

Title: FIRST CLINICAL EVALUATION OF A RAMAN SCATTERING GAS ANALYZER

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Raman light scattering has been suggested as a viable technique for monitoring respiratory gases in the operating room. Raman scattering, a well-established technique for molecular gas analysis in chemical laboratories, relies on the interaction between laser light and gas molecules. When photons collide with a molecule, light is scattered with characteristic frequency shifts for that molecular structure.

A prototype Raman device has been assembled for use during anesthesia to monitor seven respiratory gases simultaneously. A .6 ml gas sample cell is placed between the plasma tube and the output mirror of an air-cooled 40 mW argon laser. Lenses collect the scattered light and interference filters select Raman lines corresponding to the respiratory gases. Photomultiplier tubes and a microcomputer produce simultaneous readings of the gas concentrations.

The device was evaluated in a bench study, comparing its measurements with a precision gas mixer. Thirty paired measurements were taken for each gas, covering the full range of measurement. The mean difference and one standard deviation of the difference between the Raman analyzer and the gas mixer were $-.02 \pm .11$ vol% for oxygen, $-.62 \pm .08$ vol% for nitrogen, $.32 \pm .05$ vol% for CO₂, and $.19 \pm .43$ vol% for nitrous oxide. For halothane, the mean difference was $-.13 \pm .07$ vol%, for enflurane $.08 \pm .03$ vol%, for isoflurane $-.05 \pm .04$ vol%.

The analyzer was evaluated clinically by comparing its readings with a mass spectrometer. Informed consent was obtained from 10 patients undergoing general anesthesia. About 30 minutes after endotracheal intubation, when inhalation anesthetic uptake had reached steady state, gas measurements were taken from the patients' airway with the Raman analyzer and the mass spectrometer. Because of the difference in the time required to collect inspired and expired values from the Raman analyzer (15 sec) versus the mass spectrometer (60 sec) it was not possible to collect simultaneous breath-by-breath readings. The Raman analyzer inlet, drawing 190 ml/min, was connected to an airway adapter at the end of the endotracheal tube. The Perkin Elmer 1100 dedicated mass spectrometer was connected with a six-foot capillary sample line to an adapter and filter at the end of the endotracheal tube. A data

set was collected every 10 minutes; the set included inspired and expired concentrations of oxygen, nitrogen, nitrous oxide, CO₂, and volatile anesthetic.

The data was analyzed calculating the relative error for each data pair: (Raman reading minus mass spectrometer reading)/mass spectrometer reading X 100.

The results in the table show the mean relative error as per cent of reading and its standard deviation. The electrosurgical and other OR equipment did not disturb the operation or display of the Raman system. Monitoring proceeded without incident over the total 40 hours of clinical use.

The Raman analyzer provided continuous monitoring of airway gases, the readings of gas concentration were within 5% of those monitored with a dedicated mass spectrometer. The Raman device was completely autocalibrating, whereas the mass spectrometer required calibration each morning. The Raman system has capabilities similar to the mass spectrometer but it is smaller and less expensive. It is an attractive technology for simultaneous monitoring of respiratory and anesthetic gases in the operating room.

Clinical Evaluation Results

	Mean Relative Error	SD	N
Oxygen	1.12	2.50	416
Nitrogen	-3.65	3.92	206
End-tidal CO ₂	-0.91	8.26	209
N ₂ O	2.21	0.65	180
Halothane	5.38	10.87	76
Isoflurane	9.83	17.36	263

Mean relative error and SD of the difference between simultaneous Raman analyzer and mass spectrometer measurements of respiratory gas concentration (expressed as percent of reading).

Reference.

1. Van Wagenen RA, Westenskow DR, Benner RE, Gregonis DE, Coleman DL: Dedicated monitoring of anesthetic and respiratory gases by Raman scattering. *J Clin Monit* 2:215-222, 1986