Quality and Outcomes

Predicting Readmission or Death After Acute ST-Elevation Myocardial Infarction

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ABSTRACT

Background: Risk factors for emergent readmissions or death after acute myocardial infarction (AMI) are important in identifying patients at risk for major adverse events. However, there has been limited investigation conducted of prospective clinical registries to determine relevant risk factors.

Hypothesis: We hypothesize 30-day readmission or death could be predicted using patient, procedural, and process factors.

Methods: Patients presenting with ST-elevation myocardial infarction (STEMI) from 2006 to 2011 were prospectively enrolled in a STEMI registry (1271 patients). Thirty-day readmission was ascertained by administrative claims data. Death was determined by linking to the Social Security Death Master File. Univariate and stepwise multivariate logistic regression was conducted with Hosmer-Lemeshow goodness-of-fit statistics for model calibration and receiver operating characteristic (ROC) curve for model discrimination.

Results: The combined end point of 30-day readmission or postdischarge death included 135 patients (10.6%), including 109 emergent readmissions and 26 deaths. Factors associated with an increase risk of 30-day readmission or postdischarge death included age $\geq$80 years, diabetes, chest pain or cardiac arrest at presentation, and 3-vessel disease found at initial angiography. Factors associated with a decreased risk of 30-day readmission or postdischarge death included transfer to the catheterization lab from another emergency department, clopidogrel given during the procedure hypercholesterolemia, and receiving aspirin, β-blockers, and angiotensin-converting enzyme or angiotensin receptor blocker inhibitors at discharge. Index admission outcomes indicative of readmission or death postdischarge only included a new diagnosis of congestive heart failure. The model discriminated well with an ROC of 0.71 (95% confidence interval: 0.66-0.76).

Conclusions: Prehospitalization factors are overlooked and are important factors to incorporate in routine risk prediction models for readmission or death within 30 days following an AMI.

Introduction

Approximately 20% of Medicare beneficiaries are rehospitalized within 30 days of a hospital admission.[1] Beginning in fiscal year 2012, hospital readmissions following acute myocardial infarction (AMI) and other conditions will be subject to marked reductions in reimbursement from the Center for Medicaid and Medicare Services (section 3025 of the Patient Protection and Affordable Care Act).[2,3] Current risk modeling for 30-day readmission following AMI has focused on patient risk factors derived from claims.[4] Other investigations in all angioplasty patients have reported limited success in discrimination and ability to predict 30-day readmissions alone.[5,6] However, if patient safety is the goal, prediction models should focus on both readmission and the competing risk of mortality in the first 30 days after discharge. Currently, there has been little evidence developed to investigate readmission and the competing risk of death following ST-segment elevated myocardial infarction (STEMI),[7,8] and limited evidence regarding risk factors for or the underlying principal causes of readmission following STEMI.[9,10] Moreover, evidence has been sparse in describing these phenomena in rural tertiary care settings. Therefore, we sought to determine the underlying principal causes of readmission in a regional STEMI registry and develop a comprehensive predictive model for 30-day emergent readmission or postdischarge death.

Methods

Dartmouth-Hitchcock Medical Center is a rural tertiary care setting. Since 2001, all patients presenting initially to the Dartmouth-Hitchcock Medical Center emergency

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department, as well as all emergency transfers who have not received thrombolytic therapy, have been treated with a strategy of immediate primary percutaneous coronary intervention (PCI). All emergency transfers who have received thrombolytic therapy at the referring facility have been treated with a strategy of pharmacoinvasive PCI. All patients presenting to the Dartmouth-Hitchcock Medical Center cardiac catheterization laboratory with a diagnosis of STEMI between 2006 and 2011 were prospectively enrolled in the regional STEMI registry. Of the 1415 patients who were enrolled in the registry during the study period, 106 patients were excluded due to false STEMI diagnosis and 38 index admission deaths, leaving 1271 STEMI patients for analysis. The study was reviewed and approved by the Center for Protection of Human Subjects.

