Machine Learning Enhanced Predictions of Hospital Readmission or Death in Heart Failure

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Introduction

Readmissions are common, costly and often preventable. The LACE risk score is an established index to quantify the risk of readmission or death [1]. We used machine learning to develop a Heart Failure (HF) specific predictive tool.

Methods

The OM1™ Cardiology data warehouse contains deep clinical and claims data on patients seen in cardiology practices across the US. Patients with HF, hospitalized between October 2014 and Sept 2016, with at least 12 months of data before the index admission, and 30 days of data post discharge, were included. The unit of analysis was hospitalization. The outcome was all-cause unplanned readmission as defined by Centers for Medicare & Medicaid Services [2]. Those index admissions occurring before April 2016 (~70%) were used as the training set and the remainder as the validation set. Predictive features were developed by machine learning for the training set, and the performance of the resultant OM1 HF readmission risk score (on 0-100 scale; abbreviated as OM1 risk score below) was compared with that of the LACE risk score for the validation set.

One of the key predictive features is the OM1 medical burden index, which is a standardized measure of a patient's health condition, on 0-100 scale. It has been developed by analyzing the combined effect of each diagnosis and procedure in patient history on health outcomes. It has been developed by extensive analysis of OM1's 200 million patient cohort.

Patients with a LACE risk score of 10 or greater were considered at high risk of readmission. In comparison, patients with an OM1 risk score of 15 or greater were at high risk.

Results

The study included 14,065 HF related hospitalizations with 3,502 (25%) unplanned readmissions or death within 30 days of discharge; median age was 67 years, 53% were women, and 46% were white (**Table 1**). OM1 medical burden index, admission via the emergency department (ED), number of ED visits in the 6 months prior to index hospitalization, and age were the top 4 predictors determined by machine learning and were used to derive OM1 risk scores in the validation set of 4,260 index hospitalizations. The OM1 risk scores had a C statistics of 0.77 compared to 0.69 for LACE, in both the training and validation sets, respectively (Figure 1). The LACE risk score had a precision of 36% with 771 actual re-admissions or death out of the 2,170 predicted. When matched with the LACE score precision, the OM1 model was more sensitive and correctly identified 887 (81%) of the total 1093 readmissions or deaths while the LACE risk score identified 771 (71%) (**Table 2**; **Figure 2**). When dividing the OM1 risk scores into deciles at 10-point increments, the grouped OM1 risk scores were highly correlated with the readmission rates within deciles, with a strong linear trend of greater OM1 risk scores associated with higher readmission rates (R2=0.98, **Figure 3**).

Table 1. Patient Characteristics Pre-admission through Discharge from the Index Admission

Patient Characteristics		30-day Readmission n=3,502	No Readmission n=10,563	Total n=14,065
Gender	Female n, (%)	1,826 (52%)	5,644 (53%)	7,470 (53%)
Race	White n, (%)	1,468 (42%)	4,946 (47%)	6,414 (46%)
	Black n, (%)	855 (24%)	2,199 (21%)	3,054 (22%)
	Other n, (%)	397 (12%)	1,354 (12%)	1,751 (12%)
	Not reported n, (%)	782 (22%)	2,064 (20%)	2,846 (20%)
Age (years) at index admission	Mean (SD)	63 (14)	67 (13)	66 (13)
	Median (Q1-Q3)	62 (54-74)	68 (58-77)	67 (57-77)
Length of stay (days)	Mean (SD)	3.8 (11.1)	6.8 (24.4)	6.1 (21.9)
	Median (Q1-Q3)	2 (1-4)	3 (1-5)	2 (1-5)
Admission via emergency department	n, (%)	2,188 (62%)	2,076 (20%)	4,264 (30%)
Charlson comorbidity index at index admission	Mean (SD)	6.5 (3.0)	5.7 (2.8)	5.9 (2.9)
	Median (Q1-Q3)	6 (4-8)	5 (4-7)	6 (4-8)
Number of ED visits in the 6 months prior to index admission	Mean (SD)	5.3 (9.6)	1.3 (2.2)	2.3 (5.5)
	Median (Q1-Q3)	2 (0-6)	1 (0-2)	1 (0-2)
OM1 medical burden index at discharge date from the index admission	Mean (SD)	7.2 (11.2)	2.8 (4.8)	3.9 (7.2)
	Median (Q1-Q3)	3.1 (1.3-7.1)	1.6 (0.7-3.2)	1.9 (0.8-3.9)

Table 2. Distribution of Risk Prediction Scores

Risk Score	Risk Categories	30-day Readmission	No Readmission	Total
LACE Index	High risk	771 (71%)	1,399 (44%)	2,170 (51%)
	Low risk	322 (29%)	1,768 (56%)	2,090 (49%)
OM1 Risk Score	High risk	887 (81%)	1,587 (50%)	2,474 (58%)
	Low risk	206 (19%)	1,580 (50%)	1,786 (42%)

Figure 1. Receiver Operating Characteristic (ROC) Curves for the OM1 Risk Score (C Statistic 0.77) **and the LACE index** (C Statistic 0.69)

Figure 2. When Matched by Precision to the LACE Score (36%) the OM1 Risk Score (81%) was more Sensitive than the LACE Score (71%).

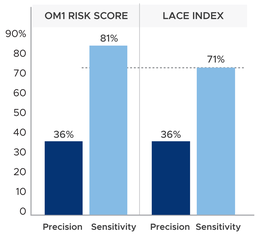


Figure 3. The OM1 Risk Score was Closely Correlated with the Observed Readmission Rate

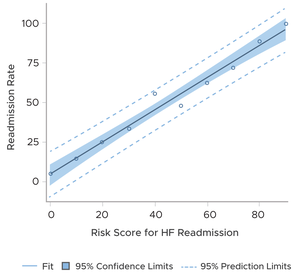
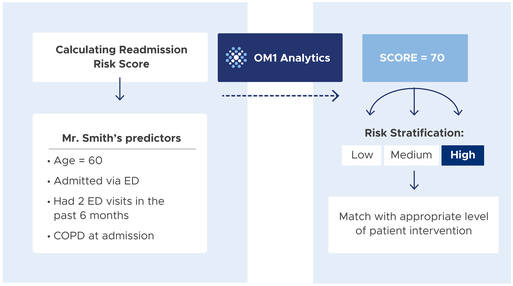


Figure 4. Clinical Application of the OM1 Risk Score



Conclusions

We present a new model to predict mortality and readmission at 30 days after an index admission for HF that has superior performance to a previously published claims-based model. Model performance is being further refined using laboratory and unstructured data. Integrating these predictive models into clinical workflow will permit timely interventions in high risk patients (Figure 4).

REFERENCES
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DISCLOSURE INFORMATION
The authors have no conflicts of interest to disclose.