Percutaneous versus Surgical Revascularization for Acute Myocardial Infarction

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Abstract

Acute myocardial infarction (AMI) is a common medical condition that requires appropriate revascularization in a timely manner. Percutaneous revascularization (PR) was the first line treatment option when feasible. Limited data is available comparing PR to surgical revascularization (SR) in the AMI setting. Study population was extracted from the 2016 Nationwide Readmissions Data using International Classification of Diseases, tenth edition codes for AMI, PR, SR, and procedural complications. Endpoints included in-hospital all-cause mortality, length of index hospital stay (LOS), stroke, acute kidney injury, bleeding, blood transfusion, acute respiratory failure, and total hospital charges. The study identified 45,539 discharges with a principal admission diagnosis of AMI who had either PR or SR as a principal procedure. Single vessel revascularization was performed in 67.8% (93.1% had PR versus 6.9% had SR, $p<0.01$). Multivessel revascularization was performed in 32.2% (64.8% had PR versus 35.2% had SR, $p<0.01$). In comparison to SR, PR was associated with higher in-hospital all-cause mortality ($P<0.01$), shorter LOS ($p<0.01$), and lower incidence of post-procedural stroke ($p<0.01$), acute kidney injury ($p<0.01$), bleeding ($p<0.01$), need for blood transfusion ($p<0.01$), acute respiratory failure ($p<0.01$), and total hospital charges ($p<0.01$). In a subgroup analysis, SR mortality benefit persisted in patients who had multivessel revascularization, but not in single vessel revascularization. In patients presented with AMI, PR was associated with higher in-hospital all-cause mortality but lower morbidity, shorter LOS, and lower total hospital charges than SR. However, the mortality benefit of SR was seen in multivessel revascularization only, and not in single vessel revascularization.

Percutaneous versus Surgical Revascularization for Acute Myocardial Infarction

Running Title: PCI vs CABG for AMI

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ABSTRACT

Introduction

Acute myocardial infarction (AMI) is a common medical condition in our clinical practice that should be treated with appropriate revascularization in a timely manner. Percutaneous revascularization (PR) has been the first line treatment option when feasible. Limited data is available comparing PR to surgical revascularization (SR) in the AMI setting.

Methods

Study population was extracted from the 2016 Nationwide Readmissions Data using International Classification of Diseases, tenth edition, clinical modifications/procedure coding system codes for AMI, PR, SR, and procedural complications. Study endpoints included in-hospital all-cause mortality, length of index hospital stay (LOS), stroke, acute kidney injury, bleeding, need for blood transfusion, acute respiratory failure, and total hospital charges.

Results

The study identified 45,539 discharges with a principal admission diagnosis of AMI (38.7% ST elevation and 61.3% non-ST elevation) who had either PR or SR as a principal procedure (79.1% PR versus 20.9% SR). Single vessel revascularization was performed in 67.8% (93.1% had PR versus 6.9% had SR, $p<0.01$). Multivessel revascularization was performed in 32.2% (64.8% had PR versus 35.2% had SR, $p<0.01$). 83% of SR was in the setting of non-ST elevation AMI (NSTEMI). In comparison to SR, PR was associated with higher in-hospital all-cause mortality (3.7% versus 2.2%, $P<0.01$), shorter LOS (4.3 versus 11.6 days, $p<0.01$), and lower incidence of post-procedural stroke (1.0% versus 1.8%, $p<0.01$), acute kidney injury (14.9% versus 24.8%, $p<0.01$), bleeding (4.3% versus 47.1%, $p<0.01$), need for blood transfusion (2.9% versus 18.5%, $p<0.01$), acute respiratory failure (10.7% versus 19.8%, $p<0.01$), and total hospital charges (120,590$ versus 229,917$, $p<0.01$). These results persist after adjustment for baseline characteristics. In a subgroup analysis, SR mortality benefit persisted in patients who had multivessel revascularization (in both ST and non-ST elevation AMI), but not in single vessel revascularization.

Conclusions

In patients presented with AMI, PR was associated with higher in-hospital all-cause mortality but lower morbidity, shorter LOS, and lower total hospital charges than SR. However, the mortality benefit of SR was seen in multivessel revascularization only, and not in single vessel revascularization.

