Prediction of Postinduction Hypotension with Deep Learning

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Introduction: Surgical patients with hypotension 0 to 10 minutes postinduction have been shown to have higher prevalence poor outcomes.[1] However, there are few tools available to help predict who is at risk for such hypotension. Recently, Kendale et al. compared machine learning methods to predict hypotension utilizing 56 EMR features and demonstrated an AUC of 0.74 for a stochastic gradient boosting machine.[2] This model utilized only static EMR features, and so we hypothesize that convolutional neural network models (CNNs) can leverage the complexity of arterial pressure waveforms (AP) as a dynamic feature to predict postinduction hypotension.

Methods: Data used in these experiments came from UCI Medical Center with IRB approval. The data includes all surgical procedures performed from November 2015 to August 2017 (n=19,545). Patients with no induction time, no MAP 10 minutes after induction, negative time difference between surgical start and induction, and < 18 years of age were excluded, resulting in 16,495 patients. Postinduction hypotension was defined as any MAP <= 55 mmHg 10 minutes post induction, taken from the EMR. Induction time was defined as first recorded induction event, etomidate or propofol administration time. For comparison, we extracted the same EMR features as described in Kendale et al., except for those related to medical comorbidities and preoperative medications due to data availability, to develop a logistic regression and deep neural network model (DNN). This resulted in 15 EMR features related to demographics such as age and ASA; and intraoperative features such as first MAP and fentanyl amount. Values for medications greater than a clinically normal maximum (M.C) were assumed as annotation error and set to the maximum. Missing values for other features were filled with the mean, and all features were rescaled to mean 0 and standard deviation 1. These features were utilized in a logistic regression and deep neural network model (DNN). For the CNN model, we extracted all available AP (100 Hz) prior to 1 minute before induction. This resulted in 237 patients (1.4%). All waveforms were processed for noise removal and then parsed into 20 second samples. Each sample was rescaled to have mean 0 and standard deviation 1 across time. The label of each sample was assigned as the label of the respective patient. All models were trained to classify hypotension and were trained on 80% of the data (n=13,196; n=204 with AP) with five-fold cross validation. 20% of the data was held out as a future test set. Performance was assessed using mean and standard deviation of AUROC from cross validation.

Results: The occurrence of postinduction hypotension is 9.6%, and 32.6% in the train patients with AP. The parsing of the waveform data available in the 204 patients with AP resulted in n=5683 waveform interval samples for training. The reported DNN with EMR features has 5 dense layers with 200 neurons each with ReLu activations. The CNN with AP had 2 convolutional layers with 8 filters of size 5 and a stride 1 with ReLu activations, followed by 5 dense layers, 100 neurons each with ReLu activations.

Table 1. 5 fold cross validated AUC results (mean ± std) on training data

	5 Fold Cross Validated AUC	
Model	**All Patients**	**Patients with Arterial Waveforms**
Logistic Regression w/ 15 EMR features	0.73 ± 0.01	0.74 ± 0.07
DNN w/ 15 EMR Features	0.75 ± 0.01	0.76 ± 0.08
CNN w/ Arterial Waveform		0.73 ± 0.06

Conclusion: CNNs with AP inputs exhibit potential for being able to not only classify patients at risk for postinduction hypotension but also predict hypotension 1 minute prior to induction start. In addition, while all other features are available prior to induction, the intraoperative medication features from Kendale et al.[2] are extracted from entry into the procedure area to 10 minutes post induction and were chosen as most common medications relevant to general anesthesia. Thus, the CNN is not only predictive prior to induction but is also independent of clinician decision. Future work is needed to further clean the AP for noise as well as to continue to assess different model architectures.

References

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