Investigating Environmental Carbon Dioxide Sensors as Proxy for Capnometry in Austere Surgical Settings

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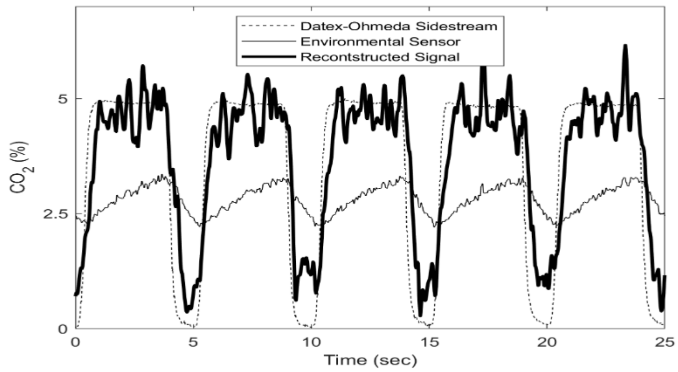
Introduction: Several medical devices have been introduced to address, in part, the discrepancy in surgical and anesthesia access between high-income regions and their lower-income counterparts. The 'Glostavent' is an anesthetic machine designed specifically for use in difficult environments, emphasizing portability, durability, and independence from electrical grids [1]. 'Lifebox' is a charity project aimed at providing pulse oximeters for use in low- and middle-income countries with a similar emphasis on durability [2]. However, there are no continuous respiratory monitoring devices intended for austere conditions despite the American Society of Anesthesiologists (ASA), World Health Organization (WHO), and the World Federation of Societies of Anaesthesiologists (WFSA) all designating capnography as an essential instrument in anesthesia monitoring [3]–[5].

Utilizing a low-cost environmental CO2 sensor typically used for emissions testing, the primary aim of this work was to develop a capnography device and then compare to other capnometry devices. Additionally, a deconvolution filter was applied to accelerate the system response to recreate the raw waveform for improved estimations in respiratory pathology detection (esophageal intubation, bronchospasm, cuff leak, etc.).

Methods: A sampling pump (Diaphragm Pump 2002 VD LC, CO2Meter, Inc., Ormond Beach, FL) was used to draw sample gas at 500mL/min through a 3 ft. long sampling tube to the environmental sensor (SprintIR 20%, CO2Meter, Inc. Ormond Beach, FL). A microcontroller (Arduino Uno, Arduino, Italy) both sampled the sensor at 40 Hz and displayed the waveform and respiratory rate on a 3.2" LCD display (Nextion NX4024T032, ITEAD Intelligent Systems Co. Ltd, China). A lung simulation model was created using a Servo Ventilator 900C (Siemens-Elema, Sweden) and a test lung (TTL Training Test Lung, Michigan Instruments, Grand Rapids, MI). A mass flow controller (Alicat Scientific, Tucson, AZ) was used to delivery carbon dioxide to the test lung. For comparison, reference waveforms were simultaneously measured using a sidestream capnography unit ((Datex-Ohmeda, Helsinki, Finland) and a mainstream capnography unit (Respironics NM3, Philips, Amsterdam Netherlands). To test the accuracy of the implemented deconvolution filter, in silico waveforms were created the simulated normal breathing, pediatric breath, obstructive disease, spontaneous breath, cardiac oscillation, and apnea.

Results and Discussion: Our proof-of-concept device was successful in determining respiratory rates and showed no discrepancy between modern capnometry and capnography devices. The reconstruction of the carbon dioxide waveform yielded mixed results, however was generally capable of revealing the underlying the waveform at the cost of noise amplification (Figure 1). Future iterations will emphasize addressing these high-frequency artifacts to recreate a more realistic waveform.



References:

[1] R. M. Beringer and R. J. Eltringham, *Anaesth. Intensive Care*, vol. 36, no. 3, pp. 442–448, 2008.

[2] G. Dubowitz *et al.*, *Anaesthesia*, vol. 68, no. 12, pp. 1220–1223, 2013.

[3] "American Society of Anesthesiologists. Committee of Standards and Practice Parameters. Standards For Basic Anesthetic Monitoring," 2015. [Online]. [Accessed: 30-Apr-2018].

[4] A. F. Merry, J. B. Cooper, O. Soyannwo, I. H. Wilson, and J. H. Eichhorn, *Can. J. Anesth.*, vol. 57, no. 11, pp. 1027–1034, 2010.

[5] World Health Organization, *Who*, p. 125, 2009.