity, and the BiPAP AVAPS is one of these products. One component of this feature is that the algorithm automatically tracks the patient's inspiratory and expiratory breath characteristics, and thus the trigger and cycle thresholds, theoretically eliminating the need for adjustable settings.

As seen in the bench testing results presented earlier, both units routinely missed spontaneous breaths when presented with a very restrictive lung condition. However, the ability to adjust the trigger setting from "Medium" to "High" on the VPAP ST-A showed that the unit could be modified to eliminate these missed triggers and provide continuous therapy, but the BiPAP AVAPS could not be adjusted similarly.

Also of note in the bench test results were the response times to the change in breath patterns. All changes were fixed, meaning both units were presented with the same exact changes in lung conditions at the same exact times, allowing for a direct comparison of the resulting output.

In most every instance, the VPAP ST-A showed near-immediate responses, adjusting its pressure support (and thus patient flow and volume) within the first three breaths of the phase transition, and stabilizing its output within the first minute of the phase transition. The BiPAP AVAPS, on the other hand, did not typically begin making any adjustments to its output until about a minute after the phase transition, and pressure support adjustments after that point occurred at a relatively fixed rate, resulting in several minutes passing before ventilator output stabilized. In some cases, such as during phase 3 of Test 3, five minutes was not a long enough period of time for pressure/volume stabilization to occur. Therefore, tidal volumes were often much higher or lower than the set tidal volume for minutes at a time.

Conclusions

Notable performance differences existed between the VPAP ST-A and the BiPAP AVAPS operating in their respective VAPS modes. When compared directly, each unit has a unique method of applying therapy, where the BiPAP AVAPS is set to maintain a tidal volume while the VPAP ST-A is set to maintain a specific alveolar minute volume. The VPAP ST-A also features clinician-adjustable triggering and cycling settings that can impact ventilator performance, such as eliminating missed spontaneous breaths, whereas the BiPAP AVAPS relies on its Digital Auto-Trak Sensitivity algorithm to automatically adjust triggering and cycling parameters—this may result in the unit being unable to deliver consistent therapy in certain conditions.

Additionally, each unit's response times to a change in breathing characteristics was markedly different—the VPAP ST-A routinely stabilized pressure/volume output within one minute, while the BiPAP AVAPS would require around one minute to elapse after a change in breath pattern before starting adjustment of pressure/volume output, and several minutes could pass before output stabilizes.

While this bench testing scenario does not directly represent conditions that may be directly seen in the clinical setting, the results of these tests do suggest that these devices should not be considered identical in performance capacity and output, and that the use of one device may not yield the same results if using the other device. Clinicians and healthcare providers should be aware of performance capacity and variability when prescribing an NIV device for hospital and/or home use.

Supported by ResMed