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F. Rutten

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Capnography in Pre- and Hospital Treatment
Patient with Head Injury after Motor Vehicle Accident

Author F. Rutten

Institute MD, Visiting Professor Emergency Medicine, University of Massachusetts Medical School, Worcester, MA, USA; Chief National Instructor Primary Emergency Medicine Course (STARtclass), SBOH, Utrecht, The Netherlands; Consultant Emergency and Critical Care Medicine, Streekziekenhuis Koningin Beatrix Hospital Winterswijk and Beatrixziekenhuis Gorinchem The Netherlands

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Corresponding author
Frans Rutten
Rutten Emergency Medical Support
Vlaggeschip 39
4902 CN Oosterhout
The Netherlands
f.rutten@rutten-ems.com

Abstract

In this underlying case the importance of capnography and end-tidal CO_2 monitoring during initial emergency medical management, transport to the hospital and admittance in the hospital is stressed. Since capnography is easily available and relatively cheap, the use of it during pre-hospital emergency care and transport has been increased significantly.

Case

While driving his car with high speed and without wearing seat belts a 28 year old male ran off the road. Another car driver witnessed the accident and called for emergency services. The 28 year old was found sitting unconsciously in his car.
Together with the fire rescue, the unconscious patient was extricated and treated rapidly in the ambulance. Because of his unconsciousness, it was decided to intubate and ventilate him.
In the meanwhile the transport ventilator (Oxylog 3000 plus, Draeger Medical, Lübeck) was made ready for use and with a mask 100 % oxygen was delivered with spontaneous ventilation on CPAP 3 cm H_2O/mbar and with pressure support 8 cm H_2O/mbar.
After crash induction with anaesthetics and muscle relaxants, endotracheal intubation followed. Because of the presence of blood in the oropharynx and a fracture of the mandible, intubation was difficult and the vocal cords could hardly be visualized. Although the patient was intubated the right positioning of the tube remains questionable.
However, after connection of the ventilator a CO_2 signal at the capnogram, incorporated in the ventilator (Oxylog 3000 plus) was immediately visible and confirmed that intubation was successful. The tube was fixed at 22 cm and ventilation started with a setting of 8 ml / kg Vt and a frequency of 14/min and AutoFlow mode activated.
The capnogram showed an $ETCO_2$ of 55 mm Hg, which is a little bit too high for head injury. The ventilator TV was a little bit increased and the $ETCO_2$ started to decrease slowly. Inspiratory pressures were normal, oxygen saturation was 100 % with FiO_2 of 1.0 and also the circulatory parameters were normal. There were no signs for severe bleeding at that moment. Two large bore catheters were introduced. Pupils were not equal: the right pupil was widened and showed weak reaction on light. It was decided to start transport and after total spinal immobilization the emergency rescue team was on the way to a trauma centre located in about 20 km.
During transport the $ETCO_2$ was slowly further decreasing and ventilator settings were adjusted for an $ETCO_2$ of 36–40 mm Hg. Everything was under control and after 20 minutes the team with the patient arrived at the hospital, where the trauma team already was activated.

CO_2 Measurement supports intubation

In the trauma room, the patient was handed over to the trauma team of the hospital and moved from the ambulance stretcher to the trauma room stretcher (**Fig. 1**). While moving to the other stretcher, a small accident occurred because the tubing of the hospital ventilator was hooked by a part of the stretcher which caused some stretch on the tube. This provoked some uncertainty about the position of the tube. The anaesthesiologist decided to check the position of the tube by laryngoscope, but because of the swelling of soft tissues and bleeding in the oropharynx he could not see the vocal cords. The capnometer of the ventilator (Oxylog 3000 plus) was reconnected and there was no CO_2 measurable during ex-

Fig. 1 CO_2 Sensor in use in trauma room (Draegerwerk AG & Co. KGaA).

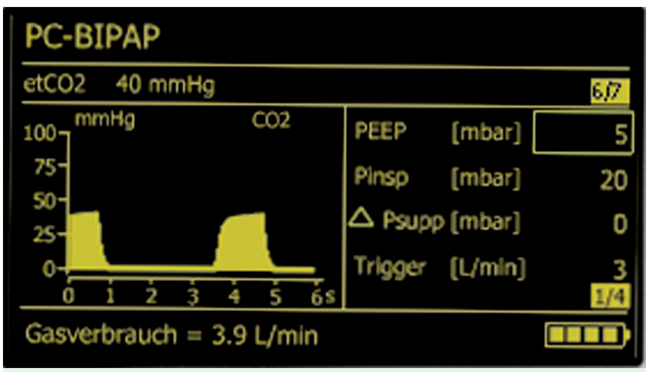

Fig. 2 Integrated CO_2 measurement using Oyxlog 3000 plus (Screenshot: Draegerwerk AG & Co. KGaA).

