Pulmonary Embolism Risk Stratification via ECG-based Machine Learning

Tanmay Gokhale MD PhD, Nathan Riek, Brent Medoff MD, Zeineb Bouzid PhD, Ervin Sejdic PhD, Murat Akcakaya PhD, Samir Saba MD, Salah Al-Zaiti RN PhD, Catalin Toma MD

UPMC LIFE CHANGING MEDICINE

University of Pittsburgh

Introduction

- Pulmonary embolism (PE) carries significant risk of morbidity and mortality
- Clinical algorithms for risk stratification require imaging and lab studies that can delay identification of highest risk patients
- Therefore, a key challenge is rapidly identifying those patients with PE who are at highest clinical risk and may warrant consideration of procedural intervention
- In this study, we sought to use the 12-lead ECG to identify patients at elevated risk.

Methods

- This was a retrospective study of patients who were diagnosed with PE and seen by the PE Response Team (PERT) at UPMC Presbyterian. Only PEs within 1 day of admission, or OSH transfer for PE were included
- PEs were clinically classified as massive, sub-massive, or low risk by the PERT consultant (pulmonary attending/fellow)

	Low Risk PE (n = 617)	Elevated Risk PE (n = 759)
Demographics		
Age, years (mean (SD))	57 (18)	62 (16)
Women	46.4%	52.3%
Medical History		
van Walraven score	2 (5)	2 (5)
Coronary artery disease	10.2%	9.0%
Diabetes mellitus	14.8%	14.9%
Hypertension	38.4%	41.2%
Heart failure	5.8%	4.5%
Atrial fibrillation	3.6%	5.5%
Asthma	22.9%	21.4%
Obstructive lung disease	6.6%	8.0%
Chronic kidney disease	4.5%	5.1%
Obesity	14.9%	18.6%
Current/recent tobacco use	20.1%	13.7%
Clinical Course		
ICU stay*	31.8%	77.7%

* Includes patients in the ICU at time of PE diagnosis

- An ECG within 1 day of diagnosis was retrieved and analyzed using a curated set of ECG spatiotemporal features
- Data split into 70% training and 30% test set
- Collinearity removal & multi-step feature selection performed
- A random forest model was trained on the training set, using 5-fold cross validation for model tuning and threshold moving
- The resulting model was validated on the hold-out test set

Results

Random Forest Model Performance

The Random Forest ML model achieved an AUROC of 0.80, compared to 0.66 for S1Q3T3 and 0.69 for the Daniel score, on a hold-out test set. At the selected operating point, the model had an accuracy of 71.9%, recall/sensitivity of 88.1%, precision/PPV of 70.2% and specificity of 50.6%

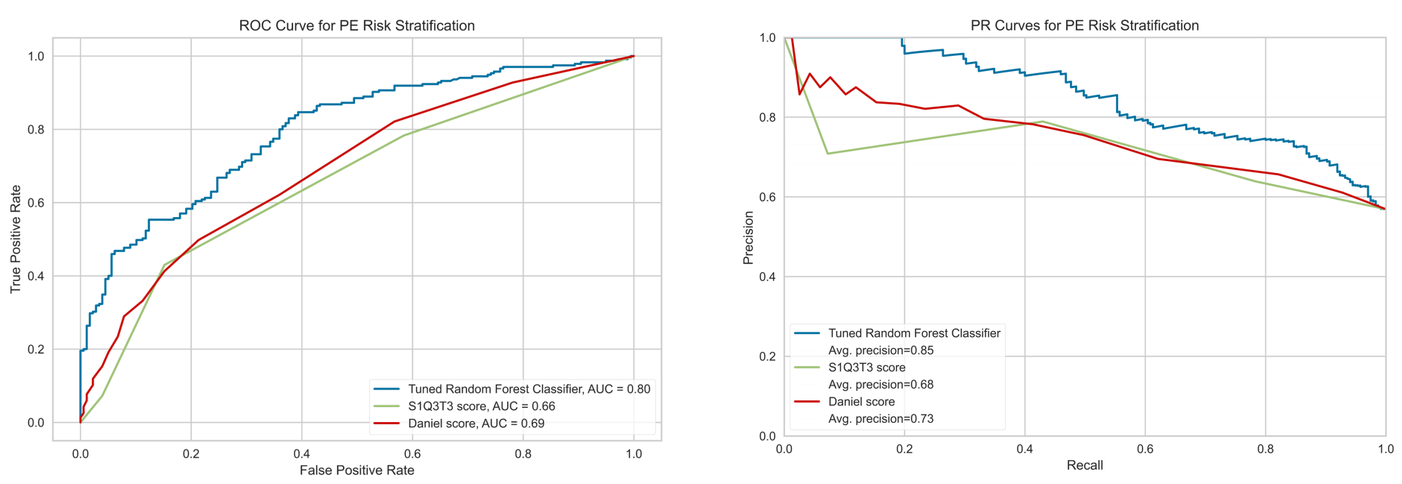

Figure 1: The EKG-based random forest model outperformed the S1Q3T3 and Daniel scores in identifying elevated risk PE, with higher AUROC and AUPRC

