Abstract Title: Digital Feedback Control of Mask Pressure using a Venturi Flow Generator

Presenting Author: Trey Blackwell, BS, University of Utah Department of Anesthesiology

Co-Authors:
Joseph Orr, Ph.D., University of Utah Department of Anesthesiology
Derek Sakata, MD, University of Utah Department of Anesthesiology

Introduction

Recent research has demonstrated that using CPAP on patients undergoing moderate sedation can reduce the risk of obstructive apnea and oxygen desaturation [1]. Providing CPAP in a sedation setting requires an expensive non-invasive ventilator that may not be readily available for use in a sedation setting. An alternative is an inexpensive and portable device that uses a venturi flow generator, which amplifies oxygen flows by combining high-pressure wall oxygen and entrained ambient air to produce high-flow output capable of overcoming mask leaks and producing CPAP pressures. When a typical venturi flow generator is used to achieve the desired airway pressure, mask pressure is selected by applying a set input oxygen flow using a flow-to-pressure table provided by the manufacturer. This method does not account for variable mask leakage, changes in oxygen supply pressure, or patient inhalation flow rate. We evaluated a digitally controlled oxygen flow meter that uses feedback control to automatically adjust the oxygen flow rate to achieve the desired airway pressure. This study hypothesized that digital feedback control utilizing a venturi flow generator can be used to control airway pressure and administer CPAP as needed during procedural sedation.

Methods

A venturi flow generator's input flow port was connected to a proportional valve connected to the output of a high-pressure oxygen source. The proportional valve was connected to a microcontroller, and the pressure sampling line connected the pressure in the mask to a pressure sensor that was digitally interfaced with the microcontroller. A PID feedback controller was implemented on the microcontroller, which adjusted the flow out of the proportional valve to control the pressure measured through the sampling line. The venturi flow generator was interfaced with a mask and placed on a manikin face attached to a test lung using a corrugated hose to simulate a patient's airway. In the first test, the mask was held on the manikin so there was no leak flow. The controller was set to various pressures (4 cmH_2O, 6 cmH_2O, 8 cmH_2O, 10 cmH_2O, 12 cmH_2O, 16 cmH_2O), and the average pressure at each was recorded over a 30-second interval using an analyzer (VT-plus, Fluke Biomedical, Everett WA) that sampled the pressure from the simulated airway. The procedure was then repeated with the mask strap loosened such that there was approximately 15 L/min of mask leak flow at each test pressure.

Results

The measured average pressure versus the desired set pressure is plotted in Figure 1. The correlation coefficient was computed as $r^2 = 0.9999$ both with and without mask leak. The ideal least squares line would be $y = x$. The least squares line for the measured pressures without leak was calculated as $y = 1.009x – 0.22$. The least squares line was calculated with mask leak as $y = 1.008x – 0.23$. The ideal and computed least squares lines are included in Figure 1. The average and standard deviation of the difference between the set mask pressure and the measured mask pressure was 0.133 ± 0.047 cmH_2O without mask leak and 0.150 ± 0.050 cmH_2O with mask leak.

Conclusion

It is observed that a digital feedback controller can be combined with a venturi flow generator to control airway pressure and administer CPAP effectively. The user can choose the desired pressure, and the system will effectively maintain that pressure in the airway by adjusting the flow out of the venturi adapter accordingly, regardless of the mask leak flow present.

Figure

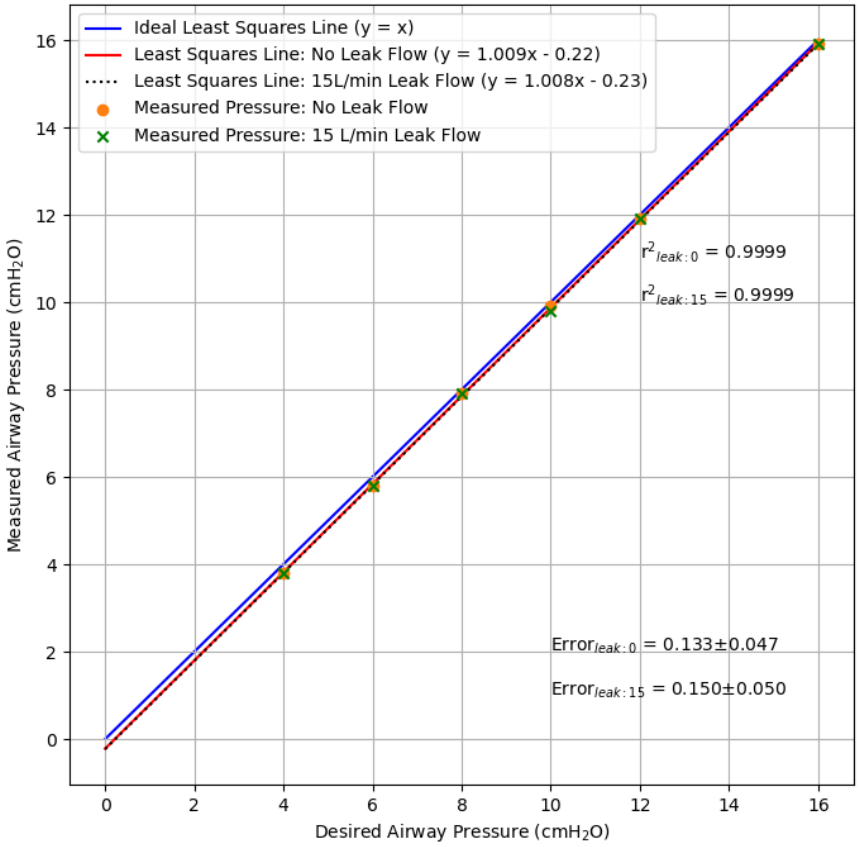

Figure 1: Measured Airway Pressure vs. Desired Airway Pressure with Ideal Least Squares Line, Calculated Least Squares Line, and Correlation Coefficient

References

1. Fogarty, Mike & Orr, Joseph & Sakata, Derek & Brewer, Lara & Johnson, Ken & Fang, John & Kück, Kai. (2020). A comparison of ventilation with a non-invasive ventilator versus standard O2 with a nasal cannula for colonoscopy with moderate sedation using propofol. Journal of Clinical Monitoring and Computing. 34. 10.1007/s10877-019-00426-5.