Capnography-Guided Intubation

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***Abstract*—The device uses capnography to guide intubation for more effective airway management. The carbon dioxide concentration is conveyed to the anesthesiologist through an audible signal, which is used to direct the endotracheal tube into the trachea. The process significantly speeds up procedure time in difficult airway cases while reducing the risk of improper tracheal tube placement.**

I. Introduction

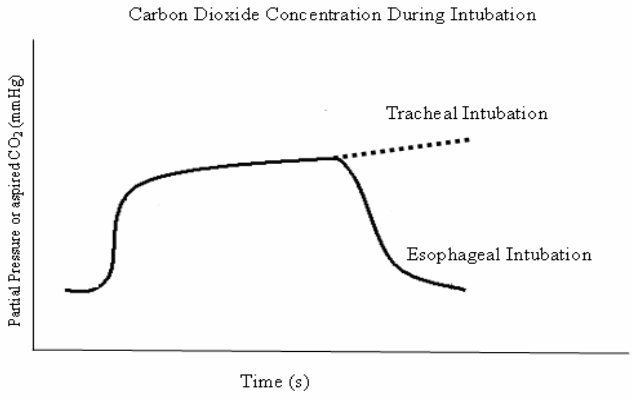
A. Background

Intubation is a commonly performed medical procedure in which an artificial airway is established in a patient to provide proper gas exchange. It depends on the proper insertion of the endotracheal tube into the trachea instead of the esophagus. The placement of the endotracheal tube into the esophagus can lead to death, brain damage, insufflation of the stomach, damage to the epiglottis and does not correct the improper gas exchange. Improper placement of the endotracheal tube can be difficult to detect and dramatically increases the intubation procedure time, often leading to complications. This problem is significantly magnified in difficult airway cases such as those involving trauma or anatomical obstructions.

Capnography is the monitoring of the concentration of exhaled carbon dioxide in order to assess the physiologic status of patients with acute respiratory problems. Up to now, capnography was primarily used after the insertion of the endotracheal tube into the body to verify the position of the ET tube. Though effective, the process is quite time consuming, requiring the complete retraction and reinsertion of the tube to change the location.

B. Objective

The purpose of the proposed device is to give physicians, paramedics, and other airway management personnel the ability to better manage difficult airway cases by using capnography to guide the intubation. By providing real-time CO_2 feedback, the intubator will know immediately when the ET tube has entered the trachea ($aspCO_2$ >5 mmHg) or the esophagus ($aspCO_2$ <5 mmHg) and can take immediate action to correct the position of the tube. The primary application of this device will be in difficult intubations, where the airway pathway is obstructed by a large wound, fluids, tumor, or any other major abnormality that prevents conventional intubation. As a result, overall procedure time is shortened and the risk of an esophageal intubation is greatly reduced, saving money, time, and lives.



II. Preliminary Study

A preliminary study was performed on 12 patients by Dr. Atlas of the Anesthesiology Department at the University of Medicine and Dentistry of New Jersey (UMDNJ) to confirm feasibility of the design. The results showed that aspired CO_2 from tracheal intubations had a mean partial pressure of 23.25 mmHg with a standard deviation of 14.01 mmHg. Whereas esophageal intubations had a mean $aspCO_2$ partial pressure of 2.25 mmHg with a standard deviation of 2.06 mmHg (P = 0.0036). The design immediately differentiated between the trachea and the esophagus, resulting in a much faster intubation.

III. Design

The proposed device integrates a mainstream capnograph, a suction unit, and an audio circuit to obtain a direct measurement of CO_2, which is conveyed to the physician through a dynamic audio circuit. For a standard 7.0 mm diameter endotracheal tube, an applied suction of 180 mmHg, a turbulent airflow of 0.5 liters/second is generated with a corresponding Reynolds number of 9,375, ensuring the extraction of a sufficient gas sample quickly. The 180 mm Hg is critical to the proper functionality of the device. If the applied pressure is significantly greater then 180 mmHg, physical damage to the lungs, trachea, pharynx or esophagus could result. If it is significantly lower, an insufficient sample will be extracted, resulting in a false reading.

