
# 2022 CAS Annual Meeting

## Equipment Monitoring

(Abstracts and Case Report/Series)

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# Characterizing Drivers of Changes in Intraoperative Cerebral Saturation using a Supervised Machine Learning Classification Algorithm

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**Introduction:**

Regional cerebral oxygen saturation ($rSO_2$) has increasingly been used intraoperatively as a monitor of cerebral perfusion. There is evidence that monitoring and optimization of $rSO_2$ may improve patient outcomes.[1] To rationally manipulate $rSO_2$ an understanding of its drivers is necessary, ideally in the form of a hierarchical structure defining the relative importance of intraoperative variables including mean arterial pressure (MAP), systemic saturation, cardiac output, end-tidal (ET) $CO_2$, $ETO_2$, and ET anesthetic vapour, amongst others. To achieve this, we have implemented a supervised machine learning approach using eXtreme Gradient Boosting (XGBoost). Machine learning has many advantages over traditional statistical models when dealing with large, high dimensionality time series data sets, particularly through incorporating complex, non-linear, and non-pre-specified interactions between variables. Determining the relative contribution of various hemodynamic and ventilatory variables to a trained model's predictions allows for quantification of their importance as drivers of $rSO_2$ changes.

**Methods:**

Intraoperative data was collected from 146 patients with a minimum age of 60 years undergoing open abdominal or vascular surgery under general anesthesia. Institutional research ethics approval and informed patient consent were obtained prior to data collection. In all, 118 patients remained after exclusion for missing data. The signals obtained included continuous cardiac index, MAP, ET-$CO_2$ and $O_2$, pulse oximetry ($SpO_2$), fraction of inspired $O_2$, heart rate, and ET concentration of volatile anesthetic agent. The rSO2 was measured using bilateral near infrared spectroscopy, using the mean of the two signals. Each mean $rSO_2$ signal was partitioned into segments based on significant changes in the signal trend, with a minimum duration of 5 minutes. Segments that were up-sloping or down-sloping with a threshold corresponding to a change of at least 3 percentage points over 5 minutes were used for model training, which yielded 11517 segments (6461 down-sloping, 5056 up-sloping). Features from the independent variables including mean and slope were used to train the XGBoost classifier for prediction of association with either up or down-sloping $rSO_2$. The classifier was optimized and validated using 5-fold cross validation. The importance of the included features was then quantified based on information gain.

**Results:**

Based on 5-fold cross-validation, the classifier performed with a mean accuracy of 76.9% (SD 9.5%) and a mean area-under-ROC-curve of 0.85 (SD 0.08). The most important feature included in the model based on average gain (total information gain divided by the number of splits taken on the feature in ensemble of decision trees) was the slope of the associated $ETCO_2$ signal. The other top 5 features relative to this and in order of importance were the mean of the associated MAP signal (relative importance to $ETCO_2$ slope, RI = 0.74), SpO2

slope (RI = 0.69), $ETO_2$ mean (RI = 0.66), and $ETCO_2$ mean (RI = 0.46). The most important pairwise interaction was $ETCO_2$ slope x $ETO_2$ mean. The other top 3 pairwise interactions relative to this and in order of importance were $ETCO_2$ slope x $SpO_2$ slope (RI = 0.70), and $ETCO_2$ mean x MAP mean (RI = 0.62).

**Discussion:**

This model confirms existing evidence that $CO_2$ is a potent mediator of cerebral blood flow (CBF) and supplements evidence that hypocapnia has deleterious effects on cerebral oxygenation.[2-4] It quantifies the relative importance of blood pressure to CBF despite theoretically intact autoregulation. Published algorithms for reversing cerebral desaturation prioritize addressing blood pressure and systemic saturation prior to ventilatory parameters, and although this model agrees with the relevance of these variables, it challenges their hierarchy.[5] Finally, this approach demonstrates a novel use of machine learning for analysis of high-fidelity intraoperative data streams and its potential for new insights into patient management.

