Using Differential Pressure to Determine Isoflurane Gas Concentration

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Introduction: Knowing the inspiratory and expiratory concentration of volatile anesthetics is essential when administering inhalational anesthesia. Current technology predominantly uses side stream infrared analysis to identify the anesthetic agent as well as its concentration with high accuracy. However, this technology contributes to a large portion of the capital cost of anesthesia machines. Thus, these machines become cost prohibitive for both small-office practices and low-resource areas, causing clinicians to seek alternative forms of general anesthesia. Alternative approaches exist to determine anesthetic concentrations, using more economic technologies. Anesthetic gases are approximately five times denser than oxygen and nitrogen and have an impact on the fluid dynamic properties of the flowing gas. Based on the Bernoulli Effect, a flowing fluid that changes density alters the internal pressure. Using this principle, this study aimed to determine whether the pressure difference before and after a constriction, the differential pressure, would change as anesthetic concentration changes and whether this could then be used as an alternative to infrared analysis for determining anesthetic concentration.

Methods: A fixed orifice flow module (Respironics Fixed Orifice Flow Module, Philips, Amsterdam, Netherlands) was used in conjunction with a differential pressure sensor (DLVR-L01D E1NS-C, All Sensors, Morgan Hill, CA) in a custom rebreathing circuit. A radial blower (U51DL-012KK-4 Miniature Radial Blower with Integrated Electronics, Micronel, Tagelswangen, Switzerland) was used to drive the rebreathing circuit gas at rates of 2-12 liters per minute (measured using the integrated electronics of the radial blower, independently verified using a VT-Plus Gas Flow Analyzer, Fluke Corp., Everett, WA). Isoflurane (Piramal Healthcare Limited, Andhra Pradesh, India) was introduced to the rebreathing circuit with a custom vaporizer, at concentrations ranging from 0-3.5% measured using a standard side stream infrared gas bench (Datex-Ohmeda, Helsinki, Finland). Baseline measurements at all flow rates were used to calibrate the differential pressure system. As isoflurane was introduced to the rebreathing circuit, deviations from this baseline were attributed to changes in the isoflurane concentration. A model was generated to estimate the isoflurane concentration and compared to actual isoflurane concentrations in real time.

Results And Discussion: Isoflurane concentration estimations were highly correlated to measured isoflurane concentrations ($R^2 = 0.99$). In a sample size of N=53, the mean error was

0.016% isoflurane with a standard deviation of 0.089% isoflurane (Figure 1). Further tests will include dynamic conditions by ventilating a test lung.

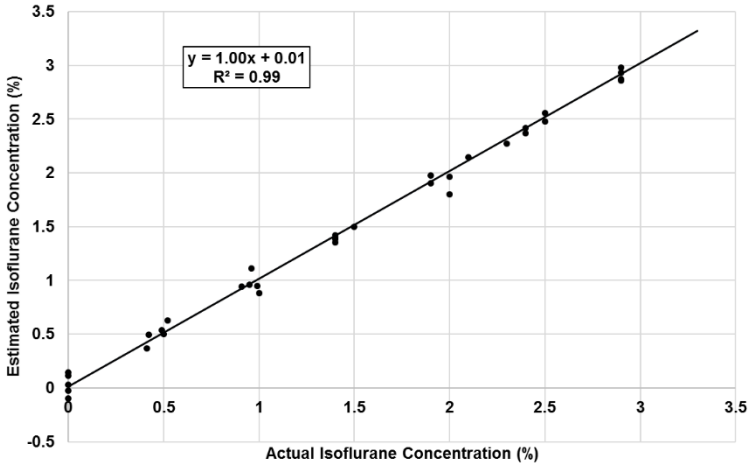

Figure 1 - Estimated isoflurane concentration using differential pressure versus actual isoflurane concentration with accompanied linear regression.