The CO_2 concentration of the extracted gas is measured by a pre-calibrated infrared detector within the capnograph, this data is then relayed to the rest of the system through a voltage converter. The entire system will operate from a single 120

AC power source and/or a single built-in battery, with an expected operating time of about 4 hours. The entire package will be portable, lightweight and rugged, ideal for hospital and pre-hospital settings.

A. Measurement

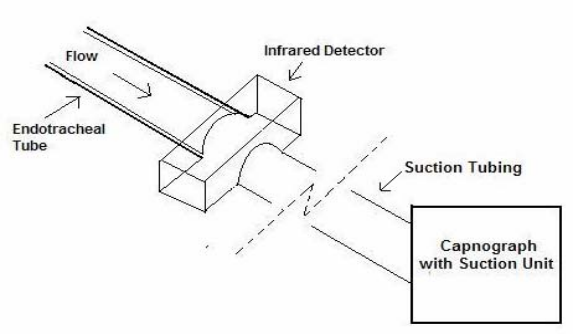
Mainstream capnographs function by using an infrared sensor to scan a small volume of gas, which is analyzed to determine the partial pressure of CO_2. The capnograph selected for this design, unlike side-stream capnographs, had an external infrared detector which was positioned on the proximal end of the endotracheal tube, rather then inside the main unit. Combined with a suction unit, this feature allows for real-time data acquisition. The vacuum pump of the unit is attached to the capnograph sensor and provides enough suction to deliver sufficient gas from the end of the ET tube to the capnograph sensor for a proper CO_2 concentration measurement. The suction unit is small enough to be incorporated into the base of the capnograph. The low power consumption of the suction unit allows it to be incorporated into the main power supply of the capnograph

B. The Audio Circuit

To streamline the intubation process, an audio circuit was designed to correlate the concentration of aspired CO_2 to the pitch of the projected sound. The change in pitch varies with each incremental increase in the CO_2 concentration; a difference of even 5 mmHg can easily be detected by an untrained professional. Guided by the pitch of the sound, the intubator will be able to make real-time adjustments in the position of the ET tube as to increase the pitch and guide the tube into the trachea. In future models, the volume and audio output can be adapted to accommodate most environmental conditions.

C. Operation

The device is operated by activating and calibrating the capnograph using the built-in optical infrared standards. The suction unit is then connected to hollow stylet. A sterilized ET tube is then connected to the infrared detector of the capnograph. The stylet is then inserted into the proximal end of the ET tube, creating a closed path from the ET tube to the infrared detector and the suction unit. When the intubator is ready to perform the procedure, the suction unit is activated and the intubation is performed normally, except the intubator relies on the audio signal for any position adjustment. The audio circuit is calibrated to initially produce a low audible pitch correlating to a low CO_2 reading of normal atmospheric air and assuring the intubator that the device is properly working. Upon entering the trachea, the sound will change to a higher pitch in response to the increase in CO_2 concentration, indicating that the ET tube is properly positioned and ready to be fixed in place. The stylet is then removed and discarded, along with the tubing of the suction unit.



IV. TESTING

The preliminary testing of the device will be performed using laboratory means to test the response of the device to different levels of carbon dioxide at the distal end of the endotracheal tube. A two pump system will be used to obtain the proper mixture of oxygen and carbon dioxide, the flow of the mixture will be closely regulated to resemble that of the trachea.

After IRB approval at UMDNJ, the device will be tested during actual intubations to ensure the optimal operating conditions. A laptop-based data acquisition system will be used to track and record the performance and output of the device. The laptop system will be operated independently of the device by a technician with no connection to the intubator. Adjustments in the volume, quality and pitch sensitivity of the audio circuit will be adjusted based on the result of the study

ACKNOWLEDGMENT

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