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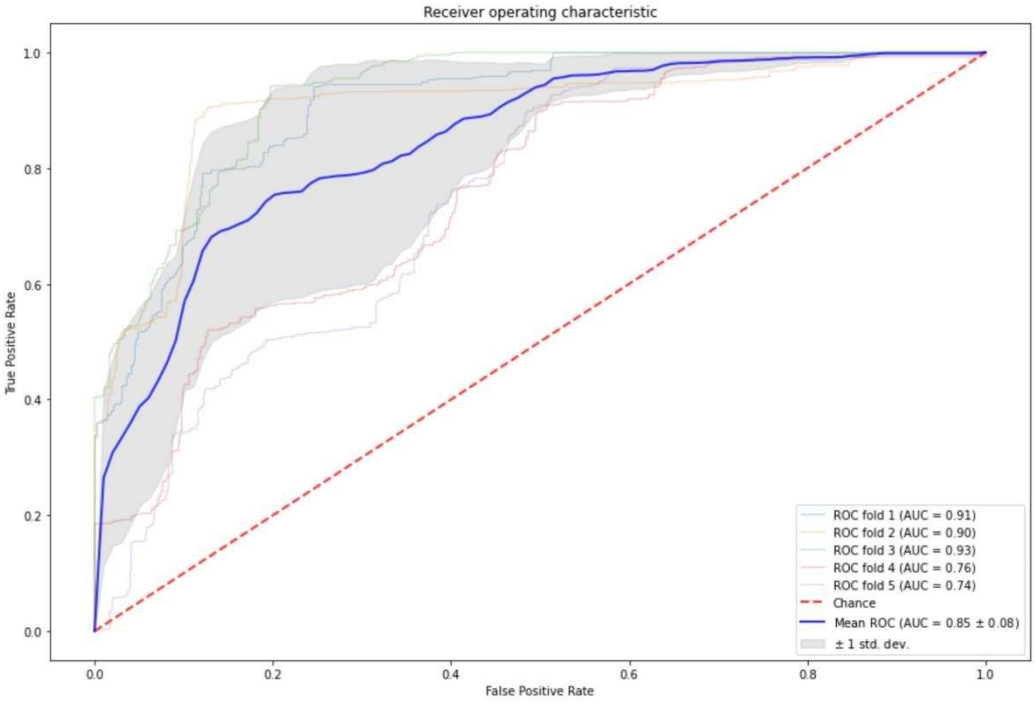
Figure 1:


Receiver operating characteristic
True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
ROC fold 1 (AUC = 0.91)
ROC fold 2 (AUC = 0.90)
ROC fold 3 (AUC = 0.93)
ROC fold 4 (AUC = 0.76)
ROC fold 5 (AUC = 0.74)
Chance
Mean ROC (AUC = 0.85 ± 0.08)
± 1 std. dev.

# Comparison of Hemodynamic Stability with Continuous Non-Invasive Blood Pressure Monitoring and Intermittent Oscillometric Blood Pressure Monitoring in Hospitalized Patients – A Systematic Review

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**Introduction:**
The most commonly and reliably used modality of blood pressure monitoring in non-critical care settings is the intermittent oscillometric non-invasive blood pressure (NIBP) monitoring which is widely accepted throughout the world. However, for some major surgeries and/or some critically ill patients invasive blood pressure monitoring may be desirable to detect earlier events of low or high blood pressure. But this modality is invasive and may rarely be associated with complications like arterial injury, thrombosis, limb ischemia, pseudoaneurysms, etc.[1] Recently, newer innovations have devised continuous non-invasive blood pressure monitors, which display real-time blood pressure with a continuous waveform using a finger cuff.[2-5] These devices while remaining non-invasive, will be ideal to fill the gap in the hemodynamic monitoring between invasive arterial and intermittent oscillometric NIBP monitoring methods. This systematic review was performed to assess the advantages of continuous non-invasive monitoring of arterial blood pressure in comparison to standard NIBP monitoring on the hemodynamic stability in hospital clinical care settings.