Preadmission emergency medical service, index hospital, and procedural data were collected by clinical staff and recorded in a prospective STEMI registry. Death following the index admission was obtained from the Social Security Death Master File. Hospital readmissions were defined by the time from STEMI admission to 30 days. Readmissions were obtained through Dartmouth-Hitchcock's electronic data warehouse. Once readmission was determined, 2 investigators adjudicated the principal reason for readmission (Table 1). All readmissions were included in the principal causes of readmission. Only emergent readmissions and postdischarge death occurring within 30 days of the STEMI admission were included for the development of the prediction model. Primary cause of death within 30 days was not available.

Statistical Methods

Patient demographics, comorbidities, procedural variables, in-hospital outcomes, and discharge location were evaluated for inclusion in the prediction model using χ^2 and Student t test comparisons and univariate logistic regression.[11,12] Using only factors with univariate associations with the composite end point of death or readmission, with an α of 0.10, both forward and backward step logistic regression were conducted to determine factors to be included in the multivariable model using an α of 0.10. Factors remaining in the multivariate models were evaluated, and only factors with an alpha of <0.10 were included in the final prediction model. First-order interaction terms were evaluated. Model calibration was assessed using plots of observed and expected by deciles of predicted risk using the methods by Lemeshow and Hosmer.[13] The discriminating ability of the final multivariate logistic regression model was assessed by estimating the area under the receiver operating characteristic (ROC) curve C-statistic (ROC area).[14] The bootstrapping method was used to calculate the 95% confidence interval (CI) around the ROC curve.[15]

Table 1. Principal Causes of Readmission

	Events	Percent
Ischemic heart disease	54	43%
Chest pain	20	16%
Gastrointestinal	10	8%
Heart failure	9	7%
Arrhythmia	4	3%
Atherosclerosis	4	3%
Valve disease	3	2%
Renal failure	3	2%
Respiratory	3	2%
Medication	3	2%
Shock	2	2%
Cerebral	2	2%
Bleeding	2	2%
Other	8	6%

Results

There were 14 elective readmissions, 109 emergent readmissions, and 26 postdischarge deaths within 30 days of STEMI. The principal causes of any readmission are listed in Table 1, the most common of which included ischemic heart disease (43% of all readmissions), chest pain (20%), gastrointestinal complications (8%), and heart failure (7%). The combined end point of 30-day emergent readmission or death included 135 patients (11.7%), including 109 emergent readmissions and 26 deaths. Patient demographics and characteristics are reported in Table 2. Table 3 summarizes periprocedural characteristics, hospitalization risk factors, and discharge medications. Patient, procedural, and hospital factors included in the final multivariate model are reported in Table 4. Risk factors associated with 30-day emergent readmission or postdischarge death following acute hospitalization for STEMI included age $\geq$80 years, diabetes, chest pain at presentation, cardiac arrest at presentation, and 3-vessel disease. Preadmission transfer to the catheterization lab from another emergency department and hypercholesterolemia were factors that lowered the risk of readmission or postdischarge death. Clopidogrel given during the procedure was protective against readmission and postdischarge death. Index admission outcomes indicative of readmission or death only included a new diagnosis of congestive heart failure. The final multivariate model for readmission or death had good calibration with the Hosmer-Lemeshow χ^2 of 8.0 and $P = 0.4$. The model discriminated well with an ROC of 0.71 and 95% CI: 0.66-0.76.

Discussion

We have developed a comprehensive model for estimating risk of 30-day emergent readmission or postdischarge death after STEMI. Because this combined end point encompasses nearly all patients with major adverse events, the creation of this model is intended to assist in addressing the problem of readmission without ignoring patient safety. We report on patient factors in addition to STEMI presentation factors, and procedural and index hospitalization risk factors for readmission or postdischarge death within 30 days of STEMI with an ROC of 0.71 and 95% CI: 0.66-0.76. We are among the first to report on novel risk factors for

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Table 2. Patient and Disease Characteristics

