Fusion of Basic Spirometers for Anesthetic Gas Concentration Sensing

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Introduction: Volatile anesthetic gas monitoring confirms both a functioning anesthesia machine as well as aids clinicians in identifying and titrating anesthetic depth of the patient. Operating rooms capable of volatile anesthetic gas monitoring accomplish this with infrared spectroscopy units. However, the high capital and maintenance costs make these devices ill-suited and quickly obsolete in low-resource settings. Infrared absorption represents only one of several physical and chemical property differences between volatile anesthetic agents and carrier gases. Density, viscosity, thermal conductivity, and acoustic resonance are all features that differ between volatile anesthetic agents and carrier gases and are also features that are used to measure respiratory flow already. We hypothesize that through smart fusion of these sensors and studying their measurement changes as a function of volatile anesthetic gas changes could yield a combination capable of determining both respiratory flows and anesthetic gas concentration.

Methods: Several spirometers were placed in series in a recirculating system driven by a radial turbine. Included were a custom orifice-plate differential pressure anemometer, hot-wire anemometer, and rotary vane anemometer. Flow rates were also measured via a VT-Plus Gas Flow Analyzer (Fluke Corp., Everett, WA), a commercial thermal flow sensor (AwM700, Honeywell International Inc., Morris Plains, NJ), as well as the internal tachometer existing in the driving radial turbine (U51DL-012KK-4 Miniature Radial Blower with Integrated Electronics, Micronel, Tagelswangen, Switzerland). All sensors were sampled at a rate of 20 Hz with flow rates ranging from 10-60 liters/minute. During steady-state flow, isoflurane was introduced into the system at concentrations ranging from 0-3.5% by volume, and the reported changes in flow from all sensors monitored. Multiple linear regressions were developed across all sensors in a scatter plot matrix to determine which sensors were independent or dependent on the presence of isoflurane.

Results and Discussion: Several of the standard spirometers exhibited significant variability in reported flow with the presence of isoflurane, indicative of an underlying sensitivity. Two linear regressions of note were between the rotary vane and hot-wire anemometer as well as the orifice-plate anemometer and commercial Honeywell thermal sensor, with both exemplifying clear patters of difference to determine isoflurane concentration and flow rate simultaneously (Figure 1 and 2).

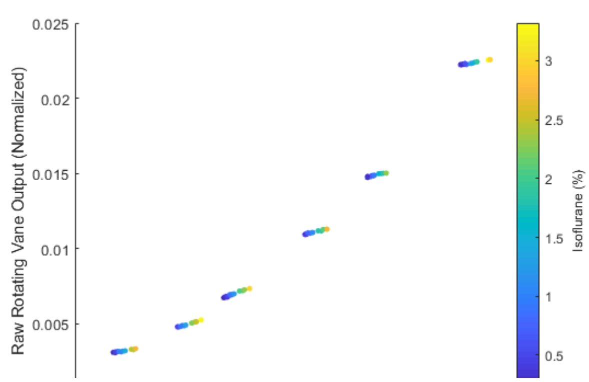

Figure 1 - Relationship between the hot-wire anemometer and rotating vane spirometer at 10, 15, 20, 30, 40, and 60 liters per minute with changes in isoflurane concentration from 0-3.5%.

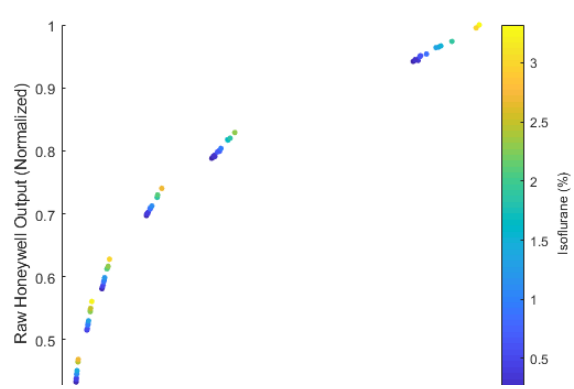

Figure 2 - Relationship between the orifice-plate spirometer and commercial Honeywell sensor at 10, 15, 20, 30, 40, and 60 liters per minute with changes in isoflurane concentration from 0-3.5%.