Using Predictive Mortality and Cardiogenic Shock Identification Tools to Support Team-Based Treatment Intervention on Adult Cardiology Patients at Duke University Hospital

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Background

Cardiogenic shock is a state of cardiac dysfunction which leads to hypoperfusion of critical organs and can lead to death. At Duke University hospital there are approximately eight hundred patients with cardiogenic shock each year with a high mortality rate of 30%. In order to optimally care for these high risk patients the primary clinician often needs to coordinate care across multiple subspecialty teams. The Duke Heart Center identified the opportunity to assess whether a new, expedited, team-based treatment intervention on these patients could improve the process of care and impact clinical outcomes. To support this new treatment intervention, Duke Cardiology and the Duke Institute for Health Innovation (DIHI) formed a transdisciplinary team to identify the patients who develop clinical deterioration and cardiogenic shock in real-time by creating an automated electronic phenotype. A machine-learning model was also developed to predict in-hospital mortality for all Duke cardiac patients using patient baseline and hospital stay data extracted from the EHR. We will then combine the digital phenotype and model output into a visual tool to catalyze the deployment of a new team-based workflow and to inform the team's treatment decisions.

Intervention Solution Design

We surveyed 230 Duke Cardiology clinicians on the potential value of a rapid intervention team and of a real-time mortality model output on care for patients who show early signs of deterioration, and found that 80% of both physician and nurse groups estimated a high or medium amount of value added by those care strategies. We designed a new multi-disciplinary cardiogenic shock team (Shock Team) workflow, which begins with the cardiac intensive care unit (CICU) fellow calling together the Shock Team after assessing a patient. The team consists of physicians in advanced heart failure, interventional cardiology, cardiac surgery, and cardiac critical care. This team integrates the clinical tool (Shock Dashboard) that we develop into the care discussion to help risk stratify and determine the need for additional interventions, such as mechanical circulatory support. In parallel, we developed a four-part cardiogenic shock phenotype based on a patient cohort comprised of all adult DUH Cardiology patients over a 47-month timespan from October 2014 to August 2018, totaling 12,613 unique patients and 18,614 unique encounters. We used 228 clinically determined predictors including patient labs, vitals, and interventions to fit a lasso-penalized logistic regression, a ridge regression, a random forest, and an extreme gradient boosted decision tree model to predict inpatient mortality within a 48-hour window for patients at the time of admission into cardiology service (t0), and also at 4 hours (t4), 8 hours (t8), and 16 hours (t16). 48-hour mortality was 1.20%, 1.01%, 1.00%, and 0.97% at the respective time points. For each cohort, a subgroup of the latest encounters (N = 3722, 3713, 3703, 3672) was held out for evaluation. The remaining encounters were split into a training set (N patients (encounters) = 8692 (11909), 8677 (11879), 8634 (11847), 8590 (11750)) and a validation set (N = 3722, 3713, 3703, 3672). Missing values for quantitative variables in the validation and test sets were imputed using those variables' means in the training set. The validation set was used to tune hyperparameters.

Clinical Tool Results and Implementation

Resulting models for t0 had predictive performance area under receiver operator characteristic (AUROC) curve values ranging from 0.81 to 0.88 and area under precision recall (AUPR) curve values ranging from 0.10 to 0.26 calculated on the test set. The t4, t8, and t16 models incorporated additional lab and other values as they were measured during the encounter, and saw improved performance ranging from 0.87 to 0.94 AUROC curve values, with AUPR curve values ranging from 0.18 to 0.32. Among our cohort of encounters, 4,767 (25.6%) met the phenotype. Within the phenotype, there are four definitions with specified criteria. Definition 1 specified concurrent reduced blood pressure and hypoperfusion indicators, as well as fever exclusion indicators during the encounter, with initial results showing that 1,867 of 18,614 cohort encounters (10.0%) met the definition. Phenotype definition 2 specified new or increased vasopressor administrations, with 2,160 of 18,614 encounters (11.6%) meeting this definition. Phenotype definition 3 involved identifying patients with a mechanical support device, with 2,088 of 18,614 encounters (11.2%) meeting this definition. Phenotype definition 4 involved identifying patients with worsening cardiac hemodynamics, with 1,246 of 18,614 unique encounters (6.7%) meeting criteria. The Shock Team was launched in the spring of 2019, and the Shock Dashboard is set to launch in late summer 2019 in silent mode, followed by full go live in fall 2019. We aim to determine whether this intervention will have an impact on hospital length of stay and ICU length of stay, with secondary metrics of in-hospital mortality, need for renal replacement therapy, and mechanical ventilation.