Modern Clinical Gas Monitoring

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Abstract: This presentation will review some of the basic principles and technical solutions behind the state-of-the-art clinical gas monitoring, consider relevant practical problems and forecast future directions in the field.

INTRODUCTION

Modern gas measurement technology specially designed for clinical applications offers comprehensive analysis of all the respiratory gases commonly present during anesthesia and intensive care. Concentrations of CO_2 , O_2 , N_2O, N_2 and all the five commercially available volatile agents can be measured on breath-by-breath basis [1]. It is also possible to automatically identify the agents. Most of the patients requiring continuous analysis of respiratory gases are under machine ventilation and to obtain both inspiratory and expiratory gas values the measuring spot needs to be at the entrance of the endotracheal tube connecting the patient airway to the ventilator. This represents quite harsh environment for the sensors because of presence of humidity and excretions.

SIDE STREAM PRINCIPLE

The dominant designs in the clinical gas measurement are still based on the side-stream principle. The gas mixture to be analyzed is pumped along a thin plastic sampling line into one or more sensors inside a patient monitor. Infrared absorption can be used to measure all relevant gases except O_2 and N_2. Separate simple infrared spectrometers are able to identify the anesthetic agents. In oxygen measurement the fast paramagnetic sensors [2] have practically replaced the electrochemical cells. Nitrogen can be measured only by mass spectrometers or Raman spectrometers which however have only obtained limited popularity in routine clinical use.

MAIN STREAM PRINCIPLE

The idea of the mainstream sensor is to measure on- site, in other words right at a cuvette attached to the airway the patient. Then only an electrical connection between the sensor and monitor is required.. At the moment main-stream sensors only for CO_2 are available . The main challenge in this approach is to continuously compensate against cuvette window contamination, which has an unpredictable spatial and temporal distribution. The only possibility is to utilize a real or virtual single beam configuration producing a reference signal obtained along the same axis as the effective measuring signal.

Some interesting developments aiming to mainstream O_2 sensors have been around during the past few years. These are based either on NIR optical absorption or luminescence quenching .

AIRWAY FLOW AND PRESSURE

The measurements of airway flow and pressure are a natural extension to advanced gas monitoring. The introduction of compact spirometry sensors [3] combining flow and pressure measurements into the standard adapter used in sidestream gas measurement, has opened way to routine monitoring of patient airway patency and lung mechanics during mechanical ventilation. It should be emphasized that an acceptable accuracy in gas flow measurement can be reached only by knowing the gas composition, because the signal depends on the density and/or viscosity of the gas mixture. Then integrating and interfacing the spirometry sensor to a multigas monitor with a display offers obvious added value both regarding the accuracy of the measurements and the graphical presentation capabilities of the results.

PRACTICAL PROBLEMS

Both gas analysis and flow measurement are prone to errors introduced by presence of humidity, moisture and secretions in the patient breathing circuit No perfect solutions exist. in spite of many ingenious designs and new materials employed to remove water vapor and prevent water droplet and secretion interference. These include special tubing designed to remove extra water vapor by using an ion exchange process, hydrophobic and/or hydrophilic membranes to collect condensed water droplets and heated constructions to prevent condensation. A good practical solution should basically ensure continuous measurement while protecting the sensors over a well specified time range, including a prompt alert to give a message when it is time to exchange any disposables or clean the reusable parts of the system.

FUTURE

The future of clinical gas monitoring will be rather be evolutionary than revolutionary. leading to still more miniaturized, and more reliable equipment. A great challenge will be to develop a compact and accurate device also for the gas exchange parameters like O_2 uptake and CO_2 elimination.

REFERENCES

[1] J.S.Gravenstein, D.A.Paulus, T.J.Hayes, Gas monitoring in clinical practice, Boston: Butterworth-Heinemann, 1995.

[2] P.T.Meriläinen , "A differential paramagnetic sensor for breath-by-breath oximetry", J Clin Monit, vol. 6, pp. 65-73, 1990.

[3] P.T.Meriläinen, H.Hänninen and L.Tuomaala, “A novel sensor for routine continuous spirometry of intubated patients”, J Clin Monit, vol. 9, pp. 374-380 , 1993.