

Machine Learning Predicts Intraoperative Hypotension from End-Tidal Carbon Dioxide Measurement

Presenting Author: Nathaniel R. Greenbaum, MD, SUNY Downstate Health Sciences University

Co-author: Seth T. White, MB ChB, MSc, SUNY Downstate Health Sciences University

Background/Introduction: Intraoperative hypotension has been linked to acute kidney injury, myocardial infarction, and both 30-day and 1-yr mortality¹. Non-invasive blood pressure (NIBP) monitoring is a vital tool in detecting hypotension, but only provides periodic snapshots of a patient's hemodynamic status. Moreover, by the time NIBP monitoring detects hypotension the patient has already been exposed to harm.

We leveraged End-Tidal Carbon Dioxide (ETCO₂) data from a high resolution dataset of intraoperative biosignals² and machine learning techniques to create a model capable of predicting new episodes of hypotension five minutes before they were detected by NIBP monitoring.

Methods: All open, general surgery cases performed on patients 18 to 65 years of age in the Seoul National University College of Medicine's VitalDB Data Bank were included (n=2084). Laparoscopic procedures were excluded to eliminate changes in ETCO₂ resulting from CO₂ insufflation. For each NIBP measurement we collected the mean value of ETCO₂ for each minute in the window from 5 to 15 minutes before the current NIBP measurement; we also recorded the NIBP immediately prior to the current measurement. NIBP cuff cycle times were typically two and a half minutes [Median: 2.47 minutes, IQR: 1.97-2.57 minutes]. The first and last 30 minutes of each case were excluded to reduce confounding caused by induction and extubation. In total 38,790 timepoints were identified for further analysis. Timepoints with missing ETCO₂ data (0.5%) were excluded. Each timepoint was evaluated independently. The VitalDB Data Bank's acquisition and release were approved by its creator's IRB (H-1408-101-605) and is registered at clinicaltrials.gov (NCT02914444).

Timepoints with both a decrease in Mean Arterial Pressure (MAP) of more than 15% from the prior MAP and a MAP lower than 65 mmHg were labeled as new hypotension (n=643). A new dataframe, containing only ETCO₂ features, was randomly sorted and then split 50%/50% into testing and training sets. Features were expanded by first creating 2 minute bins for all sequential ETCO₂ measurements and then combinatorially calculating the absolute change, percent change, and log change between all features. Scikit-learn 0.21.3 was employed for normalization and instantiation of our random forest classifier.

Results: Our model is a highly specific (99.99%), precise (97.50%), and accurate (98.53%) predictor of new intraoperative hypotension (Table 1).

Table 1: Random Forest Classifier Performance

| | | | |
|-------------|--------|---------------------|--------|
| Sensitivity | 0.1223 | False Positive Rate | 0.0001 |
| Specificity | 0.9999 | False Negative Rate | 0.8777 |
| Precision | 0.975 | Accuracy | 0.9853 |

| | | | |
|---------------------------|--------|----------|--------|
| Negative Predictive Value | 0.9853 | F1 Score | 0.2173 |
|---------------------------|--------|----------|--------|

Conclusion: We created a machine learning algorithm capable of predicting intraoperative hypotension five minutes before it was detected by NIBP. Early detection of hypotension has the potential to curtail both the duration and severity of these episodes — reducing morbidity and mortality. We assess that our predictions can likely be improved by incorporating additional biosignals into our model.

References: 1. Brady, K., & Hogue, C. (2013). Intraoperative Hypotension and Patient Outcome. *Anesthesiology*, 119(3), 495-497. doi: 10.1097/aln.0b013e3182a10cce
2. Lee, H., & Jung, C. (2018). Vital Recorder—a free research tool for automatic recording of high-resolution time-synchronised physiological data from multiple anaesthesia devices. *Scientific Reports*, 8(1). doi: 10.1038/s41598-018-20062-4