Patient Factors	Readmitted or Death Within 30 Days	Not Readmitted and Alive at 30 Days	*P* Value[a]
Alive discharges (N = 1271)	135 (10.6%)	1136	
Patient comorbidities			
Age ± SD, y	66.3 ± 14.8	62.3 ± 12.9	<0.001
Age ≥80 years, %	23.0	10.6	<0.001
Female, %	37.3	26.9	0.006
Angina, %	28.0	26.3	0.646
Prior myocardial infarction, %	29.8	23.6	0.082
Prior coronary artery bypass surgery, %	3.1	3.9	0.639
Prior cerebrovascular accident, %	11.2	5.9	0.011
Diabetes mellitus, %	28.0	20.9	0.042
Hypertension, %	63.4	59.0	0.288
Underweight (BMI < 18.5), %	1.9	1.6	0.772
Obese (BMI >30), %	36.7	33.4	0.411
Aspirin therapy, %	39.8	37.9	0.649
Hypercholesterolemia, %	51.4	51.4	0.114
Statin therapy, %	33.5	30.8	0.488
Chest pain, %	95.0	92.0	0.179
Smoker, %	31.7	36.0	0.280
Presentation			
Transfer patient	69.6	78.0	0.017
Cardiac arrest, %	16.8	6.2	<0.001
Shortness of breath, %	54.7	42.4	0.003
Syncope, %	13.7	6.6	0.001
Symptom duration ± SD, min	267 ± 474	252 ± 577	0.752
Anterior ST-elevation, %	45.3	35.8	0.018
Inferior ST-elevation, %	49.1	60.0	0.008
Lateral ST-elevation, %	23.6	21.7	0.591
Left bundle branch block, %	3.1	2.8	0.820
Anterior ST-depression, %	28.0	29.0	0.791
Sinus rhythm, %	80.8	88.4	0.006
Systolic blood pressure ± SD	118 ± 40	127 ± 39	0.005
Diastolic blood pressure ± SD	69 ± 24	75 ± 24	0.009
Heart rate ± SD	74 ± 26	73 ± 24	0.571
Killip class IV, %	12.4	3.3	<0.001
Primary PCI, %	52.6	42.0	0.019
Full dose lytic given, %	21.7	29.4	0.044
Half dose lytic given, %	19.9	22.5	0.455
Persistent pain, %	50.9	49.4	0.712
Persistent ST-elevations, %	68.3	65.7	0.511
Shock, %	22.4	7.3	<0.001
Intubation, %	19.9	6.1	<0.001
TIMI flow pre			
0	47.8	43.0	0.096
1	11.8	7.7	
2	19.3	22.0	
3	21.1	27.4	
Coronary disease			
Left main disease >50%, %	8.7	5.5	0.105
2-Vessel disease >70%, %	25.5	29.9	0.241
3-vessel disease >70%, %	38.5	23.1	<0.001
Infarcted left anterior descending, %	42.9	33.0	0.013
Infarcted left circumflex, %	14.3	14.4	0.981
Infarcted right coronary, %	36.7	43.1	0.121
Infarcted ramus, %	0.6	0.6	0.941
Infarcted left main, %	1.9	0.6	0.070
TIMI flow post			
0	10.6	13.1	0.001
1	1.9	0.2	
2	3.7	1.4	
3	83.9	85.4	

Abbreviations: BMI, body mass index; PCI, percutaneous coronary intervention; SD, standard deviation; TIMI, Thrombolysis in Myocardial Infarction. TIMI Flow Pre, TIMI flow measured prior to intervention; TIMI Flow Post, TIMI flow measured after intervention.
[a]Pearson χ^2 or Student *t* test and SD.

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Table 3. Procedural Characteristics, Outcomes, and Discharge Medications