**Methods:**
The randomized trials and observational studies that compared the hemodynamic outcomes with continuous non-invasive monitoring and intermittent oscillometric BP monitoring in all types of hospital settings were searched from Medline, Embase, Scopus, Cochrane, and Web of Science databases on August 22nd, 2021. The objectives of this study were to compare the incidence of hypotension, incidence of hypertension, duration of blood pressure (BP) outside the normal range, duration of hypotension and hypertension and time to detect hypotension or hypertension while monitoring arterial blood pressure using continuous non-invasive blood pressure monitoring and standard intermittent oscillometric non-invasive blood pressure (NIBP) monitoring. Based on the assumption that the studies may be heterogeneous due to different clinical settings and varied outcome measurements, a random effects method was planned for meta-analysis for the outcomes for which data were adequate. A forest plot was obtained from the random effects model for graphical illustration of the estimates from the studies and the overall effect. For the other outcomes, a qualitative analysis was performed and the results were described to obtain inferences. The data were extracted for synthesis from the eligible studies and the results were summarized. The certainty of evidence was assessed using GRADE approach. The Rob-2 and ROBINS-I tools were used to assess the risk of bias for randomized trials and observational studies respectively.

**Results:**
Six randomized trials were done on surgical patients and six observational studies were performed on surgical, endoscopic and emergency department patients. The meta-analysis for incidence of hypotension was done with data from randomized trials in a total of 686 patients. The pooled odds ratio from random-effects model was 0.25 (0.10, 0.62);P=0.003, showing significant reduction in the incidence of hypotension with continuous non-invasive monitoring compared to intermittent oscillometric NIBP monitoring. The incidence of hypertension was similar between the patients monitored with either of the BP monitoring techniques. The

duration of hypotension and BP outside of normal range in the intraoperative period was reduced to less than half with continuous non-invasive monitoring when compared to the intermittent NIBP monitoring. The time to detect hypotension was at least 1.5 minutes earlier with the continuous non-invasive monitoring when simultaneously used with intermittent oscillometric NIBP monitoring that was cycled every 3 minutes during caesarean sections ($p<0.001$) and 8 minutes earlier in ED patients in whom NIBP monitoring was cycled every 15 minutes.

**Discussion:**

There is moderate quality of evidence to suggest that the incidence of hypotension with continuous non-invasive BP monitoring is less when compared to intermittent oscillometric BP monitoring based on the data from surgical patients. There is limited data comparing this monitoring modality in non-surgical hospital settings where this technique could be potentially beneficial. The duration of hemodynamic instability and time to detect hypotension are shorter with continuous non-invasive monitoring indicating a potential for improving quality of patient care and safety in appropriate clinical settings. Findings in this review thereby warrants further research with studies of large size and better methodological quality in diverse hospital settings.

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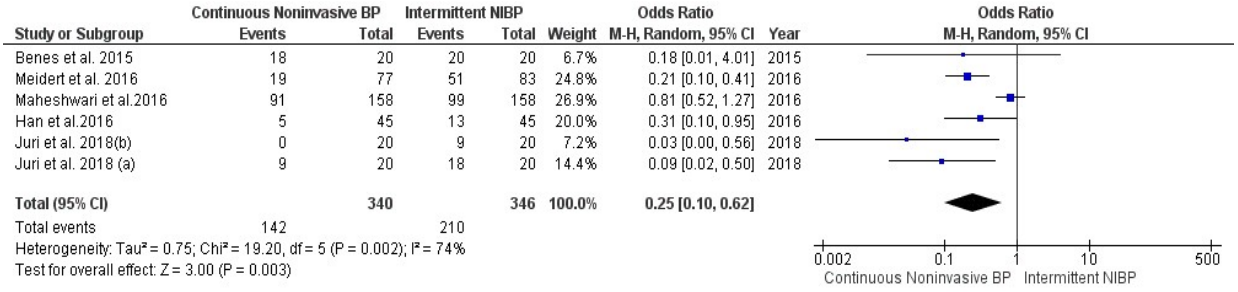
Figure 1:



# Evaluation of Sevoflurane Consumption During General Anesthesia when using the MemsorbTM Membrane and Low Gas Flow Versus the Classical Chemical Absorbents with 2L.min-1 Gas Flow for CO2 Removal from the Anesthesia Circuit. The MEMSEV Study.

