Development of Machine Learning Models to Predict Admission from ED to Inpatient and Intensive Care Units

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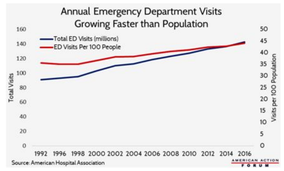
Background

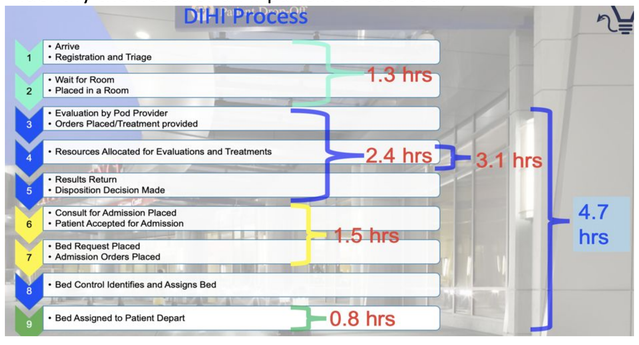
- Emergency Departments (EDs) treat millions of patients each year. While a vast majority of those patient visits result in the patient being discharged, the ED continues to be the primary source for admissions to the hospital.[1]



- There have been some attempts to develop a scoring system that can be used at the time of triage to help predict whether or not an individual patient will be admitted or discharged. However, the reliability of those systems is poor.[1,2]
- Previous studies have demonstrated that experienced ED physicians are accurate at predicting when a patient will be discharged, but not when a patient will be admitted.[3]
- Having a tool to predict patient admission would allow improved patient care by enhancing patient flow while within the ED via expediting patient assignment to the appropriate care area within the ED. It would also impact patient flow for admitted patients throughout their stay until their discharge home.[4]
- The purpose of this study was to develop a machine learning model to accurately predict need for admission to the inpatient wards or intensive care units (ICUs) to reduce the time from a patient's arrival to the ED to securing an appropriate inpatient bed.

Clinical Workflow

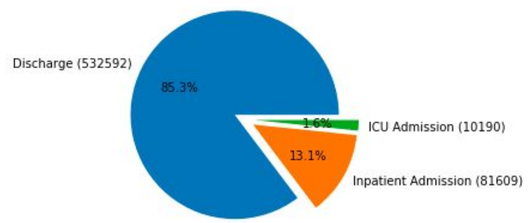
- This model is intended to be used as a predictive tool for use by the ED triage team and the patient placement team. Specifically, this model is intended to be used to more quickly identify the need for an inpatient or ICU bed.



Setting, Data, & Model Development

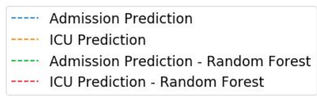
- This model uses Electronic Health Record (EHR) data collected at a patient's time of presentation to the ED to estimate the probability that the patient will need to be admitted to the inpatient wards or ICU bed at the hospital.
- Patient Cohort: All admitted and discharged adult patients (age 18+) who presented at 3 Duke University-affiliated EDs from October 2014 - August 2018, a total of 642,391 patients
- **Data elements included as model features:**
  - Demographic elements (age, gender)
  - Comorbidities/patient history (e.g., history of stroke, admission and length of stay within the last year)
  - Patient mode of arrival
  - Initial triage elements (chief complaint, ESI, vitals)
  - Orders and labs at triage, stratified by count and selected for highest associated outcome (admission vs. discharge)
  - Medications administered

