Title: A TECHNIQUE FOR AUTOMATIC CALIBRATION OF MEDICAL MASS SPECTROMETERS

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Introduction. Medical mass spectrometers are devices that accurately measure the concentration of physiologic and medical gases. Commercially available models usually incorporate facilities for automatic verification of the accuracy and linearity of the instrument against calibration gases of known concentration. In clinical practice, however, mass spectrometers are seldom used as standalone monitors; rather, they are centrally located and connected through 30-50m long lines to multiple bedside stations. Thus, potential errors can be related to inadequate response time of the entire gas sampling apparatus. Waveform distortion and signal damping can occur when transport lines are partially obstructed, or when the gas sampling pump operates at unacceptably low flow rates. However, the information thus displayed can mimic pathologic conditions, such as low end-tidal CO2 concentration or rebreathing of exhaled gases in an unsealed circuit, and therefore lead to clinically incorrect decisions.

Materials and Methods. We propose here a method to measure the dynamic response of each bedside station of a centralized mass spectrometer monitoring system, operating in an Intensive Care Unit (ICU). A mixture of 94.5% O_2 and 5.5% CO_2 was delivered to a port of an electronic solenoid valve (internal volume <0.1ml; opening time < 5msec), while the other port was connected in turn to each bedside gas sampling port. When the valve was closed, the tubings were flushed with 30 L/min of room air. Analog signals representing O_2, CO_2 and N_2 concentration were obtained from the mass-spectrometer by an analog-to-digital converter (ADC) at a frequency of 125 Hz each. Data was stored in computer files as integer values with 12-bit (0.05%) precision. After calibrating the ADC and the static response of the mass spectrometer to within ± 1% accuracy, we measured at each station 5-95% rise time and peak concentration of the three gases, while the solenoid valve operated at 25 and 50 cycles/min with an on-time of 50%. The solenoid valve was also connected to a line that was identical to those used at bedside stations but had never been used, to obtain reference values.

Results. When gases were sampled from the reference line at the flow rate recommended by the manufacturer, (240 ml/min) peak CO_2 concentration was 5.49% and rise time 170 msec, well within expected values. However, when the flow rate was decreased, rise time progressively increased; at 140 ml/min it was 560 msec while the peak concentration detected fell to 4.83%, due to waveform damping.(Fig. 1)

Testing lines that had been in continuous use for approximately 2 years, rise time was 630 ± 15 msec (mean ± SD), while peak CO_2 concentration was 4.80±0.03%. After thoroughly cleaning the lines with detergent solution, however, rise time could be restored to 230 ± 12 msec and peak concentration to 5.37±0.02% even at 50 cycles/min (Fig. 2). Similar results were obtained for the other two gases considered (O_2 and N_2). Of notice, the self-test program of the mass spectrometer never reported any error, since the gases it measured were not transported through the faulty lines or the suction pump.

Conclusion. This investigation suggests that reliance on information obtained from medical mass spectrometers cannot be based only on successful self-tests. Gas sampling flow rate and rise time must also be tested, to identify technical problems that could markedly affect results.

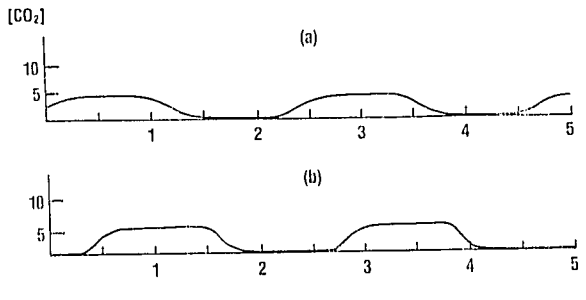

Fig. 1 - CO_2 waveforms obtained when gases were sampled at flow rates of 140 ml/min (a) and 240 ml/min (b). Rate = 25 cycles/min.

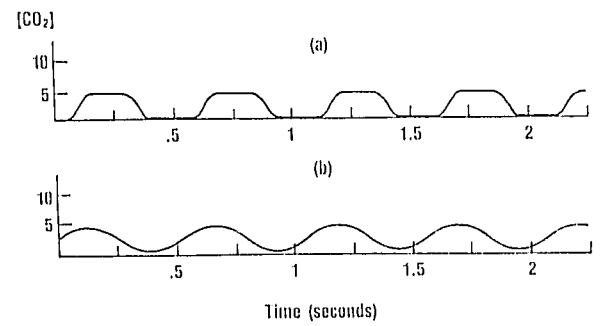

Fig. 2 - CO_2 waveforms obtained from a bedside station through a line that had been used for 2 years (b) and from the same line after cleaning it with a detergent solution (a). Rate = 50 cycles/min.