Procedural Factors and Outcomes	Readmitted or Death Within 30 Days	Not Readmitted and Alive at 30 Days	*P* Value[a]
Procedure characteristics			
Door-to-balloon time within 90 minutes, %	14.9	12.7	0.437
Cardiac catheterization within 4 hours, %	88.8	89.4	0.817
Attempted PCI, %	90.1	87.8	0.401
Stent, %	85.1	84.7	0.907
2b3a Inhibitor during catheterization, %	46.0	46.1	0.973
Antithrombotic during catheterization, %	93.8	92.9	0.666
Clopidogrel during catheterization, %	54.7	65.5	0.007
Heparin, %	62.2	65.3	0.476
Bivalirudin, %	18.5	18.2	0.933
Thrombectomy, %	31.1	32.3	0.779
Intra-aortic balloon pump, %	19.9	7.6	<0.001
Intubation during catheterization, %	10.6	3.2	<0.001
In-hospital outcomes			
Recurrent MI, %	1.2	1.2	0.574
Persistent neurological deficit %	3.7	1.2	0.010
Cerebrovascular accident, %	5.0	1.2	<0.001
Intracranial hemorrhage, %	1.2	0.4	0.162
Congestive heart failure, %	26.7	9.2	<0.001
Coronary artery bypass graft surgery, %	3.7	2.1	0.177
Left ventricular gram, %	78.3	71.8	0.083
Ejection fraction (%) ± SD	46.0 ± 13.9	51.4 ± 11.3	<0.001
Ejection fraction <40%, %	25.5	12.3	<0.001
Length of stay (days) ± SD	5.7 ± 4.8	4.6 ± 3.1	<0.001
Length of stay >6 days, %	28.0	15.8	<0.001
Discharge medications			
Aspirin, %	87.9	97.5	<0.001
β-Blockers, %	87.9	96.0	<0.001
ACE or ARB inhibitors, %	74.0	80.7	0.078
Aspirin, BB, and ACE or ARB combined, %	64.4	74.6	0.012
Calcium channel blockers, %	6.7	7.1	0.859
Lipid-lowering agents, %	87.1	96.6	<0.001
Antiarrhythmics, %	5.8	2.3	0.023
Platelet inhibitors, %	94.1	95.7	0.441
Warfarin, %	22.0	16.1	0.088

Abbreviations: ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; BB, β-blocker; MI, myocardial infarction; PCI, percutaneous coronary intervention; SD, standard deviation.
[a]Pearson χ^2 or Student *t* test and SD.

Table 4. Final Multivariate Logistic Model for Emergent 30-Day Readmission or Death

Risk Factor	Adjusted Odds Ratio	95% CI	*P* Value
Patient comorbidities			
Age ≥80 years	2.25	1.39-3.63	0.001
Diabetes	1.90	1.21-2.96	0.005
Hypercholesterolemia	0.61	0.41-0.91	0.016
Presentation and disease			
Transfer patient	0.56	0.37-0.85	0.006
Chest pain	3.37	1.35-8.43	0.009
Cardiac arrest	3.02	1.71-5.34	<0.001
3-Vessel disease	1.95	1.31-2.90	0.001
Clopidogrel given during procedure	0.69	0.47-1.02	0.061
In-hospital outcomes			
In-hospital new heart failure	2.15	1.32-3.51	0.002
Discharge medications			
Aspirin, β-blocker, ACE or ARB inhibitors combined	0.67	0.45-0.99	0.050

Abbreviations: ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blocker; CI, confidence interval.

readmission and death including presenting a history of chest pain, shortness of breath, cardiac arrest, and whether or not the patient was transferred from another facility. The incorporation of these factors into routine clinical risk models for 30-day readmission or death should be considered.

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There is sparse evidence on the principal causes of readmission following acute hospitalization for STEMI. We demonstrated in Table 1 the principal causes of 30-day readmission, including elective (staged) and emergent readmissions. We found the most common causes of readmission were ischemic heart disease, chest pain, gastrointestinal complications, and heart failure (7%). We observed similar results to previous reports on PCI causes of readmissions listing ischemic heart disease, chest pain, and heart failure as 3 of the leading causes of readmission after PCI.[5,10] However, we expanded our modeling to incorporate 30-day mortality in an effort to cluster 2 major accepted 30-day quality measures of patient safety, and move the field toward the development of predictive models targeting patient safety measures and not readmissions alone, which could be used to help institutions reduce readmissions but not at the expense of patient safety.

