Title: MEASUREMENT OF FUNCTIONAL RESIDUAL CAPACITY DURING N2O ANESTHESIA

Authors: R. Prutow, Ph.D., M.D., N. Head, R. Dueck, M.D.

Affiliation: Departments of Anesthesiology, University of California, San Diego, Veterans Administration Medical Center, San Diego, California 92161

Introduction. Significant changes in functional residual capacity (FRC) occur following induction of anesthesia. However, measurement of such changes during N2O anesthesia has been limited by the special technical problems which are introduced by clinical concentrations of N2O when measuring FRC with any one of the three standard methods (helium dilution, body plethysmography, nitrogen washout). We therefore examined the feasibility of replacing the thermal conductivity measurement of helium concentration used in the field with the helium dilution technique with the mass spectrometry method. Measurement of helium (He) by mass spectrometry causes a known helium loss from the closed circuit. In addition to this problem we examined the possibility that N2O uptake or elimination would produce an observable effect. The opposite effect (second gas effect) or dilutional effect, respectively, of helium within the lung. Such an effect could potentially alter the measured FRC, depending on the relative concentration of N2O in the lung and the closed circuit prior to equilibration.

Methods. The FRC circuit employed was similar to that of Hewlett et al. in which a CO2 absorber, fan and spirometer were placed in series. Valving allowed a mechanical ventilator to be incorporated into the circuit when necessary, thereby allowing for FRC determination during both spontaneous and mechanical ventilation. Inspired (Fi) and end tidal (FET) concentrations were measured using a mass spectrometer (Perkin Elmer, sampling rate 1.0 ml/min).

To determine FRC during anesthesia, the circuit was first primed with N2O and O2. A known amount of helium (sufficient to maintain final He between 3-5%) oxygen, and N2O was added to increase system volume by one liter while maintaining O2 concentration constant (30%). Following mixing, He was measured and used to calculate the system volume (V1).

During closed circuit lung helium mixing, sufficient oxygen was added to maintain the total volume (V2) constant. Helium concentration was measured for five seconds at one minute intervals. Sampling was terminated when the [He] (corrected for He sampling loss) remained unchanged for three consecutive readings.

Linearity of this method with respect to volume was determined by adding serial increments of volume to the system. Reproducibility was examined by repeated determination of a known volume. Sensitivity of the technique to duration of measurement was examined by serial He measurements at two minute intervals for a 50 minute closed circuit helium dilution procedure. To examine whether N2O uptake or elimination alters [He], hence FRC determination, repeated FRC measurements (in sheep) were made with either a) 20% N2O initially present in the "V1" circuit, or b) 20% N2O breathing without N2O initially being present within the "V1" circuit. The second gas effect of N2O upon helium was accounted for by applying the factor: FRC (corrected) = (Fi/Fe) FRC (uncorrected).

Results. The linearity of the mass spectrometry method for measuring known increments of volume showed a correlation coefficient of 1.00. The reproducibility for a known volume of 1300 ml showed a standard deviation of 6 ml (0.5%). Sensitivity of the method to duration of sampling, examined in both man and sheep, showed in each case a very slow linear decrease in [He]. The rate (relative to the initial concentration) being 0.16 ± 0.03%/min. After correction for mass spectrometer sampling loss (0.093 ± 0.005%/min), the remaining decrease in [He] was 0.07 ± 0.03%/min. Separate measurement of volume and helium loss within the "V1" circuit was examined by weighting the spirometer (2 Kg) for 20 minutes. No observable change in volume or [He] (5.22%) occurred. Minimum measurable [He] change was 0.01%.

This means that any diffusional loss of helium through the circuit must be less than 0.01%/min.

Therefore, the observed 0.07%/min decrease must be associated with uptake of helium via the lung (most likely by diffusion into intestinal gas). This caused an apparent upward drift in calculated FRC of 3.8 ml/min. Initial FRC 1370 ml. Serial FRC determinations after correction for the above drift at two minute intervals for 50 minutes yielded a standard deviation of 50 ml (3.0%). This suggests that the level of variability of our measurements of a known volume (0.5%) was significantly less than the physiologic variability of FRC.

Breathing of N2O prior to FRC determination, or conversely, priming the FRC circuit with 20% N2O initially caused significant and opposite changes in inspired versus end tidal helium concentrations (second gas effect). However, within five minutes the helium concentrations stabilized and no significant difference in calculated FRC (corrected) could be detected although uptake or elimination of N2O continued.

Conclusion. Closed circuit helium dilution FRC determination employing a mass spectrometer was shown to provide a sufficient level of linearity and reproducibility for application during N2O anesthesia. Use of a mass spectrometer requires modification of the standard expression for FRC determination to account for helium loss secondary to sampling. Ability to determine both inspired and end tidal helium concentrations allows correction of FRC for the second gas effect of N2O uptake or elimination of helium.