INTRODUCTION

Coronary artery disease (CAD) affects over 18 million people in the United States, with over 8.4 million cases present as acute myocardial infarctions.[1] Half of acute myocardial infarctions (AMI) are associated with multivessel disease.[2] Data suggest better outcomes with complete percutaneous revascularization (PR) vs culprit-only PR in the setting of multivessel AMI mainly driven by less need for future urgent revascularization.[2,3] Incomplete PR in patients with multivessel CAD, has been recognized as an independent predictor of mortality [4,5]. On the other hand, surgical revascularization (SR) is the preferred strategy over PR in stable coronary disease when there is complex anatomy, diabetes, and/or left ventricular dysfunction [6–10]. Moreover, SR allows for more complete revascularization than PR and less need for future revascularization.[7][11]

Some studies have shown PR to be associated with lower rates of early stroke than SR, and is known globally to be more widely available.[8] PR can achieve revascularization of the culprit vessel in a more timely manner which is of particular importance in the setting of AMI.[12–15] There are limited data comparing the two revascularization strategies in the setting of AMI given to pros and cons of each strategy.

METHODS

Data Source

The Nationwide Readmissions Data (NRD) is a part of the Healthcare Cost and Utilization Project (HCUP) databases, which has been developed through a Federal-State-Industry partnership and sponsored by the Agency for Healthcare Research and Quality (AHRQ). HCUP databases include the largest collection of de-identified longitudinal hospital care data in the United States, with safeguards to protect the privacy of individual patients, physicians, and hospitals. The NRD contains more than a hundred clinical and nonclinical variables for each hospital stay including a verified patient linkage number for linking hospital visits for the same patient across hospitals, International Classification of Diseases, Tenth Revision, Clinical Modification/Procedure Coding System (ICD-10-CM/PCS) for principal and secondary procedures and diagnoses (including comorbidities and complications), age, gender, length of stay (LOS), and others.[16,17]

Study Cohort

ICD-10-CM/PCS codes were used to search discharges in the 2016 NRD who had a principle diagnosis of AMI (including ST and non-ST elevation AMIs) and a principle procedure of either PR or SR during the index hospitalization; baseline characteristics, comorbidities, in-hospital procedural complications, and endpoints of interest were subsequently extracted. To differentiate post-procedural complications from chronic conditions, the 2016 NRD has a present-on-admission indicator for chronic conditions that present on admission. We also utilized the ICD-10-CM codes used in the Elixhauser comorbidity index to identify comorbid conditions and utilized ICD-10-CM codes that are specific for post-procedural complications, Supplemental Table 1.[17] We excluded patients that did not have AMI as a principle diagnosis and AMIs that were not treated invasively (i.e. PR or SR) or when the revascularization was not the principle procedure. We also excluded AMIs that were treated with a combination of both PR and SR during the same indexed admission. The NRD excludes discharges with missing age, missing or questionable linkage numbers or from hospitals with more than 50% of their discharges excluded because of these criteria, as patients treated in these hospitals may not be reliably tracked over time.[16] All HCUP recommendations and best practices to use the HCUP datasets highlighted by Khera et al were followed.[18]

Study Endpoints

The study endpoints included in-hospital all-cause mortality, LOS, post-procedural stroke, acute kidney injury, bleeding, need for blood transfusion, acute respiratory failure, and total hospital charges. The 2016 NRD reports in-hospital all-cause deaths and mean LOS. The other endpoints were assessed during the index hospitalization using specific ICD-10 codes for post-procedural complications, Supplemental Table 1. Stroke included new intra or post-procedural cerebral infarction secondary to bleeding, thrombosis and/or embolism to one or more cerebral arteries. Acute kidney injury included any new post-procedural acute worsening of kidney function. Bleeding included any circulatory or central nervous system bleeding during or post-procedure, or post-procedure hemorrhage/anemia. Transfusion included blood or blood product transfusion post-procedure. Acute respiratory failure included new post-procedural hypoxemic or hypercapnic respiratory failure or acute worsening of chronic respiratory failure. Total hospital charges represented how much the hospital billed for the service but not necessarily the actual cost or the amount the hospital actually received.

