Capnography

Capnography is the monitoring of the concentration or partial pressure of carbon dioxide (CO_2) in the respiratory gases. Its main development has been as a monitoring tool for use during anaesthesia and intensive care. It is usually presented as a graph of expiratory CO_2 plotted against time, or, less commonly, but more usefully, expired volume. The plot may also show the inspired CO_2, which is of interest when rebreathing systems are being used.

The capnogram is a direct monitor of the inhaled and exhaled concentration or partial pressure of CO_2, and an indirect monitor of the CO_2 partial pressure in the arterial blood. In healthy individuals, the difference between arterial blood and expired gas CO_2 partial pressures is very small, and is probably zero in children. In the presence of most forms of lung disease, and some forms of congenital heart disease (the cyanotic lesions) the difference between arterial blood and expired gas increases and can exceed 1 kPa.

During anaesthesia, there is interplay between two components: the patient and the anaesthesia administration device (which is usually a breathing circuit and a ventilator or respirator). The critical connection between the two components is either an endotracheal tube or a mask, and CO_2 is typically monitored at this junction. Capnography directly reflects the elimination of CO_2 by the lungs to the anaesthesia device. Indirectly, it reflects the production of CO_2 by tissues and the circulatory transport of CO_2 to the lungs.

When expired CO_2 is related to expired volume rather than time, the area beneath the curve represents the volume of CO_2 in the breath, and thus over the course of a minute, this method can yield the CO_2 minute elimination, an important measure of metabolism. Sudden changes in CO_2 elimination during lung or heart surgery usually imply important changes in cardiorespiratory function.

Capnographs usually work on the principle that CO_2 absorbs infra-red radiation. A beam of infra-red light is passed across the gas sample to fall on to a sensor. The presence of CO_2 in the gas leads to a reduction in the amount of light falling on the sensor, which changes the voltage in a circuit. The analysis is rapid and accurate, but the presence of nitrous oxide in the gas mix changes the infra-red absorption via the phenomenon of collision broadening. This must be corrected for. Measuring the CO_2 in human breath by measuring its infra-red absorptive power was established as a reliable technique by John Tyndall in 1864, though 19th and early 20th century devices were too cumbersome for everyday clinical use.[1]

Diagnostic usage

Capnography provides information about CO_2 production, pulmonary (lung) perfusion, alveolar ventilation, respiratory patterns, and elimination of CO_2 from the anaesthesia breathing circuit and ventilator. The shape of the curve is affected by some forms of lung disease; in general there are obstructive conditions such as bronchitis, emphysema and asthma, in which the mixing of gases within the lung is affected.

Conditions such as pulmonary embolism and congenital heart disease, which affect perfusion of the lung, do not, in themselves, affect the shape of the curve, but greatly affect the relationship between expired CO_2 and arterial blood CO_2. Capnography can also be used to measure carbon dioxide production, a measure of metabolism. Increased CO_2 production is seen during fever and shivering. Reduced production is seen during anaesthesia and hypothermia.

Use in anaesthesia

Capnography has been shown to be more effective than clinical judgement alone in the early detection of adverse respiratory events such as hypoventilation, oesophageal intubation and circuit disconnection; thus allowing patient injury to be prevented. During procedures done under sedation, capnography provides more useful information, e.g. on the frequency and regularity of ventilation, than pulse oximetry.

Capnography provides a rapid and reliable method to detect life-threatening conditions (malposition of tracheal tubes, unsuspected ventilatory failure, circulatory failure and defective breathing circuits) and to circumvent potentially irreversible patient injury.

Capnography and pulse oximetry together could have helped in the prevention of 93% of avoidable anaesthesia mishaps according to an ASA (American Society of Anesthesiologists) closed claim study.

Capnography in emergency medical services

Capnography is increasingly being used by paramedics to aid in their assessment and treatment of patients in the prehospital environment. These uses include verifying and monitoring the position of an endotracheal tube. A properly positioned tube in the trachea guards the patient's airway and enables the paramedic to breathe for the patient. A misplaced tube in the esophagus can lead to death.