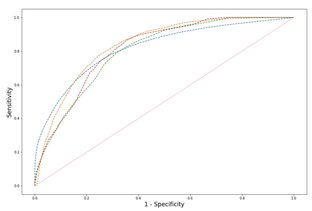
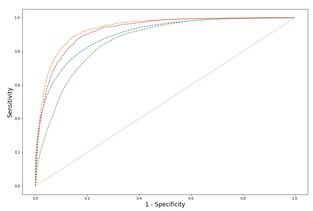
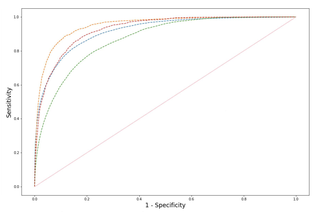
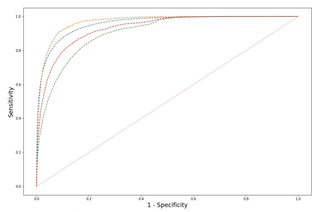
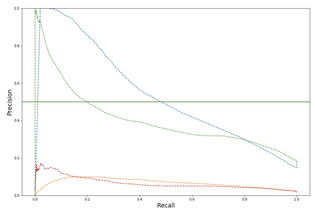
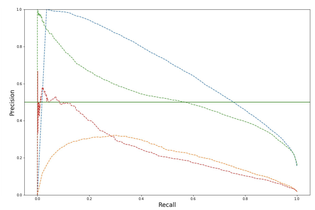
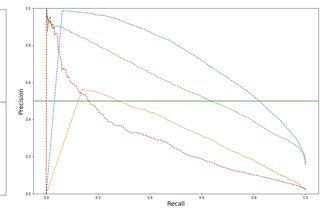
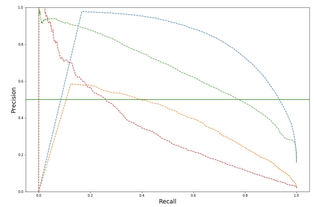
Total Cohort: 642,391 patients



Results

- Both a logistic regression and a random forest model were developed and evaluated at different timepoints throughout the ED encounter - preadmission (solely using patient history); initial triage presentation; one hour after arrival; and last hour of ED encounter.
- AUROCs and AUPRCs are being utilized to compare model performance.

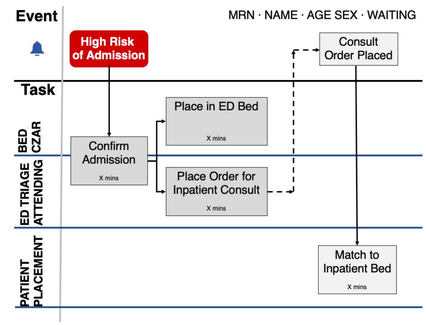


Preadmission (305 features)	Triage (357 features)	First Hour (577 features)	Last Hour (577 features)
			
Admission Prediction AUROC: 0.82 ICU Prediction AUROC: 0.83	Admission Prediction AUROC: 0.90 ICU Prediction AUROC: 0.93	Admission Prediction AUROC: 0.91 ICU Prediction AUROC: 0.95	Admission Prediction AUROC: 0.96 ICU Prediction AUROC: 0.97
			
Admission Prediction AUPRC: 0.54 ICU Prediction AUPRC: 0.07	Admission Prediction AUPRC: 0.67 ICU Prediction AUPRC: 0.21	Admission Prediction AUPRC: 0.71 ICU Prediction AUPRC: 0.32	Admission Prediction AUPRC: 0.76 ICU Prediction AUPRC: 0.37

Conclusions/Next Steps

- A machine learning model accurately predicts patient admission to an inpatient ward or ICU bed, and model accuracy increases as time progresses into the encounter.
- A logistic regression model outperforms a random forest model in most instances.
- Implementation of this model may improve patient flow by expediting patient triage and admission to appropriate units.

Proposed Model Implementation



- Currently developing a data pipeline and provider dashboard to allow for real-time prediction as patients present to the ED.
- Outcomes of interest include:
  - Decreased patient wait time in the emergency department from patient presentation to the ED to assignment of an inpatient bed
  - More efficient bed turnover in Duke ED
  - Lower numbers of patients in Duke ED waiting room

References

1) Hong WS, Haimovich AD, Taylor RA. Predicting hospital admission at emergency department triage using machine learning. PloS one. 2018 Jul 20;13(7):e0201016.
2) Cameron A, Rodgers K, Ireland A, Jamdar R, McKay GA. A simple tool to predict admission at the time of triage. Emerg Med J. 2014 Jan 11:emermed-2013.
3) Vlodaver ZK, Anderson JP, Brown BE, Zwank MD. Emergency medicine physicians' ability to predict hospital admission at the time of triage. Am J Emerg Med. 2019;37(3):478-481.
4) Dugas AF, Kirsch TD, Toerper M, Korley F, Yenokyan G, France D, Hager D, Levin S. An electronic emergency triage system to improve patient distribution by critical outcomes. The Journal of emergency medicine. 2016 Jun 1;50(6):910-8.