Statistical Analysis

Statistical Analysis System (SAS) software 9.4 (TS1M4, SAS Institute Inc, Cary, North Carolina) was used for data extraction and statistical analysis which was performed on unweighted (i.e. actual number) discharges. Pearson's Chi-Square of Independence and unpaired-sample t -test were used to compare the endpoints of interest and baseline characteristics in both PR and SR groups. Logistic regression was used to create propensity score, based on the basic demographics and baseline characteristics for one-to-one parallel, balanced propensity score matching model using a caliper of 0.001. The McNemar test was used to compare paired categorical variables of the baseline characteristics and endpoints of interest, while paired-samples t -test was used to compare continuous variables. A two-tailed p-value of <0.05 was used for statistical significance.[19,20]

RESULTS

The 2016 NRD database included approximately 17.2 million discharges. There were 328,570 discharges with a principal diagnosis of AMI. Of which, 45,539 (38.7% ST elevation and 61.3% non-ST elevation) had either PR 79.1% or SR 20.9% as a principal procedure, Figure 1. The mean age of the overall cohort was 64.8+ 12.2 years and 29.8% were women. History of CAD, hypertension, hyperlipidemia, diabetes, and smoking were the most common comorbidities, Table 1.

SR group had significantly more comorbidities including congestive heart failure and diabetes. Single vessel revascularization was performed in 67.8% (93.1% PR versus 6.9% SR, p<0.01). Multivessel revascularization was performed in 32.2% (64.8% PR versus 35.2% SR, p<0.01). 16.5% in the SR group had ST elevation AMI and 83.2% had non-ST elevations, while 44.6% of the PR group had ST elevation and 54.9% had non-ST elevation AMI, Table 1.

In comparison to SR, PR was associated with higher in-hospital all-cause mortality (3.7% versus 2.2%, P<0.01), shorter LOS (4.3 versus 11.6 days, p<0.01), and lower incidence of post-procedural stroke (1.0% versus 1.8%, p<0.01), acute kidney injury (14.9% versus 24.8%, p<0.01), bleeding (4.3% versus 47.1%, p<0.01), need for blood transfusion (2.9% versus 18.5%, p<0.01), acute respiratory failure (10.7% versus 19.8%, p<0.01), and total hospital charges (120,590$ versus 229,917$, p<0.01) (Table 2).

There were 6,938 comparable pairs were identified using propensity matching (Table 1), these pairs also comparable in terms of cardiogenic shock (10.0% versus 9.5%, p=0.35) and mechanical complications of AMI (0.2% versus 0.2%, p=055). The results remained consistent after propensity matching (Table 2).

In subgroup analysis, SR mortality benefit persisted in patients who had multivessel revascularization (in both ST and non-ST elevation AMI), but not in single vessel revascularization. Furthermore, the mortality benefit persisted in patients with and without diabetes, systolic heart failure, cardiogenic shock and mechanical complications of AMI.

DISCUSSION

In this study, SR of AMI was associated with lower in-hospital mortality but higher morbidity, longer LOS, and total hospital charges than PR. These results remained consistent in patients who had multiple vessel revascularization (in both ST and non-ST elevation AMI), but not single vessel, and in patients with/without diabetes, systolic heart failure, cardiogenic shock or mechanical complications of AMI, despite the fact that SR group had higher baseline comorbidities. These results persist after adjustment for baseline characteristics using propensity matching.

Most of the previous studies that showed comparable or superior outcomes of SR in patients with stable CAD, rather than AMI, and over a longer period of time.[21] A pooled data from multiple trials that compared SR to PR in patients with NSTEMI showed that SR was associated with lower composite end points over 5 years which was mainly driven by lower infarction rather than lower mortality.[23] However, another study showed a trend to lower events rate and lower mortality in comparison to PR.[24]

Advancements in surgical techniques such as off pump surgery, clampless and no-touch surgery, epiaortic ultrasonography, and minimally invasive/robotic SR all have contributed to lower both operative and long-term mortality and complications rates.[25]Moreover, the heart-team approach for SR patient selection using a multidisciplinary team could increase the operative safety and success rate.[26]

