Improved Predictive Models for Acute Kidney Injury with IDEAs: Intraoperative Data Embedded Analytics

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Introduction

- Acute kidney injury (AKI) is one of the most common postoperative complications[1] associated with mortality and increase in healthcare cost[2].
- The majority of current perioperative risk scores are limited to certain surgical populations[3] and do not fully utilize rich physiologic intraoperative data[4].
- We proposed an intelligent machine learning model that is able to improve patients' postoperative AKI risk score by taking the intraoperative features into account.

Data Cohort

- A single center retrospective cohort of 2,911 patients (age ≥ 18)
- All underwent surgery at the UF Health between 2000 and 2010 and had length of stay > 24 hours.
- Variables: Demographic, socio-economic, operative features, laboratories, medications, vital signs, etc.
- Binary outcomes:
  - AKI within first 3 postoperative days (AKI-3day)
  - AKI within first 7 postoperative days (AKI-7day)
  - AKI up to discharge date (AKI-overall)

Method

- Preoperative stage: We predicted the AKI risk score from our existing model only using preop data (see Fig. 1).
- Intraoperative stage: We proposed to incorporate intraop time series data (see Fig. 1, bottom layer):
  - Considered blood pressure, heart rate, etc.
  - Statistical features were extracted. E.g.:
    - Average during the surgery
    - Long and short term variance
    - Minimum, maximum, variance
    - Time spend in different ranges, etc.
- Trained a Random Forest classifier in Python for intraop features incorporated preoperative prediction score data:
  - 70% -30% training-test split was used
  - Used 5-fold CV for parameter tuning and feature selection

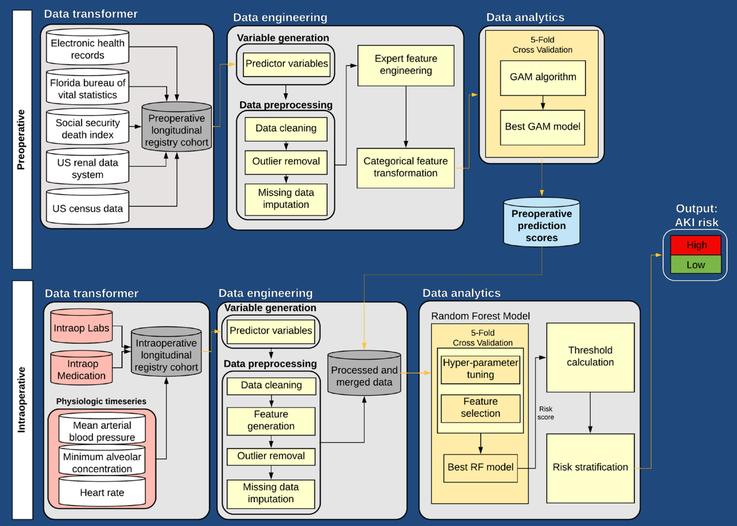


Figure 1. The conceptual design of the proposed model.

Results

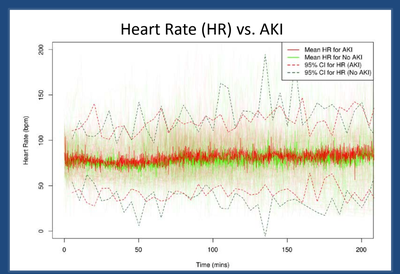


Figure 2. HR time series variations stratified by AKI-7day for 100 randomly selected patients during the first 200min of the surgery.

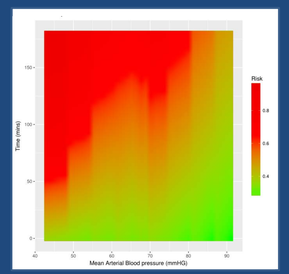
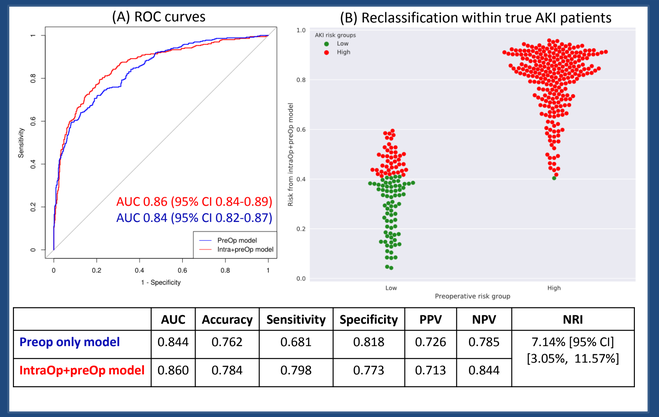
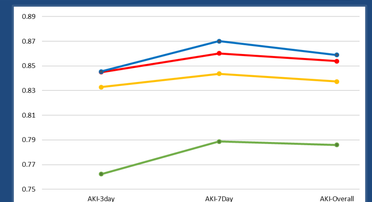


Figure 3. AKI-7day risk over the MAP and time. Note: Short durations of MAP less 55 mmHg are associated with AKI[5].



	AUC	Accuracy	Sensitivity	Specificity	PPV	NPV	NRI
Preop only model	0.844	0.762	0.681	0.818	0.726	0.785	7.14% [95% CI] [3.05%, 11.57%]
IntraOp+preOp model	0.860	0.784	0.798	0.773	0.713	0.844	

Figure 4. (A) ROC curves for the preoperative model and preop prediction score integrated intraoperative model with the AKI-7day outcome from the testing cohort. (B) The perioperative model reclassified false negative patients in the preoperative model as high AKI risk patients.



Model	AUC [95%CI] on test cohort for each outcome
IntraOp model - RF	0.7624 [0.729, 0.795]
	0.7888 [0.758, 0.819]
	0.7860 [0.756, 0.817]
PreOp data only model - GAM	0.8328 [0.804, 0.861]
	0.8436 [0.818, 0.870]
	0.8373 [0.811, 0.863]
IntraOp + PreOp prediction score model - RF	0.8450 [0.817, 0.873]
	0.8602 [0.835, 0.886]
	0.8538 [0.828, 0.879]
IntraOp + PreOp full model - RF	0.8455 [0.817, 0.874]
	0.8700 [0.845, 0.895]
	0.8589 [0.834, 0.884]

AKI-3day, AKI-7day, AKI-overall

Figure 5. AUROC comparison between all possible models.

Conclusions

- Proposed a machine learning model based on random forest that is able to improve patients' postoperative AKI risk score by integrating intraoperative features.
- There was a significant improvement in net reclassification (NRI):
  NRI for AKI-3day = 8%, AKI-7day = 7%, and AKI-overall = 4%.
- Full preoperative data integrated model and only preoperative prediction integrated model (proposed) are comparable – training time vs. AUC.
- Future work:
  - Apply gradient boosting on our new data cohort: 2014-2016
  - Validate on a external cohort
  - Apply deep learning on perioperative data with minimum feature engineering

References

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