Recently, there has been an emergence of evidence from major state-based registries and hospitals reporting on the risk factors associated with 30-day readmission after AMI. However, these reports have predominantly focused their modeling efforts on the entire PCI population and were not restricted to PCI following STEMI.[5,10] Various investigations that have developed models to predict 30-day readmission have been moderate in performance including reports using Medicare claims (ROC 0.63)[16] and state registries where all PCI procedures reported a readmission rate of 12.4% to 15.6%, however with poor discrimination with ROC curves ranging from 0.64 to 0.67.[5,10] Others have reported the composite outcome of readmission or death within 30 days at 9.4% and 0.68%, respectively.[6] Four common risk scores have been developed to predict 30-day and 1-year mortality after STEMI, including the Controlled Abciximab and Device Investigation to Lower Late Angioplasty complications (CADILLAC),[17] Thrombolysis In Myocardial Infarction (TIMI),[18] Global Registry for Acute Coronary Events (GRACE),[19] and Primary Angioplasty in Myocardial Infarction (PAMI).[20] These risk scores have been externally validated and perform with moderate to good discrimination, with ROCs from 0.72 to 0.82.[21] Several shared risk factors in these models with our composite outcome include older age, 3-vessel disease, and diabetes. We expanded on the science by contributing risk factors derived from the time of presentation with STEMI, including whether or not the patient was transferred from another facility, chest pain, and cardiac arrest at the time of STEMI presentation. We also expanded the research in this field by combining 2 major patient safety quality measures, 30-day readmission and 30-day all-cause mortality after alive discharge, in an effort to redirect the field to routinely model early postdischarge adverse events that are threats to patient safety and not solely on readmission. Unfortunately, the majority of these preliminary reports on readmission do not separate out acute hospitalization for AMI or primary PCI.[5,6,10,22] We contributed to the literature a clinical risk model for STEMI 30-day readmission or death and evaluate risk factors at the time of presentation with STEMI.

There are several limitations of this investigation to consider. First, we presented results from a single rural academic tertiary medical center receiving STEMI patients from Vermont and New Hampshire. Nearly all of our patients were treated with an initial strategy of either primary PCI or pharmacoinvasive PCI, and therefore our report may not be generalizable to medical centers performing predominantly primary PCI for STEMI or those treating predominantly with a stand-alone lytic therapy strategy. Regardless, our results appear to be consistent with the PCI models reported from other regions including New York, Massachusetts, and Minnesota. Moreover, we used prospectively collected STEMI registry data to measure, for the first time, STEMI presentation and prehospitalization measures with readmission. Although it is possible that unmeasured factors during the index admission or postdischarge may be associated with readmission (eg, discharge planning and quality, medications, medication compliance, and referrals to primary care and cardiac rehabilitation services), we believe that along with the inclusion of STEMI processes of care, using patient and procedural factors is a comprehensive approach toward developing a prediction model for STEMI readmission, and contributes novel evidence on modeling readmission and mortality. In our modeling, we observed transfer patients to be a protective factor against 30-day death or readmission. There are several reasons our transfer patients may be a protective population. We limited our analysis to patients alive at discharge. Patients transferred to our hospital from an outlying hospital must have survived both the transit and index admission to be included in the analysis. It is likely that high-risk patients or patients in shock died prior to arrival during a transfer or did not survive the index admission, leaving only low- to moderate-risk patients alive at discharge among the transfer patients. Over the study period we also noted a marked improvement in transfer 30-day mortality and reduction in door-to-needle and door-to-balloon times. Finally, the ascertainment of readmission was conducted using hospital administration data. In our region, all major cardiac complications are referred back to our tertiary medical center for observation, readmission, or repeat angiography with or without angioplasty. As noted by Desai and colleagues,[9] conducting readmission investigations in the United States requires the use of Medicare data to completely ascertain the end point of readmission. Although we did not link our data to Medicare claims, in doing so, the ascertainment of readmission would only supplement patients over the age of 65 years and not include HMO-covered beneficiaries under Medicare (in some geographic regions, the HMO penetration for Medicare beneficiaries is more than 50%), and will still underestimate the ascertainment of readmission for the uninsured, those under 65 years, and those over 65 years HMO-covered Medicare beneficiaries.[9]

Conclusion

We present a prediction model for 30-day emergent readmission or postdischarge death following acute hospitalization for STEMI. We report on novel patient and modifiable risk factors derived from the time of presentation with STEMI and their utility in predicting readmission or death. Our model can be used to develop routine surveillance systems when planning for STEMI discharge to determine the likelihood of near-term adverse events that may eminently jeopardize patient safety.

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