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 hypothesized that the use of more dynamic arterial blood pressure (ABP) waveform features and deep neural networks (DNN) could improve prediction.

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, < 18 years of age, or no arterial blood pressure (ABP) waveform prior to induction were excluded resulting in 224 patients. Postinduction hypotension was defined as 1) postinduction MAP decrease of > 40% from preinduction and postinduction MAP < 70 mmHg or 2) postinductioin MAP < 60 mmHg. Induction time was defined as first recorded induction event in the EMR, 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. We added an additional 9 EMR features of our own related to HR, MAP, and SpO2 pre-induction. 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. For ABP waveform features, we extracted all available ABP waveforms (100 Hz) 5 minutes prior to induction. All waveforms were processed for signal quality and 8 beat-to-beat features such as MAP using the algorithms provided by Physionet[4] and the mean of the features were taken as input. These EMR and waveform features were utilized in a logistic regression and deep neural network model (DNN). Models were trained to classify hypotension 0 to 5 minutes and 5 to 10 minutes postinduction. Due to the small size of the data set, we utilized leave-one-out cross validation (LOO).

Results and Conclusion: The occurrence of hypotension 0 to 5 minutes postinduction is 8.9% (n=20); for 5 to 10 minutes postinduction occurrence is 9.8% (n=22). The best performing model overall was the waveform only DNN model for the prediction of 0 to 5 minutes postinduction hypotension (AUC 0.88 (0.812-0.934)) (Table 1). This model had 2 hidden layers and 60 neurons, and was trained with dropout probability of 0.25, L2 regularization with a lambda 0.0001, batch size 128, and a learning rate 0.001. Overall, all DNN models had higher AUCs than logistic regression (LR) for each feature set, and waveform only features performed best overall (Table 1). EMR only features performed the worst, except in predicting 5 to 10 minutes postinduction hypotension with LR.

Table 1. Leave-one-out validation AUC results

0 to 5 Minutes Post Induction		
Feature Set	**DNN Model**	**LR Model**
Waveform Only	0.88 (0.812-0.934)	0.875 (0.81-0.929)
EMR Only	0.51 (0.402-0.623)	0.505 (0.363-0.637)
Waveform + EMR	0.804 (0.703-0.888)	0.792 (0.695-0.873)

5 to 10 Minutes Post Induction		
Feature Set	**DNN Model**	**LR Model**
Waveform Only	0.703 (0.557-0.823)	0.613 (0.452-0.752)
EMR Only	0.63 (0.497-0.76)	0.667 (0.555-0.78)
Waveform + EMR	0.653 (0.512-0.779)	0.603 (0.475-0.725)

References

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