Pressure and Flow Waveform Characteristics of Eight High Frequency Oscillators

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Objectives:
The aim of this bench top study was to describe the pressure and flow waveform characteristics of eight commercially available oscillators.

Details:
The older devices were classified according to their mechanism of waveform generation. There are now five newer oscillators available and the described mechanism of generating oscillations differs between all of them. Hence the traditional way of classifying oscillators may no longer be applicable.

The Sensormedics 3100A and 3100B (Carefusion), Fabian (Acutronic), SLE5000 (SLE), Sophie (Stephan), Leoni+ (Heinen+Löwenstein), VN500 and Babylog 8000 (Drager) were studied using recommended circuits but without humidifiers.

A 3.5mm ET tube, 15cm long, was connected to an infant test lung with a residual lung volume of 70ml/cm and was leak free. Compliance was set to 1ml/cm H2O. Flow was measured at the airway opening using a hot wire anemometer sampling at 200Hz. Airway pressure was measured at 1000Hz using calibrated pressure transducers at the proximal end of the ventilator, the airway opening and within the test lung.

Standard HFO mode was used at MAP of 10 and 20cm H2O; with frequencies of 5, 10, 15 Hz. I:E Ratio was set at 1:2 except for the SLE5000 which had a fixed 1:1 ratio. 30 dp set and Babylog and Sophie titrated to deliver dp30.

The waveforms were characterised using the following criteria: square or sine (curved) wave and the presence of unique incisura (notches). The peak, trough and amplitude of each waveform were determined. The analysis process used allowed for the oscillator wave form to be separated into its different harmonics and analysis was performed of the non-fundamental frequencies that contribute to the high frequency waveform at 10Hz.

Results:

Waveforms

Square or sine wave patterns with varying harmonics were shown by all ventilators. The Fabian, Leoni+, and Babylog flow profiles resembled sine waves. The VN500 showed a pure sine wave with a shear expiratory slope.

The SM3100B waveforms at 1:2 I:E Ratio differed from the square waveforms at 1:1 and the SM3100A at both I:E Ratios. At 1:2 ratio, the SM3100B waveforms showed an initial inspiratory pulse and incisura then stepwise reductions in pressure and flow preceding peaks.

The Sophie generated sine pressure and flow waves, but unlike other sine waveform devices the pressure waveform had incisura on the inspiratory slope similar to square waveform devices.

The SLE5000 showed a square PAO that was comparable to the SN3100A and B at 1:1 ratios.

Delivered Pressure and Flow at Experimental Settings

All oscillators except the BL8000 generated pressure amplitudes greater than 28.9 cmH2O and a tidal volume greater than 6ml at frequencies above 10Hz. At the settings tested all but the BL8000 and SM3100A (1:2 Ratio) achieved sub or atmospheric airway pressures during expiration. In the SLE5000 as frequency increased minimum flow and pressure became negative. Delivered volume was similar between all devices at comparable I:E Ratios except for the BL8000.

Power Spectral Density (PSD)

The PSD for the square waveform ventilators conformed to known square waveform characteristics with peaks at odd multiples or 1:1 I:E Ratios and consecutive peaks for 1:2 Ratios. Oscillators generating square waves (SM3100A and B, SLE5000), and/or a distinct inspiratory slope incisura generated waveforms with a higher number of non-fundamental frequency components, resulting in the most complex frequencies with potentially greatest transmissive power.

Discussion:

Traditionally HFO ventilators have been classified according to the mechanism used to generate HFO. This study suggests that the engineering design nomenclature is obsolete. The study proposes that using the waveform characteristics and frequency composition is more useful in classifying modern high frequency oscillators. HFOV is reliant on the waveforms generated to achieve gas exchange at small tidal volumes. The SM3100A and the BL8000 are known to produce very different waveforms resulting in important difference in clinical performance. Unlike the SM3100 oscillators, modern ventilators offer both conventional and HFO ventilation. Only the SLE5000 produced a waveform similar to the SM3100 oscillators.

Conclusion:

This study shows that the waveforms generated by modern oscillators differ in shape, frequency characteristics, and resultant amplitudes at comparable settings. Clinicians need to be aware of these differences which may lead to variations in effectiveness between the devices.

For further information regarding this clinical paper review please contact marketing@sle.co.uk. Any opinions expressed are the opinion of the SLE reviewer and not necessarily the original authors.