A study in the March 2005 *Annals of Emergency Medicine,* comparing field intubations that used continuous capnography to confirm intubations versus non-use showed zero unrecognized misplaced intubations in the monitoring group versus 23% misplaced tubes in the unmonitored group. The American Heart Association (AHA) affirmed the importance of using capnography to verify tube placement in their 2005 CPR and ECG Guidelines.

The AHA also notes in their new guidelines that capnography, which indirectly measures cardiac output, can also be used to monitor the effectiveness of CPR and as an early indication of return of spontaneous circulation (ROSC). Studies have shown that when a person doing CPR tires, the patient's end-tidal CO_2 (ETCO2, the level of carbon dioxide released at the end of expiration) falls, and then rises when a fresh rescuer takes over. Other studies have shown when a patient experiences return of spontaneous circulation, the first indication is often a sudden rise in the ETCO2 as the rush of circulation washes untransported CO_2 from the tissues. Likewise, a sudden drop in ETCO2 may indicate the patient has lost pulses and CPR may need to be initiated.

Paramedics are also now beginning to monitor the ETCO2 status of nonintubated patients by using a special nasal cannula that collects the carbon dioxide. A high ETCO2 reading in a patient with altered mental status or severe difficulty breathing may indicate hypoventilation and a possible need for the patient to be intubated.

Capnography, because it provides a breath by breath measurement of a patient's ventilation, can quickly reveal a worsening trend in a patient's condition by providing paramedics with an early warning system into a patient's respiratory status. As more clinical studies are conducted into the uses of capnography in asthma, congestive heart failure, diabetes, circulatory shock, pulmonary embolus, acidosis, and other conditions, the prehospital use of capnography will greatly expand.

See also

- Medical equipment
- Medical test
- Pulse oximeter
- Integrated Pulmonary Index

References

[1] Michael B. Jaffe (2008), "Infrared Measurement of Carbon Dioxide in the Human Breath: “Breathe-Through” Devices from Tyndall to the Present Day", in *Anesthesia & Analgesia*, vol. 107, pages 890-904. Downloadable (http://www.anesthesia-analgesia.org/cgi/reprint/107/3/890.pdf)

- The effectiveness of out-of-hospital use of continuous end-tidal carbon dioxide monitoring on the rate of unrecognized misplaced intubation within a regional emergency medical services system (http://www.annemergmed.com/article/S0196-0644(04)01442-8/abstract), Silvestri S, Ralls GA, Krauss B, Thundiyil J, Rothrock SG, Senn A, Carter E, Falk J. Annals of Emergency Medicine. May 2005; Vol. 45, Issue 5, 497-503.
- Microstream capnography improves patient monitoring during moderate sedation: A randomized,controlled trial (http://pediatrics.aappublications.org/cgi/reprint/117/6/e1170), Lightdale JR, Goldmann DA, Feldman HA, Newburg AR, DiNardo JA, Fox VL. Pediatrics. June 2006; Vol. 117, No. 6, e1170-1178.
- Does end-tidal carbon dioxide monitoring detect respiratory events prior to current sedation monitoring practices? (http://www.ncbi.nlm.nih.gov/pubmed/16569750), Burton JH, Harrah JD, Germann CA, Dillon DC. Academic Emergency Medicine May 2006; Vol. 13, No. 5, 500-504.

External links

- American Society of Anesthesiologists (http://www.asahq.org/)
- Textbook: Capnography: Clinical Aspects (http://www.cambridge.org/uk/catalogue/email.asp?isbn=0521540348)
- Capnography.com (http://www.capnography.com/Homepage/HomepageM.htm)
- Capnography for Paramedics (http://emscapnography.blogspot.com/)
- CapnoBase.org: Respiratory signal database that contains clinical and simulated capnogram recordings (http://www.capnobase.org/)
- Research project on capnography (http://ecem.ece.ubc.ca/research.htm#SmartCapnography)

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