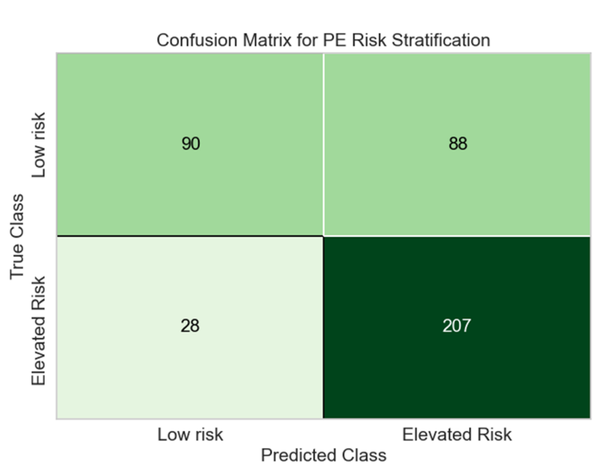

Figure 2: Confusion matrix for random forest predictor of elevated risk PE

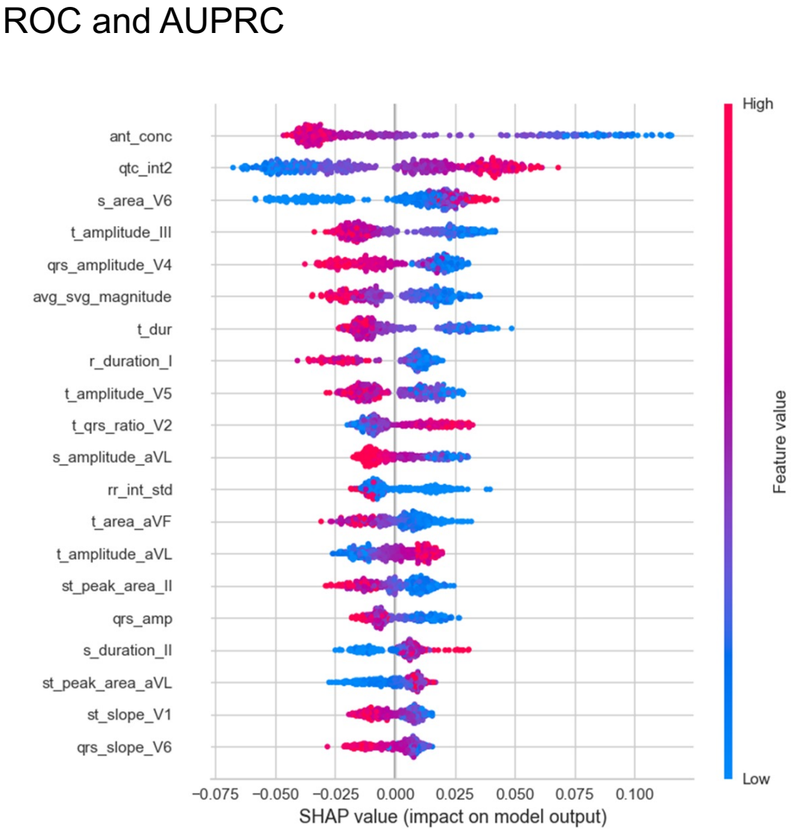

Figure 3: Known and novel EKG features played key roles in model performance

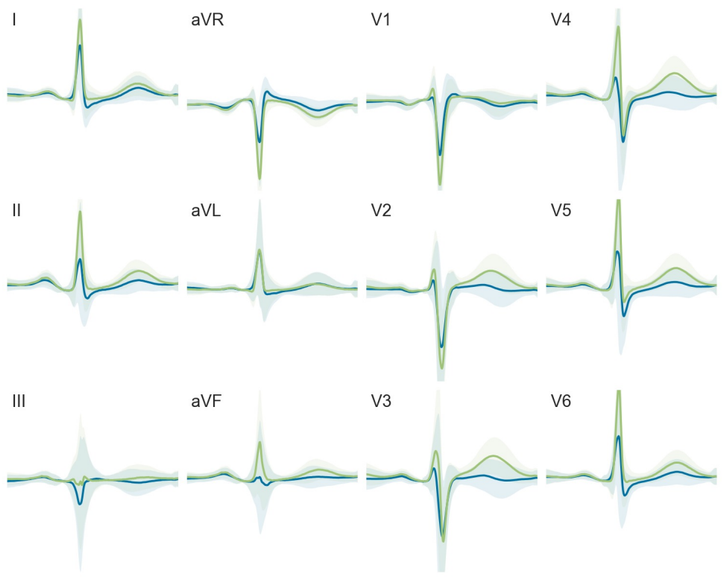

Figure 4: Average EKG waveforms of patients with predicted low and elevated risk

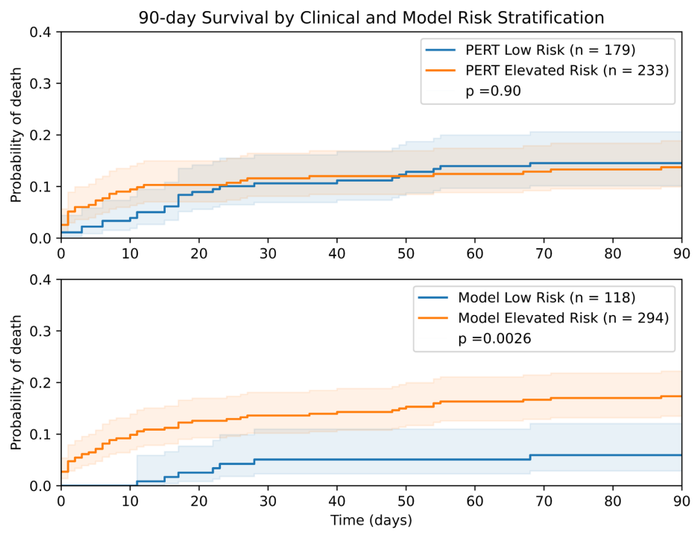

Figure 5: Model prediction of PE risk predicts 90 day all-cause mortality

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Conclusions

- Machine learning based models can accurately risk stratify patients with pulmonary embolism based on EKG alone
- These models could help more effectively deliver care in the emergency department setting
- Model prediction of risk correlates with 90-day survival following pulmonary embolism