Conduit selection has also showed to improve outcomes and mortality.[11] Internal mammary artery (IMA) grafting to left anterior descending is a major survival determinant independently from the presence of other graft. This is likely because of superior patency rates in comparison to vein grafts[27] and high proportion of elastic composition compared to muscle or adventitia making it more able to tolerate coronary blood flow. Furthermore, IMA grafts have physiological functions that result in anti-atherosclerotic effects by producing much greater levels of nitric oxide and decreased release of vasoconstrictors. Nitric oxide is a known potent angiogenic agent which initiates neocapillary and microvascular bed formation in the affected and adjacent areas.[11,27] These factors could have resulted in the lower early in-hospital mortality seen in this study despite the higher complications rates.

Most of AMI results from non-flow-limiting lesions; however, PR treats flow-limiting lesions only therefore it is not expected to prevent new infarcts and subsequently lacks mortality benefit. On the other hand, SR bypasses the whole diseased segments which creates "surgical collateralizations"; a condition that allows revascularization of the diseased-vessel which subsequently causes no or nonfatal AMI which could also decrease mortality. [21]

This study is based on a large nation-wide database and represents real-world outcomes in the United States. It adds to the current literature that SR in the AMI setting is still a feasible option, especially when PR is expected to be suboptimal or results in incomplete revascularization, and might be associated with lower in-hospital mortality in patients with multivessel CAD.

Limitations

This was a retrospective study. ICD-10 codes do not specify the involved coronary artery, the location, severity, or complexity of the coronary lesions. The type and the intensity of the medical therapy, core laboratory and the exact ejection fraction were not provided. The details of the procedures, such door-to-intervention time, duration of the procedure, etc. could not be assessed. Furthermore, the reason why patients underwent SR vs PR could be determined. Long term outcomes could not be assessed.

CONCLUSIONS

Percutaneous revascularization was associated with higher in-hospital all-cause mortality but lower morbidity, shorter LOS, and lower total hospital charges than SR in patients with acute myocardial infarction. The mortality benefit of SR was seen in multivessel revascularization only, and not in single vessel revascularization.

Disclosures

All authors have no conflict of interest, financial disclosures, or relationship with industry.

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Figure Legend

Table 1: Demographics, baseline characteristics and comorbidities of percutaneous revascularization (PR) and surgical revascularization (SR) groups before and after propensity matching.

Table 2: Study endpoints before and after propensity matching.

Figure 1: Flowchart demonstrating data extraction process.

Supplemental Table 1: International Classification of Diseases, Tenth Revision, Clinical Modification/Procedure Coding System (ICD-10-CM/PCS) codes used to define baseline characteristics, comorbidities, and in-hospital and post-procedural complications from the 2016 Nationwide Readmissions Data (NRD).

Table 1: Demographics, baseline characteristics and comorbidities of percutaneous revascularization (PR) and surgical revascularization (SR) groups before and after propensity matching.

Baseline/Group	Before Matching PR	Before Matching SR	P-value	After Matching PR	After Matching SR	P-valu
Number of patients	35,989	9,550	-	6,938	6,938	-
Mean Age in years (SD)	64.7(12.6)	65.1(10.7)	<0.01	65.9 (12.5)	65.3 (10.7)	
Female	30.8%	25.7%	<0.01	31.0%	28.1%	<0.01
ST Elevation AMI	44.6%	16.5%	<0.01	21.7%	21.5%	0.81
Non-ST Elevation AMI	54.9%	83.2%	<0.01	77.8%	78.0%	0.78
Single-vessel Revascularization	79.9%	22.2%	<0.01	32.5%	30.5%	<0.01

