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Equipment Monitoring

(Abstract and Case Report/Series)

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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 ($ETCO_2$). Capnography is recommended for general anesthesia and specifically laparoscopic cases for early detection of venous carbon dioxide (CO_2) embolism.[1, 2] The differential diagnosis for an acute rise in $ETCO_2$ includes increased CO_2 production from hypermetabolic disease states, exogenous CO_2, 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 $ETCO_2$ between 35-40mmHg.

$ETCO_2$ gradually increased to 51mmHg as expected with prolonged retroperitoneal CO_2 insufflation. As the surgeons were exposing the right adrenal gland, $ETCO_2$ 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 $ETCO_2$ decreased to 49mmHg showed pH = 7.27, PaO_2 = 300mmHg, HCO_3 = 24mmHg $PaCO_2$ = 53mmHg, and $PaCO_2$-$ETCO_2$ gradient = 4mmHg. Eventually, $ETCO_2$ decreased to 45mmHg and the retroperitoneum was re-insufflated. Within seconds, the $ETCO_2$ 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 $ETCO_2$ 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 CO_2 emboli can occur.[3] These typically present as hypotension, dyspnea, cyanosis, arrythmia, or a decrease in $ETCO_2$ 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 $ETCO_2$ 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 CO_2 embolism.

This case report reinforces the importance of $ETCO_2$ monitoring during laparoscopy and its potential role in diagnosing vascular injury.

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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 (CO_2) removal from anesthesia circuits. A semipermeable polymeric membrane removes CO_2 from the anesthesia circuit while conserving inhalational agents[1]. First clinical trials indicate functionality with Draeger anesthesia machines[2]. We evaluated the performance of the Memsorb (DMF Medical, Halifax, Canada) device for removal of CO_2 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 simulator[3]. We hypothesized that Memsorb device performance would be non-inferior to standard CGA for maintenance of end-tidal CO_2 ($EtCO_2$) and fraction of inspired CO_2 ($FiCO_2$) 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 CO_2 release, imitating alveolar gas exchange. CO_2 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 CO_2 washout of the Memsorb was used (FiO_2: 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. $EtCO_2$, $FiCO_2$, 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. $EtCO_2$ was comparable between groups with 2 l/min FGF over the observation period (Fig. 1 A). $FiCO_2$ 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, $p<0.0001$). $EtCO_2$ 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, $FiCO_2$ 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 CO_2 elimination in a high-fidelity lung simulator. With 0.5 l/min FGF, statistically significant higher $EtCO_2$ 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 $FiCO_2$ compared to CGA. Despite these higher concentrations of inspired CO_2, this did not translate into a meaningful increase in EtCO2. These results indicate that Memsorb is a suitable device for CO_2 removal under simulated conditions and justifies clinical trials with GE anesthesia machines in the future.

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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.