ASA ABSTRACTS

A470

Title: PHASE DELAY AND FREQUENCY RESPONSE AS SOURCES OF ERROR IN GAS ANALYSIS

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Background: Real-time multiple gas analyzers can fail to provide accurate gas concentration data at respiratory rates above 0.3 Hz (20 breaths/sec) which are physiologically important for pediatric patients. The known sources of error for analysis at higher breathing frequencies (f) include signal degradation in sampling tubing and water trap, and the actual frequency response of the analyzer bench. We have observed clinically-significant discrepancies between displayed values for inspiratory and expiratory gases and their corresponding waveforms, and have observed flipping of inspiratory and expiratory values at higher f under some conditions. These conditions suggested the importance of phase offsets between waveforms of different gases as an important source of error at higher respiratory rates.
Methods: A lung model test bench was devised using an anesthesia machine, CO_2 cylinder, and solenoid valves driven by an electronic function generator. The I:E ratio was programmed to 1:1 and f varied from 0.2 to 3 Hz. Four multiple gas analyzers from three different manufacturers using different analysis methods were tested. Analog data was acquired off the waveform screens and by analog-to-digital conversion of analyzer analog output. Data which was digitized by the analyzer for user reference on the screen was acquired via serial port. Attenuation of the waveforms and digitized output was computed as percent full-scale value and percent full-scale I-E difference, with data at 0.2 HZ taken as full scale for each device. Phase lag between gases was computed by extrapolation from beginning of inspiration of exhalation detected from the CO_2 waveform.
Results: Analyzer A had the poorest frequency response for oxygen but also failed to reverse its inspiratory and expiratory values. Analog waveforms were severely phase-delayed, but digitization was accurate. Analyzer B flipped inspiratory and expiratory values for oxygen almost exactly at the 180 degree phase frequency for O_2 relative to CO_2. The digitized values for oxygen differed markedly from the analog output at high f, suggesting that the response time of the analyzer itself was much shorter than the phase lag. Analyzer C exhibited attenuation, phase lag, and flipping of the O_2, N_2O, and agent concentrations at lower f than analyzer B, suggesting both lower frequency response capability and greater phase delays.

Analyzer / Frequency BPM	A	B1	B2	C
10% CO_2 Atten	66	54	66	48
25% CO_2 Atten	84	66	84	60
10% O_2 Atten	36	66	30	36
25% O_2 Atten	18	78	36	48
Flip O_2 I/E	no	no	60	48
180 degree O_2 phase freq	0	-	72	-
Flip N_2O I/E	no	no	no	42
Flip Agt I/E	no	no	no	66

Discussion: When frequency response exceeds the 180 degree phase shift frequency, flipping of inspiratory and expiratory values for gases relative to the CO2 waveform can occur. If frequency response is less than phase frequency, attenuation of inspiratory-expiratory difference results. Fast-response analyzers demand either simultaneous analysis methodologies or precise compensation for the transport time of gas samples between analysis benches.

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TITLE: ESTIMATION OF EMBOLIC AIR VOLUME IN THE MIDDLE CEREBRAL ARTERY (MCA) USING TRANSCRANIAL SONOGRAPHY

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Psychological and neurologic sequelae following cardiopulmonary bypass have been described and thought to be related to incidence of intracerebral air embolism. Recent reports indicate that transcranial Doppler sonography is a sensitive means by which air emboli can be detected. The purpose of this study was to examine the auditory characteristics of the TCD output and attempt to correlate them with emboli air volumes.

TCD audio containing incidents of air were subjected to a Fast Fourier Transform (FFT). Audio segments, where no air passed through the Doppler field, were used as background and also subjected to FFT analysis. FFT spectra were compared and frequency and power differences were noted and used for development of audio bandpass filters (BPF) for isolation of frequencies associated with air emboli. Similar analyses were performed on audio segments containing artifact (electrocautery, and sensor movement.) A bench model of the middle cerebral artery was devised, and the Doppler probe positioned on the model similarly with respect to clinical orientation. A pneumatic pump, adjusted to provide a flow-pattern similar to that found in the MCA, circulated simulated blood through the model. Air was injected into the circulation via a side-port such that all air passed through the Doppler field. Five injections each were made at 0, 0.5, 0.75, 1.0, 2.0, 5.0, 10.0, and 20 ul volumes. TCD output was acquired digitally, filtered, then subjected to an FFT, power spectrum analysis and power spectrum integration. A linear least squares correlation was performed on the data.

FFT analysis of audio segments indicate that frequencies between 250 and 500 H_Z consistently appear in the spectrum when air emboli are preset. Background frequencies appear to be below 240 H_Z, and artifacts resulting from sensor movement and electrocautery appear to be below 300 H_Z. Data from the MCA model filtered through a BPF, 307-450 H_Z, yielded a linear relationship between emboli volume and the integrated value of the power spectrum up to 20 ul (r^2 =0.923). Air emboli appear to produce a distinctive audio frequency pattern which may be used for quantification, assuming the emboli pass through the Doppler field and do not become entrapped within vortices or turbulent flow patterns within the vessels that lie in the Doppler field.