Multivessel Revascularization	20.1%	41.3%	<0.01	67.5%	52.4%	<0.01
Hypertension	78.3%	87.2%	<0.01	84.5%	84.9%	0.48
Diabetes Mellitus	37.5%	49.7%	<0.01	46.7%	46.1%	0.47
Hyperlipidemia	68.9%	76.8%	<0.01	73.3%	74.2%	0.05
Chronic Kidney Disease	16.5%	20.8%	<0.01	21.5%	20.6%	0.16
Congestive Heart Failure	25.0%	34.4%	<0.01	33.1%	32.4%	0.40
Systolic Heart Failure	16.2%	23.1%	<0.01	21.6%	21.3%	0.66
Coronary Artery Disease	86.6%	93.6%	<0.01	90.7%	92.0%	<0.01
Chronic Anemia	12.9%	21.2%	<0.01	19.7%	18.6%	0.09
Atrial Fibrillation	14.0%	30.6%	<0.01	21.8%	22.6%	0.18
Atrial Flutter	1.7%	4.0%	<0.01	2.9%	3.0%	0.80
Long-term Anticoagulation	5.0%	4.7%	0.16	5.4%	4.9%	0.23
Aspirin	21.8%	26.3%	<0.01	25.2%	25.4%	0.78
Abnormal Coagulation Profile	0.3%	0.6%	<0.01	0.4%	0.5%	0.19
Peripheral Vascular Disease	10.7%	16.0%	<0.01	15.4%	14.4%	0.09
Chronic Pulmonary Disease	17.4%	23.7%	<0.01	22.3%	22.0%	0.62
Chronic Liver Disease	1.8%	3.1%	<0.01	2.5%	2.6%	0.78
Smoking	47.0%	53.0%	<0.01	49.8%	50.9%	0.19
Obesity	19.1%	29.4%	<0.01	25.1%	25.3%	0.81

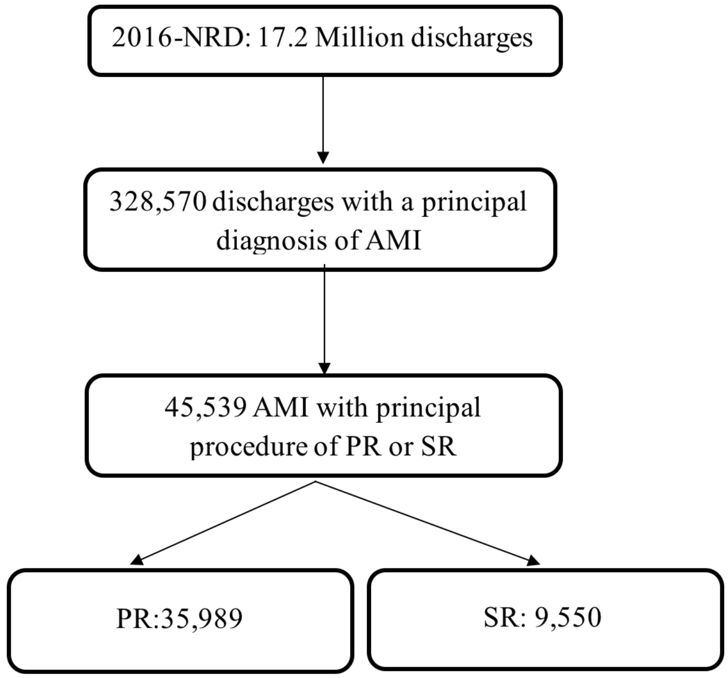
AMI: acute myocardial infarction, SD: standard deviation.

Table 2: Study endpoints before and after propensity matching.

Endpoint/Group	Before Propensity Matching PR	Before Propensity Matching SR	Before Propensity Matching P-value
Number of Patients	35,989	9,550	-
All-cause Mortality	3.7%	2.2%	<0.01
Mean Length of Stay in Days	4.3	11.6	<0.01
Stroke	1.0%	1.8%	<0.01
Acute Kidney Injury	14.9%	24.8%	<0.01
Bleeding	4.3%	47.1%	<0.01
Blood Transfusion	2.9%	18.5%	<0.01
Acute Respiratory Failure	10.7%	19.8%	<0.01
Total Hospital Charges	120,590$	229,917$	<0.01

PR: percutaneous revascularization, SR: surgical revascularization.

Figure 1: Flowchart demonstrating data extraction process.



AMI: acute myocardial infarction, NRD: Nationwide Readmissions Data, PR: percutaneous revascularization, SR: surgical revascularization.