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Equipment Monitoring

(Abstract and Case Report/Series)
Acute Elevation of End-Tidal Carbon Dioxide as the Only Indicator of Inferior Vena Cava (IVC) Injury

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Introduction: Capnography assesses adequacy of ventilation by quantifying end-tidal carbon dioxide measurement (ETCO₂). Capnography is recommended for general anesthesia and specifically laparoscopic cases for early detection of venous carbon dioxide (CO₂) embolism.¹, ² The differential diagnosis for an acute rise in ETCO₂ includes increased CO₂ production from hypermetabolic disease states, exogenous CO₂, hypoventilation, and equipment malfunction.² We describe an unusual presentation of inferior vena cava (IVC) injury resulting in an isolated abrupt rise in ETCO₂.

Case Presentation: Patient consent was obtained for publication of this case. A 30-year-old male with Cushing’s disease was scheduled for endoscopic bilateral adrenalectomy. His other co-morbidities included asthma, hypertension, Hodgkin’s lymphoma and obesity (BMI 39). Standard CAS monitors, large bore intravenous access and an arterial line were placed. An 8.0mm endotracheal tube was inserted and sevoflurane used for maintenance. Patient was placed in prone position using a Cloward saddle. Mechanical ventilation consisted of tidal volumes of 600mL, 14 breaths per minute, PEEP of 8, and a target ETCO₂ between 35-40mmHg.

ETCO₂ gradually increased to 51mmHg as expected with prolonged retroperitoneal CO₂ insufflation. As the surgeons were exposing the right adrenal gland, ETCO₂ increased suddenly from 51mmHg to 70mmHg with no obvious etiology. Surgery was paused, the retroperitoneum desufflated, and minute ventilation increased. The arterial blood gas drawn when ETCO₂ decreased to 49mmHg showed pH = 7.27, PaO₂ = 300mmHg, HCO₃ = 24mmHg PaCO₂ = 53mmHg, and PaCO₂-ETCO₂ gradient = 4mmHg. Eventually, ETCO₂ decreased to 45mmHg and the retroperitoneum was re-insufflated. Within seconds, the ETCO₂ rose to 69mmHg again. All other vital signs were stable.

Surgical exploration revealed a 2mm IVC hole with no visible hemorrhage. The lesion was packed with good hemostasis and no acute rises in ETCO₂ levels occurred for the remainder of the procedure. Postoperatively, CT angiography revealed no extravasation from the IVC. The patient was placed on bed rest for 24 hours and underwent successful open adrenalectomy 48 hours later.

Discussion: IVC injuries are a rare complication of retroperitoneal laparoscopic adrenalectomy, given the proximity of the right adrenal gland to the IVC. With large vascular injuries, hemorrhage and CO₂ emboli can occur.³ These typically present as hypotension, dyspnea, cyanosis, arrythmia, or a decrease in ETCO₂ secondary to right ventricular outflow obstruction and cardiovascular collapse.⁴ In smaller injuries, laparoscopic insufflation pressures can prevent hemorrhage, making the diagnosis challenging.⁵ In our case, an abrupt rise in ETCO₂ was the
only early diagnostic clue for vascular injury. The patient was hemodynamically stable with no signs of hemorrhage. Had insufflation continued without addressing the injury, the patient could have developed a large CO₂ embolism.

This case report reinforces the importance of ETCO₂ monitoring during laparoscopy and its potential role in diagnosing vascular injury.

REFERENCES:

Comparison of the Novel Membrane-Based Carbon Dioxide Filter Memsorb® with a Chemical Granulate Absorbent Using a Lung Simulator Device: A Prospective, Randomized, In-Vitro Feasibility Trial

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Introduction: Memsorb™ is a novel device for carbon dioxide (CO₂) removal from anesthesia circuits. A semipermeable polymeric membrane removes CO₂ from the anesthesia circuit while conserving inhalational agents¹. First clinical trials indicate functionality with Draeger anesthesia machines². We evaluated the performance of the Memsorb (DMF Medical, Halifax, Canada) device for removal of CO₂ from a General Electric Datex-Ohmeda Aisys CS2 (GE, USA) anesthesia machine compared to a standard chemical granulate absorber (CGA) (Amsorb, GE, USA), using a high-fidelity lung simulator³. We hypothesized that Memsorb device performance would be non-inferior to standard CGA for maintenance of end-tidal CO₂ (EtCO₂) and fraction of inspired CO₂ (FiCO₂) at commonly used, pre-defined fresh-gas flows.

Methods: Ethics approval was not applicable because the study did not involve human or animal research. The in-vitro lung simulator based on a U-tube manometer (DuCT, Dr. Enk, Muenster, Germany) allows controlled CO₂ release, imitating alveolar gas exchange. CO₂ gas was released in the water portion of the simulator device at a flow of 0.175 l/min. The lung simulator was connected to the anesthesia machine ventilator via a standard anesthesia circuit tubing and an endotracheal tube (ID 7.5 mm). An air-oxygen blender for CO₂ washout of the Memsorb was used (FiO₂: 0.40, flow: 15 l/min). Fresh gas flow (FGF) was randomized to either 0.5 L/min or 2 L/min, completing 3 trials for each FGF. Ventilator settings were identical for all measurements. EtCO₂, FiCO₂, ventilation pressures and dynamic compliance were evaluated at 5-minute intervals for 30 minutes duration. Statistical analysis was performed using two-way ANOVA, p<0.05 was considered statistically significant.

Results: Ventilation parameters and dynamic compliance were similar between groups. EtCO₂ was comparable between groups with 2 l/min FGF over the observation period (Fig. 1 A). FiCO₂ was significantly higher in the Memsorb group during the trial (2 l/min; difference between means 3.9 mmHg, 95%CI of difference 4.4-3.3, p<0.0001). EtCO₂ with 0.5 l/min FGF was different between the two groups (3.7 mmHg, 95%CI 2.7-4.7, p<0.001, Fig 1B). With 0.5 l/min FGF, FiCO₂ was significantly higher in the Memsorb group compared to CGA (6 mmHg, 95%CI 6.4-5.5, p<0.0001).

Discussion: We showed for the first time under controlled conditions that Memsorb was non-inferior to standard CGA in CO₂ elimination in a high-fidelity lung simulator. With 0.5 l/min FGF, statistically significant higher EtCO₂ levels were observed using Memsorb. However, the magnitude of difference is unlikely to be clinically relevant. In this experimental setup, use of Memsorb resulted in higher FiCO₂ compared to CGA. Despite these higher concentrations of inspired CO₂, this did not translate into a meaningful increase in EtCO₂. These results indicate...
that MemSorb is a suitable device for CO₂ removal under simulated conditions and justifies clinical trials with GE anesthesia machines in the future.

REFERENCES:


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Figure 1. Figure showing mean end-tidal carbon dioxide (EtCO2) and inspired carbon dioxide (FiCO2) at 2 l/min and 0.5 l/min fresh gas flow. CGA= Chemical Granulate Absorbent.

A. 2 l/min Fresh Gas Flow

B. 0.5 l/min Fresh Gas Flow