piration, indicating that the tube probably was out of the trachea. The anaesthesiologist decided to remove the tube and to reintubate the patient. With assistance of suction equipment the vocal cords were visible a small moment but just enough to reintubate. Now there was CO_2 visible on the monitor of the ventilator, indicating that the intubation was successful (▶ **Fig. 2**). This time the tube was fixed more secure and ventilation was continued.
It became obvious that the neurological status of the patient was worsening quickly. Also, there were no clear clinical signs of severe bleeding and the patient was transported rapidly to the CT-scanner.
The CT-scan showed an epidural hematoma which had to be operated as soon as possible.
During the scanning maneuver however, the $ETCO_2$ was slowly decreasing and was 22 mm Hg, about half of the initial values of about 40 mm Hg. The ventilator settings were not changed during transport, the scanning temperature was the same and it was concluded that this could be a sign of circulatory failure. Blood pressure was lower than initially, but was thought to be caused by the anesthetics given. The trauma surgeon wanted to check the abdomen by ultrasound which showed free fluid in abdomen, and also an indication for a laparotomy. The patient was brought immediately to the operating room where simultaneously the epidural hematoma was operated by the neurosurgeon and the abdominal bleeding by the trauma surgeon.
The patient recovered steadily and after three weeks he could be discharged from the hospital with minimal impairments.

Discussion

There were several moments where this favorable outcome could have been worse. Main reason why this was not the case is that capnography was available during the whole emergency ventilation period: on scene, during transport, during referring to another stretcher, transport to the CT-scanner and during CT-scanning as well.
This case shows how easily a complication can occur during the whole period of trauma care and also how easily some life threatening events can be recognized and corrected by using capnography.
Although it is known that hypo- or hyperventilation can cause adverse outcomes in head trauma, capnography is not always used during emergency trauma care. Calculated prehospital ventilation settings only reached in 18 % of the cases the target $PaCO_2$ upon hospital admission in a study by Kuhnigk et al., suggesting the value of the use of capnography in pre-hospital trauma care [1]. However, setting the ventilator only by end-tidal carbon dioxide monitoring can be problematic because of unknown arterial end-tidal carbon dioxide tension difference in the out of hospital setting. In major trauma patients, severe thoracic trauma, and severe hypovolemia can reduce end-tidal carbon dioxide with an increase in the end-tidal – arterial carbon dioxide tension differences to more than 10 mm Hg [2–8]. In a study by Helm and colleagues it was shown that the incidence of normoventilation can significantly be increased while the incidence of hypoventilation upon hospital admission was reduced significantly by using end-tidal carbon dioxide monitoring. The incidence of hyperventilation, however, was not reduced in the monitored group [9].
Capnography is not only a non-invasive monitoring technique which allows fast and reliable insight into ventilation, but also into circulation and metabolism. In patients with hemorrhage, capnometry provides improved continuous haemodynamic monitoring, insight into tissue perfusion, optimation within current hypotensive fluid resuscitation strategy, and prevention of shock progression through controlled fluid administration [10].
When ventilation performed by manually by bag the reduction in end-tidal CO_2 could be caused by hyperventilation, while in patients ventilated mechanically by sophisticated emergency ventilators with maintenance of minute volume, a decrease in end-tidal CO_2 can be a hint for unrecognized hemorrhage. Guzman et al showed that with constant minute ventilation, changes in end-tidal CO_2 correlate well with changes in oxygen consumption in hemorrhagic shock, and these changes also indicate the onset of oxygen supply dependency during hemorrhagic shock [11]. For this reason it is also recommended to ventilate major trauma patients by advanced emergency or transport ventilators, where expired minute volume can be controlled and end-tidal CO_2 can be measured simultaneously.

Capnography – background information

What is Capnography?

Capnography is the non-invasive measurement of the partial pressure of carbon dioxide (CO_2) in exhaled breath displayed as a numerical value or waveform on the display of the measurement unit. The numerical value is the end-tidal CO_2 ($EtCO_2$), or the maximum CO_2 concentration at the end of each tidal breath [12].

The operating principle of most capnometers is based on using infrared radiation absorbed by CO_2. A beam of infrared radiation from a light source is sent by an infrared capnometer to a detector. The presence of CO_2 in the gas leads to a reduction in the amount of light falling on the detector, which allows the quantity of CO_2 in the sample to be calculated [13].

Types of CO_2 measurement

There are two possible types of CO_2 measurement: mainstream and sidestream.

Devices with mainstream technique measure CO_2 directly from the airway. Here the sensor is located directly within the airway circuit [12]. The advantage of mainstream analyzers is a fast response time, which provides real-time data. Furthermore, no sample flow is detracted from tidal volume [13].

Devices with sidestream technique aspirate a small sample flow from the exhaled breath to measure CO_2 through a capillary tube. This is lead to a remote sensor located inside the capnometer and away from the patient's airway [3]. The disadvantage of this system is that the sampling tubing can become occluded with water and secretions [14]. In addition, with sidestream system a delay in recording can be the case because of gas movement from the ET to the unit and changes in water vapor pressure affect CO_2 concentrations [15].

Conflict of interests

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The author states to have worked for Draeger Medical Best in the Netherlands till 2010, being responsible as consultant for clinical R&D for the Product Oxylog 3000.

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