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**Introduction:**

Assessing the impact of anesthesia practice on global warming and carbon footprint becomes part of the standard of care (1). Sevoflurane is expelled in the atmosphere where it contributes to global warming. Strategies aiming at reducing sevoflurane carbon footprint are limited by the need to maintain a fresh gas flow rate ≥ 2L.min$^{-1}$ when chemical absorbents are used and to avoid the formation of compound A. A new $CO_2$ removal membrane technology-based product (Memsorb™, DMF Medical Inc., Halifax, NS, Canada) has been recently approved by Health Canada and allows to drastically reduce FGF. We hypothesized that the use of Memsorb$^{TM}$ with minimal fresh gas flow (FGF), would significantly decrease the sevoflurane consumption and its related atmospheric pollution compared to classical chemical absorber (Dräegersorb-800+) for $CO_2$ removal with the recommended 2L.min$^{-1}$ FGF during general anesthesia (GA).

**Methods:**

Single center, randomized study. REB approval and CT.gov registration were obtained. Inclusion criteria: ASA 1-3 patients, BMI < 40, age > 18 years old, and scheduled for laparoscopic surgeries under GA from 1 to 4 hours. Randomization was done prior to induction and the appropriate device was set in the operating room for $CO_2$ extraction (Memsorb™ = M group; Draegersorb$^{TM}$ = D group). The induction of anesthesia included intravenous midazolam, lidocaine, propofol, remifentanil and rocuronium, and was fully standardized for all patients. Classical anesthesia monitoring was used, implemented with BIS$^{TM}$ index (depth of anesthesia) and NOL$^{TM}$ index (to guide the analgesics administration). Maintenance was based on sevoflurane for a BIS [40-60], remifentanil for NOL < 25 and rocuronium for TOF < 2/4. Patients' ventilation was also standardized (7 mL.kg$^{-1}$ of ideal body weight and RR adjusted for et-CO2 35-45). In the D group, the FGF was kept at 2L.min$^{-1}$ whereas it was decreased to a minimum of 0.2 mL.min$^{-1}$ in the M group or the lowest FGF possible. We believed that Memsorb$^{TM}$ would reduce the sevoflurane consumption by at least 25% at H1. Fifty patients were needed. Five blocks of randomization of 10 patients were made.

**Results:**

Data from the first 40 patients (4 blocks of randomization of 10) are presented here. Demographic data were similar between groups. For the primary endpoint, sevoflurane consumption was significantly reduced during

the first hour of surgery (T0 incision until H1) in the M group compared to D group (0.07 (0.03) $mL.kg^{-1}.h^{-1}$ versus 0.19 (0.04); $p < 0.01$). The total consumption of sevoflurane, between intubation and incision (T0) (0.14 (0.06) $mL.kg^{-1}.h^{-1}$ versus 0.29 (0.08); $p < 0.01$) and during overall anesthesia (0.07 (0.03) versus 0.19 (0.03); $p < 0.01$) were also significantly reduced in M group. The total $CO_2$ equivalent was consequently significantly increased in the group D versus M (see figure). FGF during anesthesia was drastically reduced in M group (0.3 (0.1) versus 2.0 (0) $L.min^{-1}$). Expired $CO_2$ levels were not different between groups. Inspired $CO_2$ levels were higher in the M group but remained below 4 mmHg.

**Discussion:**

The new Memsorb™ membrane to extract $CO_2$ from the circuit of the ventilator allowed to use very low FGF in all patients of the group M which significantly reduced the sevoflurane consumption for the first hour during laparoscopic surgery (primary objective) as well as for the entire anesthesia duration. It also significantly reduced the related anesthesia induced pollution. Inspired $CO_2$ levels remained below 4 mmHg in the M group patients demonstrating the safety of this new medical device recently approved by Health Canada.

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Figure 1: