January 2014

Payments For Acute Myocardial Infarction Episodes Of Care By Hospital Interventional Capability

Gal Ben-Josef
Yale School of Medicine, gbenjose@gmail.com

Payments for Acute Myocardial Infarction Episodes of Care
by Hospital Interventional Capability

A Thesis Submitted to the

Yale University School of Medicine

in Partial Fulfillment of the Requirements for the

Degree of Doctor of Medicine

by

Gal Ben-Josef

2014

PAYMENTS FOR ACUTE MYOCARDIAL INFARCTION EPISODES OF CARE BY HOSPITAL INTERVENTIONAL CAPABILITY

Gal Ben-Josef, Lesli S. Ott, Steven B. Spivack, Changqin Wang, Sachin J. Shah, Jeptha P. Curtis, Nancy Kim, Harlan M. Krumholz, Susannah M. Bernheim, and Joseph S. Ross. Department of General Internal Medicine, Yale University School of Medicine, New Haven, CT.

It is not known whether hospitals with percutaneous coronary intervention (PCI) capability provide more costly care than hospitals without PCI capability for patients admitted for acute myocardial infarction (AMI). The growing number of PCI-capable hospitals and higher rate of PCI use at technologically advanced hospitals may result in higher costs for episodes of care initiated at PCI hospitals. However, higher rates of transfers and post-acute care procedures may result in higher costs for episodes of care initiated at non-PCI hospitals.

We identified all AMI admissions in 2008 among Medicare fee-for-service beneficiaries and classified hospitals as PCI- or non-PCI-capable based on hospitals' 2007 PCI performance. We added all payments from the time of admission through 30 days post-admission, including payments to hospitals other than the admitting hospital. We calculated and compared risk-standardized payment for PCI and non-PCI hospitals using 2-level hierarchical generalized linear models that adjust for patient demographics and clinical characteristics. PCI hospitals had a slightly higher mean 30-day risk-standardized payment than non-PCI hospitals ($20,340 v. $19,713, P<0.001). Patients presenting to PCI hospitals had higher PCI rates (39.2% v. 13.2%, P<0.001) and higher coronary artery bypass graft (CABG) rates (9.5% v. 4.4%, P<0.001) during index AMI admissions, lower transfer rates (2.2% v. 25.4%, P<0.001), and lower revascularization rates within 30 days (0.15% v. 0.27%, P<0.0001) than those presenting to non-PCI hospitals.

Despite higher PCI and CABG rates for patients who began their 30-day episode of care at PCI hospitals, PCI hospitals were only $627 more costly than non-PCI hospitals for the treatment of patients with AMI.

ACKNOWLEDGEMENTS

I would like to thank my mentors, Dr. Joseph Ross and Dr. Susannah Bernheim, for their guidance and inexhaustible support.

I would also like to thank my collaborators at the Yale-New Haven Hospital Center for Outcomes Research and Evaluation: Ms. Lesli Ott and Mr. Changqin Wang for their analytic contributions, and Mr. Steven Spivack, Dr. Sachin Shah, Dr. Jeptha Curtis, Dr. Nancy Kim, and Dr. Harlan Krumholz for their participation in the many thoughtful and rigorous discussions around this project.

Finally, I would like to thank my family and friends for their solicited and unsolicited input, and their constant confidence in my abilities.

This research was supported by the American Heart Association Student Scholarship in Cardiovascular Disease and the National Research Service Award from the National Institutes of Health.

TABLE OF CONTENTS

INTRODUCTION

In recent years, hospitals have increasingly established new programs for percutaneous coronary intervention (PCI). In 2001, approximately 25% of hospitals in the United States offered primary PCI and by 2006, this number had grown to 36% of hospitals, an increase of 44%.[1] The number of hospitals offering diagnostic angiography and coronary artery bypass graft (CABG) surgery has also risen, though more gradually, with an increase of 3% and 4% from 1996 to 2008, respectively.[2] The increase in the number of hospitals with invasive capabilities, and PCI-capable hospitals (PCI hospitals) in particular, may have implications for both the quality and cost of care for patients with acute myocardial infarction (AMI). Several key issues include the distribution of patients over more hospitals, leading to lower volume of patients with AMI treated at each hospital and fewer experts in AMI care per hospital, greater variation in patient management and outcomes, and the potential for overutilization of PCI in the absence of clear medical indications. Despite these concerns, invasive cardiac facilities are profitable and prestigious, so investing in these services is appealing to hospitals even if the new facilities will not substantially increase access to care and may in fact exacerbate the growing cost of medical care in the U.S.[2]

Access to Care

Despite the increase in the number of PCI hospitals, several recent studies have shown little to no improvement in access to emergent or elective procedures.[1-4] For example, Concannon et al. demonstrated that a 16.5% expansion in PCI programs between 2004 and 2008 increased access to timely PCI in only 1.8% of the U.S.

population.[3] Similarly, Horwitz et al. found disproportionately small changes in access to coronary angiography, PCI, and CABG between 1996 and 2008 given the associated increase in capable facilities, with increases of 1%, 5%, and 4% of the population with access to the respective procedures.[2] It follows that rates of both emergent and elective procedures remained constant between 2001 and 2008, despite the growing number of available PCI programs.[4] One explanation for this incongruity is that hospitals located in areas with existing PCI programs were more likely to open new PCI facilities than hospitals located in areas without PCI programs,[3] even when these same services were already offered within a 40 mile radius.[2] This trend is likely explained by the fact that these services are well reimbursed and draw both patients and physicians to the hospital, making the expansion profitable.

Similar trends have been documented for cardiac surgery programs.[5] Between 1993 and 2004, the creation of 301 new cardiac surgery programs – a 30% increase – was not associated with an increase in the number of CABG surgeries performed; rather, the number of CABG surgeries has been decreasing since 1997. Of the new programs, 42% were located in communities where cardiac surgery was already accessible.[5]

However, the discrepancy between availability and access is not consistent across the country. Concannon et al. have shown that there exists significant regional variation in access to PCI, ranging from 88% of the population with access to PCI in the Northeast to 76% in the South, with minimal improvement between 2001 and 2006.[1] Nevertheless, in areas with lower rates of access to PCI in 2004, new programs did significantly improve access to PCI for patients with ST-elevation myocardial infarction (STEMI), suggesting that patients living in underserved areas may benefit from the expansion of hospital PCI capabilities.[3]

Quality of Care

The growth of PCI capability in the U.S. has also spurred investigations into quality of care, including studies on appropriate use of PCI, the effect on and implications of hospital PCI volume and time to treatment, and most importantly, patient outcomes such as rates of mortality and readmissions.

Appropriate Use of PCI

Many studies have shown that the availability of invasive cardiac procedures at a facility is associated with increased utilization of these procedures both during the initial hospitalization[6-9] and within 30 days of hospital admission.[10] In a 1998 study, Krumholz et al. demonstrated that hospitals with cardiac catheterization facilities had a catheterization rate of 39%, compared with a rate of only 27% at hospitals without on-site catheterization facilities, despite adjustments for baselines patient characteristics.[8] Though the study found similar rates of revascularization between hospitals,[8] a similar study by Alter et al. found an 8% difference in the rates of revascularization between patients admitted to hospitals with and without on-site catheterization capabilities.[7] More recently, Nallamothu et al. evaluated the relationship between opening of new specialty cardiac hospitals or new cardiac programs at general hospitals and rates of coronary revascularization, finding that changes in revascularization rates in regions with new cardiac hospitals far outstripped rates in areas with new programs in general hospitals and in areas with no new programs.[9] However, in cardiac hospitals, rates of revascularization held steady in patients with AMI while use of the procedure in patients without AMI increased, calling into question the appropriateness of these procedures. The authors raised concerns that physician ownership of cardiac hospitals may result in stronger financial incentives for providing unnecessary procedures.

Given that more PCIs are performed for patients admitted to PCI hospitals, it is important to consider whether these procedures are medically appropriate. PCI is an invasive procedure that may expose patients to undue risk without significant benefit if performed in inappropriate cases. Additionally, as cardiac services can contribute 25-40% of hospital revenues,[5] many researchers have questioned whether increasing rates of invasive cardiac procedures may be attributed in part to overutilization spurred by procedure availability or other underlying incentives. Accordingly, the American College of Cardiology Foundation (ACCF), in conjunction with several professional organizations, developed appropriateness criteria for coronary revascularization in 2009 for the treatment of coronary artery disease (CAD), with approximately 180 common clinical scenarios rated on an appropriateness scale of 1 to 9 based on symptoms, prior use of medical therapy, risk level, and coronary anatomy.[11] Based on these criteria, Chan et al. conducted a study in 2011 to assess the appropriateness of PCI.[12] Of approximately 70% of PCIs performed for acute indications – including STEMI, non-ST-segment elevation myocardial infarctions (NSTEMI), and unstable angina (UA) with high-risk features – nearly 99% were classified as appropriate. However, of the remaining 30% of PCIs performed for non-acute indications, 12% were deemed inappropriate and 38% were classified as uncertain appropriateness. These non-acute procedures were utilized for patients with no angina, low-risk ischemia on noninvasive stress testing, or patients who had received suboptimal medical therapy. Finally, use of non-acute procedures varied substantially between hospitals, ranging from 0% to 50%. These findings suggest that, while PCI may be used appropriately in the context of AMI, the increasing availability of PCI may allow for increased utilization of PCI in non-acute situations, exposing patients to excess and unnecessary risk and contributing to rising healthcare costs.

Hospital PCI Volume

The increasing number of available PCI programs may also affect quality of care due to changes in volume of PCIs performed at individual hospitals. From 2001 to 2009, the proportion of STEMI patients initially admitted to hospitals with high volume of PCI increased from 62.4% to 89.7%, while the percentage of STEMI patients admitted to low-volume centers fell from 31% to 4.9%; additionally, patients admitted to non-PCI hospitals and transferred to high-volume PCI hospitals decreased from 17.6% to 13.1%.[13]

The 2011 American College of Cardiology Foundation / American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions (ACCF/AHA/SCAI) class I recommendations state that, for both emergent and elective PCI, individual operators should perform at least 75 PCI procedures per year at institutions that perform at least 400 procedures per year.[14] These recommendations apply for patients with STEMI, NSTEMI, and UA, though the guidelines for STEMI also indicate that procedures should optimally occur at institutions that perform at least 36 primary PCI procedures specifically for STEMI each year. These guidelines were developed due to evidence that treatment at higher-volume hospitals is associated with improved patient survival.[15-17] For example, in a study using data from the National Registry of Myocardial Infarction, patients who were admitted to hospitals with the highest volume of angioplasty per year had a 28% lower mortality rate than those who were admitted to hospitals with the lowest volume, a relationship that persisted even after adjusting for multiple factors, including volume of patients with AMI at each hospital.[15] Similarly, Post et al. analyzed 10 studies on the association between PCI volume and mortality.[16] The authors report 13% in-hospital mortality (an odds ratio of 0.87) for patients who underwent PCI at a high-volume hospital compared with those who underwent the procedure at a low-volume hospital. Nonetheless, recent studies demonstrate that such an association did not persist beyond an annual volume of 610 patients.[17] While these studies have not identified specific causes for the association between hospital volume and outcomes, some proposed explanations are that greater experience develops experts who can perform the procedure with better outcomes, or alternatively, that hospitals with the best results draw more patients.[16] Although studies have not investigated the impact of the increasing number of PCI hospitals on the volume of PCIs, it follows that increased availability of PCI hospitals will dilute the volume of PCIs performed at each hospital, thereby potentially increasing mortality rates.

Time to Treatment

With the creation of new PCI facilities, several studies have examined time to treatment as a quality metric. The 2007 ACC and AHA guidelines state that patients with STEMI should be treated with primary PCI within 90 minutes of their first medical contact.[18] However, of patients with STEMI who were transferred for PCI in 2005, only 4% were treated within 90 minutes,[19] though more recent data indicate that this number has increased to 17%.[20] Studies that have evaluated the impact of growing numbers of PCI hospitals on treatment times have demonstrated little improvement. Concannon et al. found that patients with AMI in 2008 could arrive at the nearest PCI hospital within a median of 25.7 minutes, a 24 second improvement as compared to travel time in 2004, although the study did find a more significant improvement in travel time of up to 4 minutes in areas with low baseline rates of access to PCI.[3] Similar studies done for patients requiring cardiac surgery have shown that travel time to cardiac surgery centers also changed little between 1993 and 2004 despite significant increases in available facilities, from 17 minutes in 1993 to 14 minutes in 2004, with the greatest effect again occurring for patients living in rural areas.[5] These findings suggest that the establishment of new PCI programs has not contributed to substantial decreases in time to treatment for patients with AMI.

Outcome Measures

Finally, many studies have focused on differences in patient outcomes, such as mortality and readmission, for patients presenting to PCI versus non-PCI hospitals, with conflicting results. In their 1998 study, Krumholz et al. demonstrated that mortality rates at 30 days and at 3 years post-admission were similar for patients admitted to Connecticut hospitals with and without on-site cardiac catheterization facilities, with 3-year mortality rates of 45.1% and 44.5%, respectively.[8] Alter et al. confirmed these findings in a population of patients with AMI treated in Ontario in the same timeframe, demonstrating that 5-year survival rates were similar among patients presenting to hospitals with and without on-site revascularization facilities.[7] However, this work was done for patients admitted between 1992-1993 in 2 specific regions, rather than on a national level.

In a more recent study, Chen et al. demonstrated that Medicare patients admitted to PCI hospitals between 2004 and 2006 had significantly lower 30-day risk-standardized mortality rates (RSMRs) compared with patients admitted to non-PCI hospitals (15.1% versus 20.7%, respectively).[10] However, further hospital-level analyses demonstrated that while PCI hospitals had lower mortality rates on average than non-PCI hospitals (16.1% versus 16.9%), quality of PCI and non-PCI hospitals varied across regions, such that mortality rates were not consistently lower at PCI hospitals. For example, in 37 of 295 regions, mortality rates at local non-PCI hospitals were equal to or lower than the mortality rates at PCI hospitals. In many regions, differences in mortality rates between PCI and non-PCI hospitals were minor, with differences of less than 1.5% between hospitals. These findings suggest that the quality of PCI and non-PCI hospitals varies across the U.S., such that non-PCI hospitals may provide superior care to PCI hospitals in some areas, despite the greater resources and capabilities available to PCI hospitals. It is therefore important to evaluate whether it is worthwhile to invest in new PCI facilities, if these hospitals do not provide uniformly better care than their non-PCI counterparts. Factors that affect the quality of care at such institutions should be studied in more detail.

Similar discrepancies exist between studies of hospital readmission rates at PCI and non-PCI hospitals. Krumholz et al. demonstrated that while 3-year all-cause readmission rates were 4.6% lower for patients admitted to hospitals with catheterization facilities than to those without, readmission rates for cardiovascular procedures were similar between hospitals.[8] Other patient-level outcome measures, such as median length of stay and mean number of days in the hospital during the subsequent 3 years after admission were similar among patients admitted to hospitals with and without catheterization facilities. In contrast, Alter et al. showed a 9% decrease in 5-year event rates, including readmission for cardiac causes and all-cause emergency department (ED) visits for patients admitted to hospitals with revascularization facilities as compared to those without these capabilities, although the study found no significant difference in readmissions for AMI.[7] Interestingly, the authors attributed the decrease in 5-year event rates at catheterization-capable hospitals to hospital teaching status rather than catheterization capability, as patients admitted to teaching hospitals were more likely to be followed by cardiologists after their initial admission as compared to patients admitted to non-teaching hospitals, regardless of hospital catheterization capability status. Importantly, the variation in outcomes between PCI and non-PCI hospitals was not attributable to differences in utilization rates of invasive cardiac procedures at the different hospitals, and rates of revascularization after hospitalization did not differ significantly between the 2 groups.

Cost of Care

From 2004 to 2008, the establishment of 251 new PCI programs added between \$2 to \$4 billion in costs to the U.S. healthcare system.[3] As discussed above, the available evidence suggests that recent investment in new PCI programs has not resulted in greater access to PCI, and PCI hospitals do not offer conclusively better patient outcomes than do non-PCI hospitals. These equivocal data lead to questions about the associated costs of care at PCI hospitals compared with non-PCI hospitals. Apart from the fixed cost of building new PCI facilities,[3] little is known about the subsequent cost of care for patients admitted with AMI to PCI hospitals versus non-PCI hospitals.

Previous studies have measured cost in several ways, the most common of which include hospital charges, cost-to-charge ratios, and estimated payments for Medicare patients. These methods are discussed in detail in the 2012 Cost Measure Methodology Report prepared by the Yale-New Haven Hospital Center for Outcomes Research and Evaluation,[21] but they are summarized here. Hospital charges are the prices set by a hospital for different services. These prices are determined by a combination of hospital expenses, profit goals, competition, and the need to offset uncompensated care. As a result, higher hospital charges may represent increased use of resources, higher fixed costs, or a combination of both. Alternatively, cost-to-charge ratios are ratios of hospital expenses to patient and operating revenue. These are often used to convert hospital charges to estimated costs. Finally, payments for Medicare patients represent Medicare reimbursement to hospitals for the care of Medicare patients, calculated using Medicare claims data from the Centers for Medicare and Medicaid Services (CMS).

In an early study by Krumholz et al., the authors examined hospital costs using hospital charge records for patients admitted to Connecticut hospitals and cost-to-charge ratios determined from the annual Medicare Cost Report for each hospital.[8] Despite adjustments for patient characteristics, the authors found no significant difference in the cost of hospitalization by catheterization capability of the index (i.e. initial) hospital, with a mean of $18,287 for patients admitted to catheterization hospitals and $17,012 for patients admitted to non-catheterization hospitals. Similarly, the authors calculated a 3-

year cost of $34,445 for patients admitted to catheterization hospitals and $32,565 for patients admitted to non-catheterization hospitals, an insignificant difference. Nevertheless, upon further evaluation of patients who underwent cardiac catheterization during their index hospitalization, those who were initially admitted to non-catheterization hospitals but transferred to catheterization hospitals incurred higher costs than those initially admitted to catheterization hospitals, with a difference in hospitalization cost of approximately $6,951. Patients who underwent percutaneous transluminal coronary angiography (PTCA), CABG surgery, both PTCA and CABG, or no procedure did not incur significantly different costs if admitted to either type of hospital. In conjunction with the rest of the paper's findings discussed above, the authors concluded that higher rates of catheterization but lower readmission rates at catheterization hospitals contribute to equalizing the 3-year cost of care for patients admitted to catheterization hospitals compared with non-catheterization hospitals.

A similar study conducted by Every et al. in 1997 evaluated cost of care for patients admitted to catheterization and non-catheterization hospitals in Seattle, Washington from 1988 to 1994.[22] In contrast to the previous study, the authors found that patients admitted to catheterization hospitals had higher 3-year cumulative costs than patients admitted to non-catheterization hospitals by approximately $2500 per patient. However, the authors found higher procedure rates on average than those reported in the study by Krumholz et al., suggesting that there may exist geographical variation in the effect of hospital catheterization capability on cost of care depending on the extent of cardiac catheterization utilization.

In a more recent study by Concannon et al., the authors constructed a model to investigate the cost of various strategies to improve access to PCI by assessing patient triage and resource utilization.[23] The authors compared the cost of a hospital-based strategy, by which hospitals constructed and staffed new PCI laboratories, with an emergency medical services (EMS) strategy, by which patients with STEMI were transported by EMS to existing PCI hospitals. These scenarios were also compared to a simulated baseline case, using a standard protocol whereby EMS transported patients to the nearest hospital, regardless of PCI capability. The authors found that when hospitals constructed new PCI facilities, part-time laboratories resulted in a cost of $30,399 per quality-adjusted life year (QALY) and full-time laboratories resulted in a cost of $14,765 per QALY. While these costs are lower than the costs of other accepted life-saving therapies, the authors also found that a strategy in which EMS diagnosed patients in the field and transported them directly to PCI hospitals resulted in a cost of $506 per QALY. Due to the costs associated with EMS diagnosis and transport, the authors added an additional $1000 per diverted patient to their cost model. The EMS strategy remained most cost-effective until the price per diverted patient entered in the model was increased above $19,769 or the expected benefit was decreased by 55%. These findings suggest that the construction of new PCI facilities requires a substantial fixed cost that is offset by increasing the number of patients with access to PCI. However, the EMS strategy can be established with considerably lower costs up front, though it necessitates reliability of EMS staff to identify patients with STEMI.

Context

Given that the growing number of PCI hospitals has not increased access to care, and that despite greater resources and capabilities, PCI hospitals may provide inferior care to non-PCI hospitals in some areas, it is important to understand the differences in cost of care between PCI hospitals and non-PCI hospitals. As described above, few studies have characterized these costs, and to our knowledge, none have done so on a national level. Results from this research may inform practices and policies influencing the conversion of non-PCI hospitals to PCI hospitals and the implementation of a regionalized system of AMI care.

Regionalization is the adoption of a national policy modeled on trauma care through which patients with STEMI would be taken directly to designated STEMI centers with PCI capability, rather than being admitted to potentially closer non-PCI community hospitals.[24] This strategy would include diagnosis of STEMI by EMS in the field with direct transport to PCI hospitals or transport to non-PCI hospitals with immediate transfer to PCI facilities. Many cardiovascular experts have supported this approach to AMI care, with the goal of improving time to triage and appropriate treatment. However, there has been little direct evidence that regionalization will improve outcomes or that it will be financially sustainable for all hospitals.[25]

Proponents of regionalization of AMI care argue that avoiding admissions to non-PCI hospitals will increase the likelihood of receiving primary PCI over fibrinolysis and will improve door-to-balloon time.[25] While patients who present to non-PCI hospitals may be treated with fibrinolysis immediately, shortening time to treatment, some studies have shown that primary PCI is associated with improved outcomes compared with fibrinolytic therapy in patients with STEMI, even when treatment is delayed due to inter-hospital transfer.[26] For example, in their meta-analysis of 6 large clinical trials, Dalby et al. found a 42% reduction in the combined outcomes of death, reinfarction, and stroke within 30 days in patients with STEMI who were transferred for primary PCI compared with those who received on-site thrombolysis at non-PCI hospitals, despite delays of approximately 70-100 minutes. In Minnesota, a regionalized system was established in which 30 community hospitals referred patients with STEMI to a central PCI hospital.[27] Through this system, patients located up to 210 miles from the PCI hospital achieved median door-to-balloon times of 120 minutes and although this time did not meet the goal of 90 minutes, in-hospital mortality was only 4.2%.

Delay in time to treatment is one of many barriers to regionalization. Researchers have also argued that low risk patients may not benefit from primary PCI compared with fibrinolytic therapy,[28] and that transferring these patients to a PCI hospital negates any incremental benefit of treatment with PCI.[29-30] Similarly, hospital PCI volume may not play as large a role as previously anticipated; if all PCIs were to be transferred from low- to high-volume hospitals, 800 transfers would be required to avoid 1 death.[31] Moreover, regionalization would require some concessions in patient autonomy that may hinder community acceptance; patients may not want to be transferred to distant PCI hospitals, where their admission may result in financial burdens for themselves, their families and friends.[25]

The impact of regionalization on cost of care is also a contentious topic. Noteworthy obstacles include loss of revenue and cardiac expertise in non-PCI hospitals, and the potential for increased cost of care as more patients are treated at academic institutions. The potential loss of revenue for non-PCI hospitals is substantial, as patients with STEMI often require additional post-hospitalization services, including noninvasive imaging and subsequent catheterization.[32] Pottenger et al. note that the conversion to a regionalized system is likely to impact Medicare disproportionately, as the majority of patients with STEMI are elderly.[25] Additionally, systems such as pay-for-performance will need to be revised to account for quality measures such as transfer times and to address provision of care by multiple providers for each patient. For example, Pottenger et al. question whether referring non-PCI hospitals would receive a percentage of the payment for each patient transferred to the regional PCI hospital, and whether such payments would be sufficient to compensate for the loss of revenue from previously performed procedures.

While the issue of cost is multifaceted, this thesis contributes to the discussion by focusing on payment for the care of patients with AMI from the perspective of Medicare. This contribution is substantial, as Medicare is responsible for a large proportion of hospitalizations for patients with AMI. For example, in 2010, Medicare paid for approximately 40% of all-cause hospitalizations nationally, and nearly 90% of hospitalizations for patients 65 years or older.[33] Finally, though the debate on regionalization has centered on care for patients with STEMI, the proposed system will likely impact patients with NSTEMI if implemented, so it is important to consider patterns of care for these patients.

Conceptual Model

This work is predicated on the following rationale: Admission to PCI hospitals may be associated with higher costs for patients with AMI due to higher rates of inpatient procedures compared with non-PCI hospitals.[6-10] Alternatively, non-PCI hospitals may be associated with higher costs for patients with AMI for several reasons. For example, admissions to non-PCI hospitals that require transfer to PCI hospitals for urgent procedures result in 2 payments from health insurers, 1 for each admission. Additionally, patients discharged from non-PCI hospitals without transfer for PCI may later undergo PCI during subsequent admissions or in the outpatient setting. In fact, the costs associated with transfers and deferred procedures for patients admitted to non-PCI hospitals may balance the cost associated with higher procedure rates at PCI hospitals.

Research Objective

In light of the conceptual model described above, we sought to characterize the cost of care provided by PCI versus non-PCI hospitals for Medicare patients presenting with AMI. We compared payments made at the hospital-level for Medicare patients over a 30-day episode of care to account for the costs of both hospitalizations in the case of a transfer and the costs of follow-up care, including non-acute procedures. In an effort to better understand the reasons underlying hospital-level costs of care, we also conducted secondary patient-level analyses examining rates of patient transfer and coronary revascularization, including both PCI and CABG surgery, for patients presenting to PCI and non-PCI hospitals.

STATEMENT OF PURPOSE, HYPOTHESIS AND SPECIFIC AIMS

Statement of Purpose

The purpose of this study is to compare payments made at the hospital-level for Medicare patients over a 30-day episode of care between PCI hospitals and non-PCI hospitals in order to better understand the cost implications of patterns of care for patients with AMI.

Hypothesis

Greater utilization of PCI at PCI hospitals compared with non-PCI hospitals and increased rates of transfer and post-acute care procedures at non-PCI hospitals compared with PCI hospitals results in similar payments to PCI and non-PCI hospitals for the care of Medicare patients with AMI.

Specific Aims

- To calculate and compare hospital-level risk-standardized payments for Medicare patients with AMI over a 30-day episode of care between PCI and non-PCI hospitals;
- To calculate and compare index admission procedure rates (PCI and CABG), transfer rates, and 30-day subsequent revascularization rates for Medicare patients with AMI between PCI and non-PCI hospitals.

METHODS

Data Sources

To identify our cohort, we used a 2008 Chronic Condition Warehouse (CCW) dataset of Medicare administrative claims to identify 100% of fee-for-service (FFS) beneficiaries 65 years or older who had an inpatient admission with a principal discharge diagnosis of AMI as identified using International Classification of Diseases, 9th revision (ICD-9) codes 410.xx, excluding those with 410.x2. The CCW data included claims data from the 7 Standard Analytic Files (inpatient, outpatient, skilled nursing facility, home health, hospice, carrier [physician/supplier Part B items], and durable medical equipment). We used this data in conjunction with publicly available fee schedules from CMS and Final Rules published in the Federal Register to calculate the total payment for the episode of care, including payments for the index admission and post-discharge payments for readmissions, other post-discharge inpatient care, outpatient services, skilled nursing facilities, home health, physician, clinical laboratory, or ambulance services, and prosthetics, orthotics, and other medical supplies. We used January 2009 CCW data to calculate post-acute care payments for patients discharged from their index admission in December 2008. We obtained institutional review board approval including waiver of the requirement for participant informed consent, through the Yale University Human Investigation Committee.

Cohort

The study cohort included Medicare FFS beneficiaries, ages ≥ 65 years, hospitalized between January 1 – December 31, 2008, with a principal discharge diagnosis of AMI as defined above. We required that all patients had both Part A and Part B coverage in both the year prior to the index admission and during the 30-day episode of care payment window. We excluded the following groups of patients: (1) patients who were admitted and discharged on the same or next day and did not die or get transferred, as these patients likely did not suffer a clinically significant AMI, (2) patients with inconsistent or unknown vital status (e.g. if the date of death preceded the date of admission), (3) patients with unreliable data (e.g. if the age was greater than 115 or the gender was discordant on the index admission claim and the denominator file), (4) patients discharged against medical advice, as hospitals had limited opportunity to provide appropriate care, (5) hospice patients, (6) patients transferred to federal hospitals, as we did not have claims data for these hospitals, so including these patients would underestimate payments, and (7) patients with missing Medicare-Severity Diagnosis Related Group (MS-DRG) code or MS-DRG weight, as we could not calculate an index admission payment for these patients.

For patients with multiple hospitalizations for AMI during this time frame, we randomly selected 1 hospitalization per patient. We chose this method because payments for repeat AMI admissions may differ from payments for patients with a first AMI, due to differences in management. Choosing only first AMI admissions could overestimate payments, while choosing only repeat admissions could underestimate payments.

Hospital Classification

We classified hospitals as PCI- or non-PCI-capable based on evidence that they performed PCIs in the year prior to the index admission. Using billing, we defined PCI hospitals as those hospitals that had billed Medicare for 10 or more PCI procedures in 2007, using ICD-9 procedure codes 36.01, 36.02, 36.05, 36.06, 36.07, 00.66 and 17.55 for PCI. Hospitals for which PCI status could not be determined (e.g. those with new hospital IDs in 2008) were excluded from the analysis (n=13 hospitals).

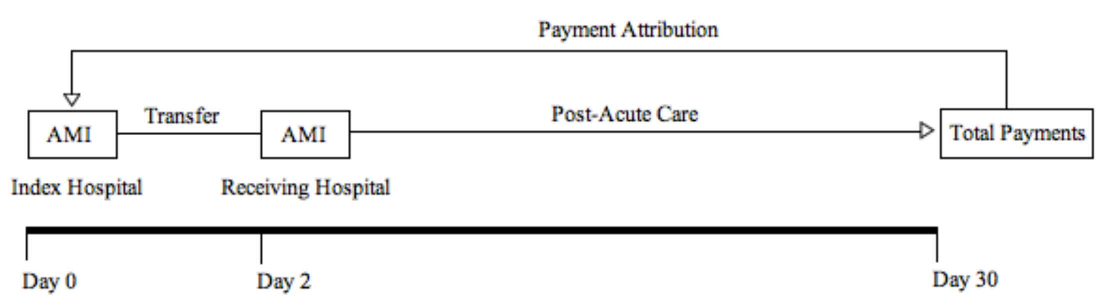
Primary Outcome

Our primary outcome was 30-day episode of care risk-standardized payments (RSPs) at the hospital level. We calculated total payment for the 30-day episode of care by summing all payments from the time of index admission through 30 days post-admission. For patients who were transferred, we considered the consecutive admissions as a single hospitalization with the 30-day episode beginning with the index admission. All payments for Medicare patients incurred during the second admission as well as during the full 30-day episode were attributed to the initial admitting hospital, constituting 1 episode of care (Figure 1).

We chose to include payments for an episode of care window rather than the acute hospitalization alone for several reasons. Hospitalizations occur due to new illnesses or exacerbation of pre-existing illnesses that require follow-up care after discharge. Care decisions made during the hospitalization likely affect care requirements when patients leave the hospital. It follows that payments for care provided soon after hospital discharge in part reflect variation in patient management during admission, and may be attributed to the index hospital as part of a continuous episode of care. We chose 30 days because it is a preset window that is consistent with publicly reported outcomes measures from CMS, such as AMI RSMR and risk-standardized readmission rates (RSRR).

We used publicly available fee schedules from CMS to calculate payments for claims that occurred in care settings reimbursed under a fee schedule. Reimbursement rates and weights for each care setting were from fiscal year, rate year, or calendar year 2008 or 2009 depending on the care setting, and were identified in either Final Rules published in the Federal Register or fee schedules listed on the CMS website. For those care settings not reimbursed using a CMS fee schedule, we obtained the data necessary to calculate payments from applicable CMS Final Rules or via the CMS website (e.g. base payments and conversion factors, MS-DRG weights, wage indexes, and average length of stay). We also used the Medicare Enrollment Database (EDB) to obtain information on enrollment, date of birth, and post-discharge mortality status.

Figure 1. Episode of care for transferred patient.



AMI denotes acute myocardial infarction.

Standardizing Payments

Medicare reimburses providers using several different mechanisms depending on the care setting. For acute inpatient stays, the Inpatient Prospective Payment System (IPPS) payments for each patient begin with an operating and capital base payment, which are held constant over a given fiscal year and reflect the cost of delivering care to a patient for an average Medicare hospitalization. Where applicable, these base payments are then adjusted for geographic differences in wages and cost of living. Geographically adjusted payments are then multiplied by the weight associated with a patient's MS-DRG. The MS-DRG accounts for the patient's principle discharge diagnosis, up to 8 secondary diagnoses, up to 6 procedures performed during the hospitalization, complications, age, gender, and comorbidities. Diagnoses that involve greater resource utilization are assigned higher MS-DRG weights. For hospitals that qualify, additional adjustments are made for the cost of teaching medical trainees (indirect medical education) and caring for low-income patients (disproportionate share policy payments). Where applicable, adjustments are made for short-stay patients and patient discharge destination. In the case of extraordinarily costly patients, an outlier payment may also be applied.

Medicare reduces payments when patients are transferred to another IPPS hospital and have a length of stay at least one day less than the geometric mean length of stay for the MS-DRG. Therefore, for transferred patients, the index hospital is paid a per diem rate. However, for stays at the index hospital that are equal to or longer than the geometric mean length of stay for the MS-DRG, the index hospital receives a full MS-DRG payment. For transferred patients, we assigned the per diem or full MS-DRG payment to the index hospital and added it to the payment for the receiving hospital to generate the full payment for the index admission.

For each care setting, we standardized payments by calculating a payment that removes the influence of Medicare geographic and policy adjustments in order to isolate the portion of payment that reflects care decisions. To calculate standardized payments for acute inpatient stays, we multiplied the operating and capital base payment rates by the MS-DRG weight for each claim. We then accounted for transferred patients as described above. Finally, we added any applicable outlier payments to arrive at our total standardized inpatient payment. Payment diagrams for each of the care setting and our approach to standardizing payments where applicable are shown in Supplementary Figures 1-17.

When the data did not allow for the removal of geographic adjustments, we used the CMS fee schedule data to calculate an average payment and uniformly applied it across all geographic areas. For example, for laboratory services, where Medicare reimburses each state at different amounts, we averaged the payment for an item across all states and replaced the state-specific payment amount for that item in a patient's claim with the average payment.

We then arrived at a total payment for each episode of care by summing our standardized payments for all applicable care settings during a patient's 30-day episode of care. We included payments that began during a patient's 30-day episode of care but ended after by applying a prorated amount (Supplementary Table 1). For example, if a patient were admitted to a skilled nursing facility on day 25 of the episode of care window and remained in the facility until day 40, we calculated the payment for the entire 16-day period and then divided it by 16 to obtain a daily payment amount. We then multiplied that amount by the number of days the patient was in the care setting during the 30-day episode of care payment window (6 in the example above).

Calculating RSPs

We calculated the RSP for each hospital using 2-level hierarchical generalized linear models that adjust for patient demographics, such as age and clinical characteristics, including comorbid conditions identified in claims for acute inpatient hospital stays, hospital outpatient care, and physician, radiology, and laboratory services for the 12 months prior to the index admission as well as select conditions indicated by secondary diagnoses codes on index admission. Hospital level random intercepts were included to account for the clustering, or nonindependence, of patients within hospitals, and to capture hospital-level signal.

We used CMS Condition Category groups (CCs) to define the comorbid risk-adjustment variables. Candidate risk-adjustment variables were selected for the model based on clinical coherence and strength of association in the same manner as for the CMS AMI mortality measure.[34] We then selected final risk-adjustment variables by bootstrapping multiple stepwise regressions and included those variables that came into the model over 90% of the time. We did not risk-adjust for diagnoses that may be complications of care during the index admission because although complications may contribute to higher costs and payments, they represent potential differences in payment that are influenced by hospital actions and such differences should be captured by the payment measurement. Additionally, we risk-adjusted for the patients' age and a history of PCI and/or CABG.

We used the following strategy to calculate the hospital-specific RSPs. We calculated these payments as the ratio of predicted AMI payment to expected AMI payment, and multiplied by the national unadjusted average AMI payment. The predicted AMI payment for each hospital was estimated using its patient mix and an estimated hospital-specific intercept. The expected AMI payment for each hospital was estimated given the same patient mix but the average intercept among all hospitals in the sample.

Secondary Outcomes

We calculated rates of PCI and CABG, transfer rates, and rates of revascularizations that followed the inpatient admission (subsequent revascularizations), including PCI and CABG performed during readmissions and PCI performed in the outpatient setting within 30 days of admission for patients who began their episode of care at PCI and non-PCI hospitals. We defined transferred patients as those patients who were either transferred between hospitals or discharged from 1 acute-care hospital and admitted to a different acute-care hospital on the same or next day, regardless of the discharge disposition listed on the claim. We identified patients who underwent PCI either during index admission or readmission within the 30-day episode of care using ICD-9 codes 36.01, 36.02, 36.05, 36.06, 36.07, 00.66 and 17.55, CABG using ICD-9 codes 36.1x, and outpatient PCI using Current Procedural Terminology (CPT) codes 92973, 92980, 92981, 92982, 92984, 92995 and 92996.

Statistical Analysis

We performed a hospital-level analysis comparing the mean RSP for PCI hospitals with the mean RSP for non-PCI hospitals. We then performed the following patient-level analyses. We first calculated and compared procedure (PCI and CABG) and transfer rates for patients at PCI and non-PCI hospitals. Additionally, we calculated and compared the rate of subsequent revascularizations that occurred after the index discharge but during the 30-day episode of care for patients admitted to PCI versus non-PCI hospitals. Procedures for patients who were readmitted within the 30-day episode of care but whose admissions extended beyond the end of the 30-day window were included in the subsequent revascularization outcome. A t-test was used to compare RSPs and χ^2 tests were used for dichotomous variables. We did not pre-specify a threshold to define clinically significant differences in RSP. We considered differences statistically significant when P values were less than 0.05. All analyses were conducted using Stata/IC statistical software, version 11.1.

Authorship Contributions

Ms. Gal Ben-Josef conceived of and designed this project along with Dr. Susannah M. Bernheim, with guidance from Dr. Harlan M. Krumholz. Ms. Ben-Josef conducted an extensive review of the literature and was responsible for running preliminary analyses, including distribution of RSPs by hospital PCI capability and secondary patient-level analyses including PCI and CABG rates, transfer rates, and subsequent revascularization rates. Mr. Changqin Wang also conducted preliminary statistical analyses, and Ms. Lesli S. Ott conducted the final analyses and generated the final data. Ms. Ben-Josef was responsible for interpreting the data and formulating implications along with Drs. Susannah M. Bernheim, Joseph S. Ross, and Harlan M. Krumholz. All authors participated in discussions on the integrity of the data and implications and reviewed the manuscript upon which this thesis is based.

RESULTS

Patient Characteristics

Of the 180,375 AMI hospitalizations in 2008 included in this study, 137,427 (76.2%) were admissions to 1,415 PCI hospitals and 42,948 (23.8%) to 2,716 non-PCI hospitals. Baseline characteristics for patients initially admitted to PCI hospitals versus non-PCI hospitals are shown in Table 1. Of note, patients presenting to PCI hospitals were younger than those presenting to non-PCI hospitals, with patients age 85 or older composing only 26.3% of patients admitted to PCI hospitals as compared to 40.6% of those admitted to non-PCI hospitals. A greater percentage of patients presenting to PCI hospitals had previously undergone PCI as compared with those presenting to non-PCI hospitals (8.4% v. 5.3%, respectively), but a smaller percentage of patients admitted to PCI hospitals had previously undergone CABG (5.7% v. 7.1%, respectively). In addition, 28.6% of patients presenting to PCI hospitals had a history of congestive heart failure compared with 39.9% at non-PCI hospitals, and only 15.2% of patients presenting to PCI hospitals had a history of dementia as compared with 24.7% at non-PCI hospitals.

RSPs and Secondary Analyses

PCI hospitals had a higher mean 30-day RSP than non-PCI hospitals (PCI $20,340; non-PCI $19,713; P<0.001). The range of RSP was similar between PCI and non-PCI hospitals (PCI $15,251-$27,317; non-PCI $16,769-$24,597) (Figure 2).

To better understand the factors contributing to this difference in hospital-level payments, we identified the following patient-level patterns of care, shown in Table 2. Patients presenting to PCI hospitals had lower transfer rates (2.2% v. 25.4%, P<0.001) than those presenting to non-PCI hospitals. Patients presenting to PCI hospitals had higher PCI rates (39.2% v. 13.2%, P<0.001) and higher CABG rates (9.5% v 4.4%, P<0.001) during the index admission than those presenting to non-PCI hospitals. Finally, the rate of subsequent revascularization within 30 days of the initial hospitalization was lower among patients who initially presented to PCI hospitals than to non-PCI hospitals (0.15% v. 0.27%, P<0.0001). However, these results represent subsequent revascularization rates for all patients, including those who were not eligible for post-acute care. The relationship persisted when data were limited to only those patients who were eligible for post-acute care, with a rate of subsequent revascularization of 0.17% among patients presenting to PCI hospitals compared with 0.31% among patients presenting to non-PCI hospitals (P<0.001).

Table 1. Baseline patient characteristics of patients with AMI in 2008, stratified by initial admission to PCI or non-PCI hospitals.

	Overall (N=180,375)		PCI (N=137,427)		Non-PCI (N=42,948)	
Variable	N	(%)	N	(%)	N	(%)
Age (65-74)	56,102	31.1	46,640	33.9	9,462	22.0
Age (75-84)	70,769	39.2	54,709	39.8	16,060	37.4
Age (≥ 85)	53,504	29.7	36,078	26.3	17,426	40.6
History of PCI	13,858	7.7	11,583	8.4	2,275	5.3
History of CABG	10,824	6.0	7,772	5.7	3,052	7.1
Congestive Heart Failure (CC 80)	56,486	31.3	39,369	28.6	17,117	39.9
Angina Pectoris/Old Myocardial Infarction (CC 83)	38,210	21.2	28,787	20.9	9,423	21.9
Heart Infection/Inflammation, Except Rheumatic (CC 85)	3,242	1.8	2,666	1.9	576	1.3
Valvular and Rheumatic Heart Disease (CC 86)	49,155	27.3	36,876	26.8	12,279	28.6
Congenital Cardiac/Circulatory Defect (CC 87-88)	1,700	0.9	1,367	1.0	333	0.8
Hypertension and Hypertension Complications (CC 89-91)	151,080	83.8	114,356	83.2	36,724	85.5
Metastatic Cancer/Acute Leukemia and Other Major Cancers (CC 7-8)	7,183	4.0	5,306	3.9	1,877	4.4

Table 1. (continued)

Diabetes and Diabetes Complications (CC 15-19, 119-120)	75,502	41.9	56,564	41.2	18,938	44.1
Protein-Calorie Malnutrition (CC 21)	8,974	5.0	6,462	4.7	2,512	5.8
Other Significant Endocrine and Metabolic Disorders (CC 22)	11,246	6.2	8,696	6.3	2,550	5.9
Obesity/Disorders of Thyroid, Cholesterol, Lipids (CC 24)	130,381	72.3	100,660	73.2	29,721	69.2
Other Gastrointestinal Disorders (CC 36)	81,382	45.1	60,561	44.1	20,821	48.5
Osteoporosis and Other Bone/Cartilage Disorders (CC 41)	26,437	14.7	19,359	14.1	7,078	16.5
Iron Deficiency and Other/Unspecified Anemias and Blood Disease (CC 47)	69,629	38.6	50,973	37.1	18,656	43.4
Delirium and Encephalopathy (CC 48)	6,733	3.7	4,815	3.5	1,918	4.5
Dementia (CC 49)	31,545	17.5	20,932	15.2	10,613	24.7
Drug/Alcohol Psychosis (CC 51)	2,104	1.2	1,624	1.2	480	1.1
Drug/Alcohol Abuse/Dependence (CC 52-53)	17,830	9.9	14,314	10.4	3,516	8.2
Severe Mental Illness (CC 54-55)	7,958	4.4	5,625	4.1	2,333	5.4

Table 1. (continued)

Reactive and Unspecified Psychosis (CC 56)	5,505	3.1	3,566	2.6	1,939	4.5
Depression/Anxiety (CC 58-59)	19,060	10.6	13,330	9.7	5,730	13.3
Precerebral Arterial Occlusion and Transient Cerebral Ischemia (CC 97)	27,561	15.3	20,703	15.1	6,858	16.0
Vascular Disease and Complications (CC 104-105)	45,323	25.1	33,423	24.3	11,900	27.7
Other Lung Disorders (CC 115)	48,611	27.0	36,612	26.6	11,999	27.9
Legally Blind (CC 116)	1,351	0.8	929	0.7	422	1.0
Dialysis Status (CC 130)	4,035	2.2	3,199	2.3	836	1.9
Internal Injuries (CC 160)	1,672	0.9	1,279	0.9	393	0.9

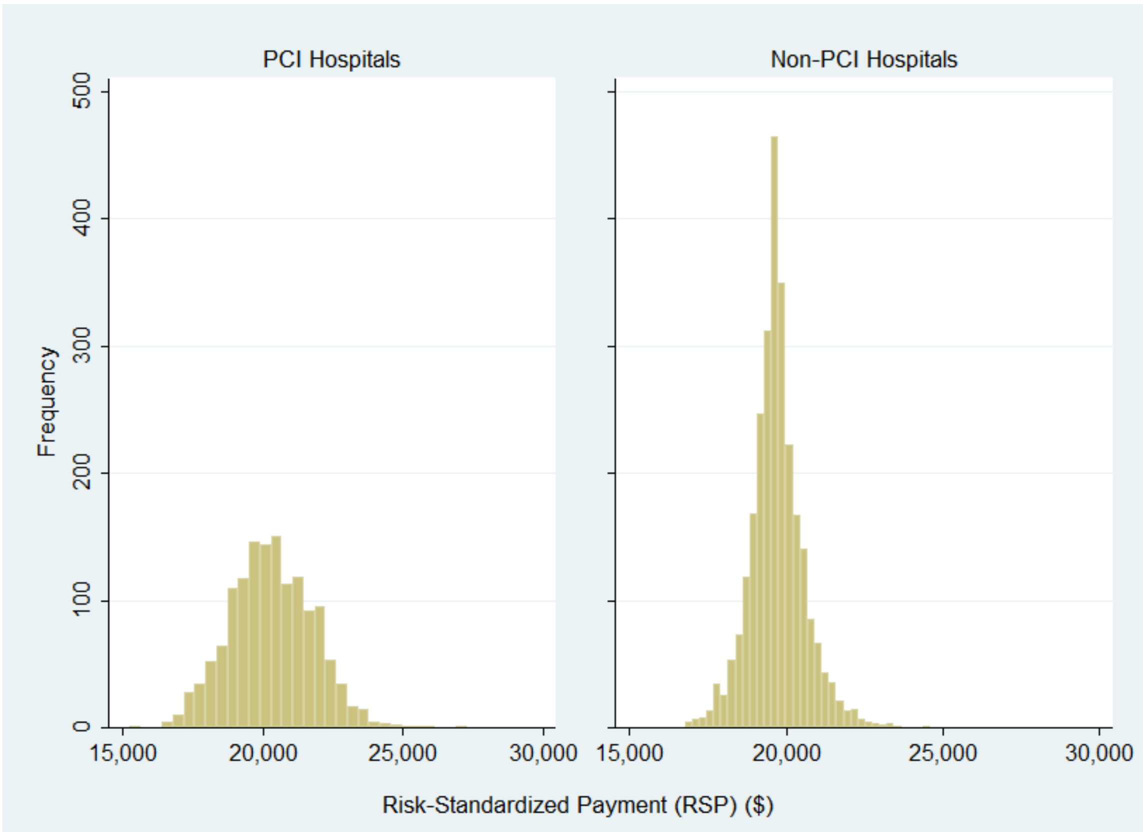
AMI denotes acute myocardial infarction; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; CC, condition category.

Table 2. Patient transfer rates, procedure rates, subsequent revascularization rates, and 30-day risk-standardized payment by PCI capability of the index hospital.

	Overall	PCI	Non-PCI
Hospital (N)	4,131	1,415	2,716
Volume (n)	180,375	137,427	42,948
Transfer Rate (%)	7.7	2.2	25.4
Index Admission PCI Rate (%)	33.0	39.2	13.2
Index Admission CABG Rate (%)	8.3	9.5	4.4
Subsequent Revascularizations (%)	0.18%	0.15%	0.27%
30-Day Risk-Standardized Payment ($): Mean (Standard Deviation)	19,928 (1,161)	20,340 (1,493)	19,713 (869)

PCI denotes percutaneous coronary intervention; CABG, coronary artery bypass graft.

Figure 2. Distributions of 30-day risk-standardized payment by PCI capability of the index hospital.



PCI denotes percutaneous coronary intervention.

DISCUSSION

In this study of Medicare administrative claims, we found that PCI hospitals were associated with slightly higher payments for an episode of care for patients with AMI when compared with non-PCI hospitals. While the difference is fairly modest – approximately $600 over a 30-day period – when spread over the hundreds of thousands of beneficiaries with AMI each year, the cost implications are important. It is critical to determine whether this extra cost provides extra value, either through improved clinical outcomes such as mortality or readmission, or improved patient satisfaction, function, or symptom burden.

There are a number of potential explanations for the difference in payments for AMI episodes initiated at PCI versus non-PCI hospitals. To understand factors that may account for the observed payment difference, we examined several patient-level patterns of care for patients admitted to PCI versus non-PCI hospitals. We found that patients who began their episode of care at PCI hospitals had higher PCI and CABG rates during the index admission than those initially admitted to non-PCI hospitals. Procedure rates may contribute considerably to higher payments. However, patients initially admitted to non-PCI hospitals had substantially higher transfer rates and subsequent revascularization rates than patients initially admitted to PCI hospitals. Patients who are transferred accrue the cost of 2 hospitalizations, which may in part balance the cost of higher procedure rates at PCI hospitals. Similarly, the increased utilization of post-acute care resources by patients admitted to non-PCI hospitals adds to the payment for the 30-day episode of care initiated at non-PCI hospitals.

The results of this study are consistent with the earlier study by Krumholz et al., discussed above, in which long term costs and outcomes were examined for patients admitted to Connecticut hospitals with or without on-site cardiac catheterization facilities.[8] The authors found no significant difference in hospital costs in the 3 years after the initial admission for patients admitted to hospitals with and without cardiac catheterization capability. Despite similar findings, the study variables differed substantially from those used in this study. This previous work was done for patients admitted between 1992-1993 in a single state, and costs were defined by each patient's hospital charge record and each hospital's Medicare cost-to-charge ratios. Conversely, our study evaluated the hospital-level payment made for Medicare patients admitted nationwide, and in the setting of growing numbers of PCI facilities in 2008.

Implications

Our finding that the cost of care at PCI and non-PCI hospitals is only modestly different impacts recent discussions on regionalization of AMI care and the establishment of new PCI programs. Many studies have considered whether regionalization of care would benefit patients with AMI, but few, if any, have considered the cost implications of such a change in patient management. If AMI care were to be regionalized, patients with AMI who present to non-PCI hospitals would be immediately transferred to specialty regional centers with the capacity to perform PCI, without admission to non-PCI hospitals. Our findings suggest that sending all patients directly to PCI hospitals is not likely to substantially increase payment for Medicare patients admitted with AMI, despite the possibility of increased PCI utilization. Since patients who present with AMI may benefit from more rapid access to PCI, and in light of our findings that payments to PCI versus non-PCI hospitals do not differ dramatically, regionalization of AMI care may provide a more efficient option for the treatment of these patients.

While this work demonstrates that transporting patients directly to PCI hospitals may be economically feasible, our findings suggest that opening new PCI programs in the absence of an organized system for regionalization of care is not a cost-effective strategy for AMI care. As discussed above, access to PCI has not changed in recent years, despite increased availability of PCI hospitals.[1-4] This is in part explained by evidence that the majority of hospitals establishing new PCI programs are those near hospitals that already offer the same services.[2,3] Moreover, increased availability of PCI has allowed for increased use of PCI for non-acute indications, resulting in unnecessary procedures that may put patients at undue risk.[12] Hospitals struggling to keep up with the cost of new PCI facilities may have an incentive to encourage PCI use. New PCI facilities have likely resulted in a distribution of patients over increasing numbers of hospitals, lowering the volume of PCI performed at each hospital and potentially impacting patient outcomes, as higher volume of PCI has been associated with improved survival.[15-17] Finally, growth in the number of PCI hospitals has not led to improvements in time to treatment for AMI.[3] This fund of knowledge suggests that increasing the absolute number of PCI hospitals has not resulted in improved care for patients with AMI.

Despite these findings, the evidence on mortality and readmission rates at PCI and non-PCI hospitals remains less clear. Recent studies have shown that although mortality is lower on average for patients who present to PCI hospitals, there exists significant variation in mortality rates among PCI hospitals across the country.[10] Geospatial modeling has demonstrated a mortality advantage both for high-benefit patients who were transported directly to PCI hospitals and for those transferred from the ED to PCI hospitals, compared with patients who were transported to the nearest hospital and treated with PCI or thrombolytics, depending on availability.[35] Though this targeted PCI strategy increased PCI use by 1.5 times compared to the closest hospital strategy and led to a 700% increase in patient volume at PCI hospitals, a strategy of universal PCI that directed all patients to PCI hospitals resulted in the same mortality rate but increased PCI use by 3 times and volume by over 1000%. These findings suggest that a regionalization strategy that relies on EMS and ED services to triage patients may improve mortality rates for patients with AMI while mitigating the economic impact on non-PCI hospitals due to loss of patient volume.

In light of these data, our finding that PCI hospitals are modestly more costly to Medicare than non-PCI hospitals suggests that investing in new PCI facilities may not be worthwhile. Although the difference in cost is fairly small, building new PCI facilities also requires a sizeable fixed cost that adds to the financial burden of PCI hospitals.[3] As the evidence discussed above suggests that greater numbers of PCI facilities have not benefited patients, the extra cost of both construction and patient care yields limited value. Importantly, modeling techniques have shown that a system that utilizes EMS to transfer patients directly to existing PCI hospitals is of better value than constructing new PCI facilities.[23] Such a system would still allow patients to benefit from the potential mortality advantage of PCI hospitals while avoiding the shortcomings of investing in new PCI facilities.

Limitations

This study has several limitations. First, this work examined payments made at the hospital-level for Medicare patients over a 30-day episode of care. We did not evaluate cost of care from the perspective of patients or hospitals through hospital charges or cost-to-charge ratios. Therefore, we cannot comment on the differences in cost of care between PCI and non-PCI hospitals from these perspectives. Second, we used Medicare admission data only, and results may not be applicable to the general population or other insurers given different payment structures. However, Medicare is the country's largest insurer and Medicare patients make up a large proportion of patients with AMI. Third, we did not assess whether the modestly higher payment to PCI hospitals contributes to better outcomes for patients, including decreasing mortality and readmissions. The effect of admission to PCI versus non-PCI hospitals on patient mortality and readmission requires further investigation.

Our analysis of transfers included only those patients who were admitted to the initial presenting hospital and transferred to a second hospital; we were unable to determine whether patients presented to the ED of 1 hospital before being transferred and admitted to a second hospital. Our payment outcome did not account for the cost of the ambulance for patients who were transported to the hospital or the cost of ambulance transfer between hospitals during the index admission. Similarly, we did not include payments for Medicare Part D drugs. Since patients who do not undergo PCI may rely more heavily on medical management than those who undergo the procedure, excluding these payments may lower the average payment for non-PCI hospitals, thus exaggerating the overall difference in payments between PCI and non-PCI hospitals. However, given a payment window of only 30 days, the added cost of medications is likely not substantial. Finally, our method of identifying patients who underwent PCI did not account for those patients who underwent a procedure greater than 30 days after their initial admission.

Lastly, our study does not address the question of what types of patients were more likely to be transferred from non-PCI hospitals in order to undergo PCI. Therefore, we were not able to appreciate whether high-risk patients who presented to PCI and non-PCI hospitals were treated similarly. It is possible that high-risk patients may be transferred less often due to their unstable condition. Since patients who presented to non-PCI hospitals were generally older than those presenting to PCI hospitals, and therefore at higher risk of complication during transfer, this may contribute in part to the lower procedure rates attributed to non-PCI hospitals.

Conclusion

In conclusion, this study demonstrates that despite increased PCI and CABG rates for patients who begin their 30-day episode of care at PCI hospitals, hospital-level payments to PCI hospitals are only modestly higher than hospital-level payments to non-PCI hospitals for the treatment of AMI patients.

REFERENCES

1. Concannon TW, Nelson J, Goetz J, Griffith JL. A percutaneous coronary intervention lab in every hospital? Circ Cardiovasc Qual Outcomes. 2012;5(1):14-20.
2. Horwitz JR, Nichols A, Nallamothu BK, Sasson C, Iwashyna TJ. Expansion of invasive cardiac services in the United States. Circulation. 2013;128(8):803-810.
3. Concannon TW, Nelson J, Kent DM, Griffith JL. Evidence of Systematic Duplication by New Percutaneous Coronary Intervention Programs. Circ Cardiovasc Qual Outcomes. 2013;6(4):400-408.
4. Epstein AJ, Polsky D, Yang F, Yang L, Groeneveld PW. Coronary revascularization trends in the United States, 2001-2008. JAMA. 2011;305(17):1769-1776.
5. Lucas FL, Siewers A, Goodman DC, Wang D, Wennberg DE. New cardiac surgery programs established from 1993 to 2004 led to little increased access, substantial duplication of services. Health Aff (Millwood). 2011;30(8):1569-1574.
6. Halabi AR, Beck CA, Eisenberg MJ, Richard H, Pilote L. Impact of on-site cardiac catheterization on resource utilization and fatal and non-fatal outcomes after acute myocardial infarction. BMC Health Serv Res. 2006;6:148.
7. Alter DA, Naylor CD, Austin PC, Tu JV. Long-term MI outcomes at hospitals with or without on-site revascularization. JAMA. 2001;285(16):2101-2108.
8. Krumholz HM, Chen J, Murillo JE, Cohen DJ, Radford MJ. Admission to hospitals with on-site cardiac catheterization facilities: impact on long-term costs and outcomes. Circulation. 1998;98(19):2010-2016.
9. Nallamothu BK, Rogers MA, Chernew ME, Krumholz HM, et al. Opening of specialty cardiac hospitals and use of coronary revascularization in medicare beneficiaries. JAMA. 2007;297(9):962-968.
10. Chen J, Krumholz HM, Wang Y, Curtis JP, Rathore SS, et al. Differences in patient survival after acute myocardial infarction by hospital capability of performing percutaneous coronary intervention: implications for regionalization. Arch Intern Med. 2010;170(5):433-439.

11. Patel MR, Dehmer GJ, Hirshfeld JW, Smith PK, Spertus JA, et al. ACCF/SCAI/STS/AATS/AHA/ASNC 2009 Appropriateness Criteria for Coronary Revascularization: a report by the American College of Cardiology Foundation Appropriateness Criteria Task Force, Society for Cardiovascular Angiography and Interventions, Society of Thoracic Surgeons, American Association for Thoracic Surgery, American Heart Association, and the American Society of Nuclear Cardiology Endorsed by the American Society of Echocardiography, the Heart Failure Society of America, and the Society of Cardiovascular Computed Tomography. J Am Coll Cardiol. 2009;53(6):530-553.

12. Chan PS, Patel MR, Klein LW, Krone RJ, Dehmer GJ, et al. Appropriateness of percutaneous coronary intervention. JAMA. 2011;306(1):53-61.

13. Forsyth CJ, Pathak EB, Strom JA. De Facto regionalization of care for ST-elevation myocardial infarction in Florida, 2001-2009. Am Heart J. 2012;164(5):681-688.

14. Levine GN, Bates ER, Blankenship JC, Bailey SR, Bittl JA, et al. 2011 ACCF/AHA/SCAI Guideline for Percutaneous Coronary Intervention. A report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines and the Society for Cardiovascular Angiography and Interventions. J Am Coll Cardiol. 2011;58(24):e44-122.

15. Canto JG, Every NR, Magid DJ, Rogers WJ, Malmgren JA, et al. The volume of primary angioplasty procedures and survival after acute myocardial infarction. National Registry of Myocardial Infarction 2 Investigators. N Engl J Med. 2000;342(21):1573-1580.

16. Post PN, Kuijpers M, Ebels T, Zijlstra F. The relation between volume and outcome of coronary interventions: a systematic review and meta-analysis. Eur Heart J. 2010;31(16):1985-1992.

17. Ross JS, Normand SL, Wang Y, Ko DT, Chen J, et al. Hospital volume and 30-day mortality for three common medical conditions. N Engl J Med. 2010;362(12):1110-1118.

18. Antman EM, Hand M, Armstrong PW, Bates ER, Green LA, et al. 2007 Focused Update of the ACC/AHA 2004 Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines: developed in collaboration With the Canadian Cardiovascular

Society endorsed by the American Academy of Family Physicians: 2007 Writing Group to Review New Evidence and Update the ACC/AHA 2004 Guidelines for the Management of Patients With ST-Elevation Myocardial Infarction, Writing on Behalf of the 2004 Writing Committee. Circulation. 2008;117(2):296-329.

19. Nallamothu BK, Bates ER, Herrin J, Wang Y, Bradley EH, et al. Times to treatment in transfer patients undergoing primary percutaneous coronary intervention in the United States: National Registry of Myocardial Infarction (NRMI)-3/4 analysis. Circulation. 2005;111(6):761-767.

20. Peterson ED, Roe MT, Rumsfeld JS, Shaw RE, Brindis RG, et al. A call to ACTION (acute coronary treatment and intervention outcomes network): a national effort to promote timely clinical feedback and support continuous quality improvement for acute myocardial infarction. Circ Cardiovasc Qual Outcomes. 2009;2(5):491-499.

21. Kim N, Ott LS, Spivack S, Xu X, Volpe M, et al. Hospital-Level, Risk-Standardized Payment Associated with a 30-Day Episode of Care for AMI (Version 1): 2012 Measure Methodology Report: Yale-New Haven Health Services Corporation - Center for Outcomes Research & Evaluation. Prepared for the Centers for Medicare and Medicaid Services, Baltimore, MD: 2012.

22. Every NR, Parsons LS, Fihn SD, Larson EB, Maynard C, et al. Long-term outcome in acute myocardial infarction patients admitted to hospitals with and without on-site cardiac catheterization facilities. MITI Investigators. Myocardial Infarction Triage and Intervention. Circulation. 1997;96(6):1770-1775.

23. Concannon TW, Kent DM, Normand SL, Newhouse JP, Griffith JL, et al. Comparative effectiveness of ST-segment-elevation myocardial infarction regionalization strategies. Circ Cardiovasc Qual Outcomes. 2010;3(5):506-513.

24. Henry TD, Atkins JM, Cunningham MS, Francis GS, Groh WJ, et al. ST-segment elevation myocardial infarction: recommendations on triage of patients to heart attack centers: is it time for a national policy for the treatment of ST-segment elevation myocardial infarction? J Am Coll Cardiol. 2006;47(7):1339-1345.

25. Pottenger BC, Diercks DB, Bhatt DL. Regionalization of care for ST-segment elevation myocardial infarction: is it too soon? Ann Emerg Med. 2008;52(6):677-685.

26. Dalby M, Bouzamondo A, Lechat P, Montalescot G. Transfer for primary angioplasty versus immediate thrombolysis in acute myocardial infarction: a meta-analysis. Circulation. 2003;108(15):1809-1814.

27. Henry TD, Sharkey SW, Burke MN, Chavez IJ, Graham KJ, et al. A regional system to provide timely access to percutaneous coronary intervention for ST-elevation myocardial infarction. Circulation. 2007;116(7):721-728.

28. Thune JJ, Hoefsten DE, Lindholm MG, Mortensen LS, Andersen HR, et al. Simple risk stratification at admission to identify patients with reduced mortality from primary angioplasty. Circulation. 2005;112(13):2017-2021.

29. Nallamothu BK, Bates ER. Percutaneous coronary intervention versus fibrinolytic therapy in acute myocardial infarction: is timing (almost) everything? Am J Cardiol. 2003;92(7):824-826.

30. Rathore SS, Epstein AJ, Nallamothu BK, Krumholz HM. Regionalization of ST-segment elevation acute coronary syndromes care: putting a national policy in proper perspective. J Am Coll Cardiol. 2006;47(7):1346-1349.

31. Epstein AJ, Rathore SS, Krumholz HM, Volpp KG. Volume-based referral for cardiovascular procedures in the United States: a cross-sectional regression analysis. BMC Health Serv Res. 2005;5:42.

32. Nallamothu BK, Taheri PA, Barsan WG, Bates ER. Broken bodies, broken hearts? Limitations of the trauma system as a model for regionalizing care for ST-elevation myocardial infarction in the United States. Am Heart J. 2006;152(4):613-618.

33. National Hospital Discharge Survey. Centers for Disease Control and Prevention. (Accessed 12/20/2013, at http://www.cdc.gov/nchs/nhds.htm).

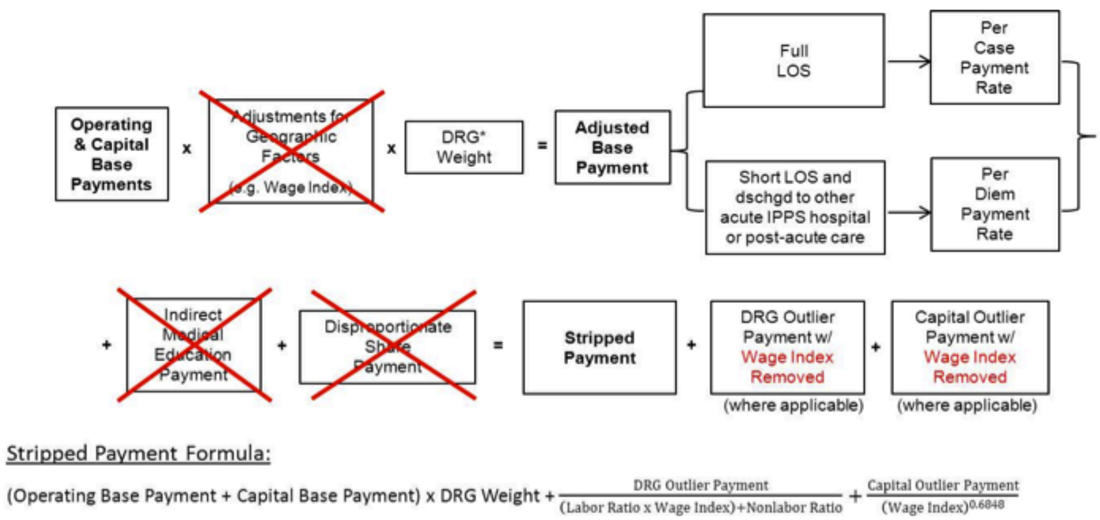
34. Krumholz HM, Wang Y, Mattera JA, Wang Y, Han L, et al. An administrative claims model suitable for profiling hospital performance based on 30-day mortality rates among patients with an acute myocardial infarction. Circulation. 2006;113(13):1683-1692.

35. Concannon TW, Kent DM, Normand SL, Newhouse JP, Griffith JL, et al. A geospatial analysis of emergency transport and inter-hospital transfer in ST-segment elevation myocardial infarction. Am J Cardiol. 2008;101(1):69-74.

SUPPLEMENTARY FIGURES AND TABLES

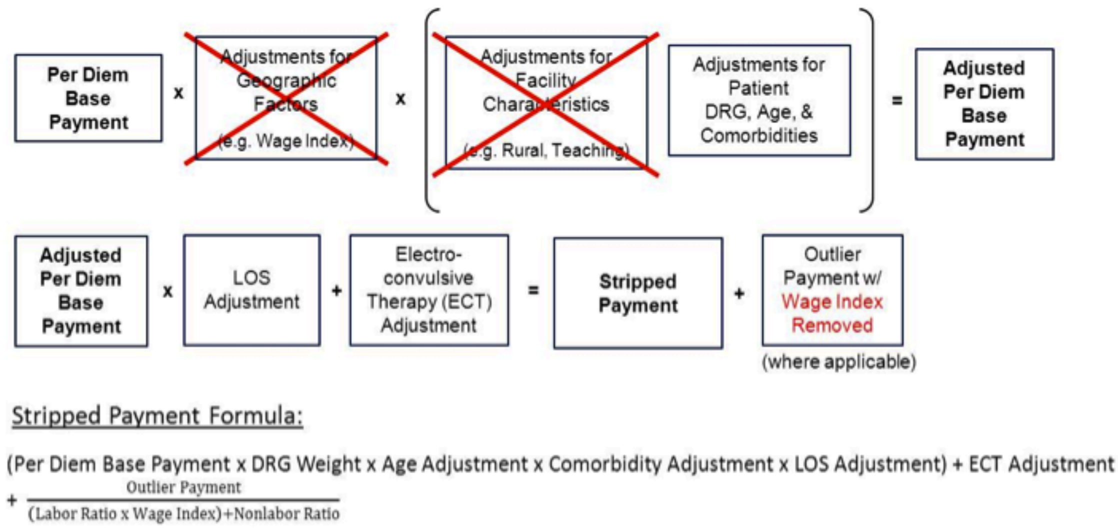
The following payment diagrams are adapted from the 2012 Cost Measure Methodology Report prepared by the Yale-New Haven Hospital Center for Outcomes Research and Evaluation[21] and are initially derived from the MedPAC Payment Basics series, October 2007.

Figure 1. Payment and standardization method for the inpatient setting.



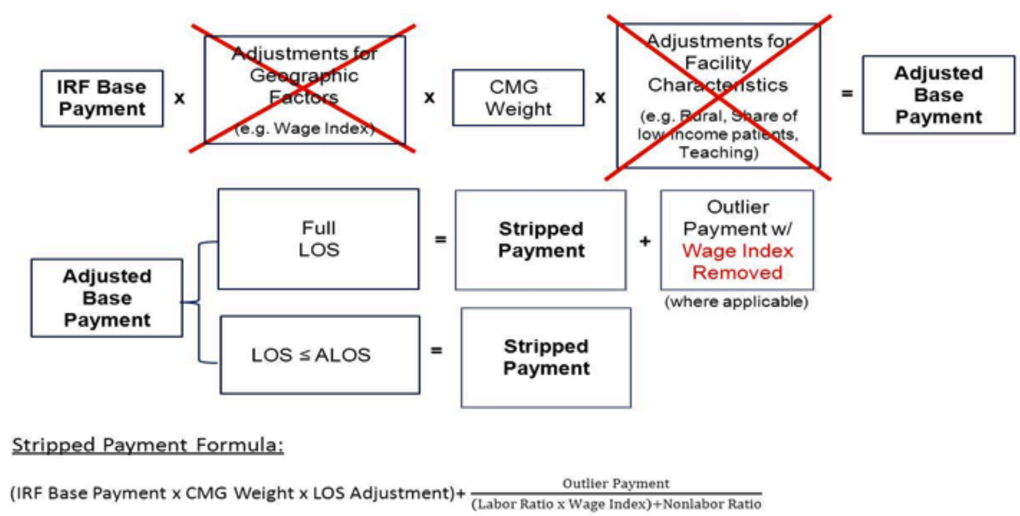
DRG denotes diagnosis related group; LOS, length of stay; IPPS, inpatient prospective payment system.

Figure 2. Payment and standardization method for inpatient psychiatric facilities.



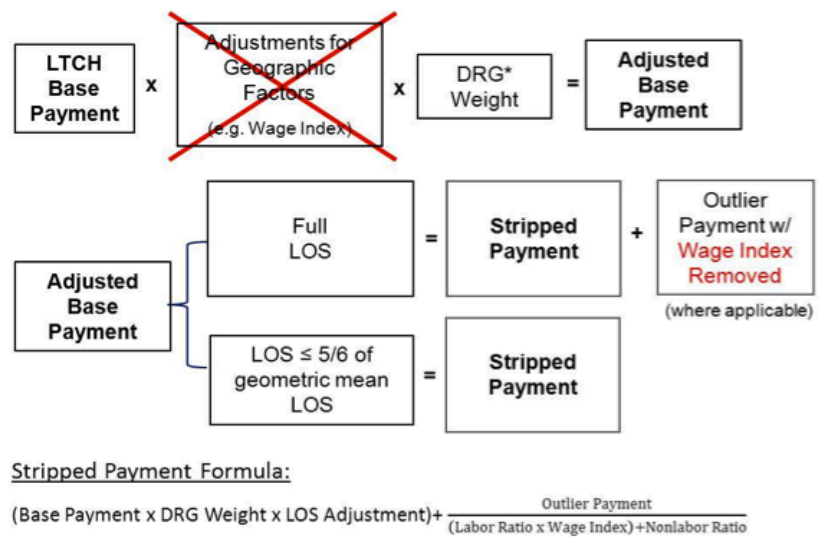
DRG denotes diagnosis related group; LOS, length of stay.

Figure 3. Payment and standardization method for inpatient rehabilitation facilities.



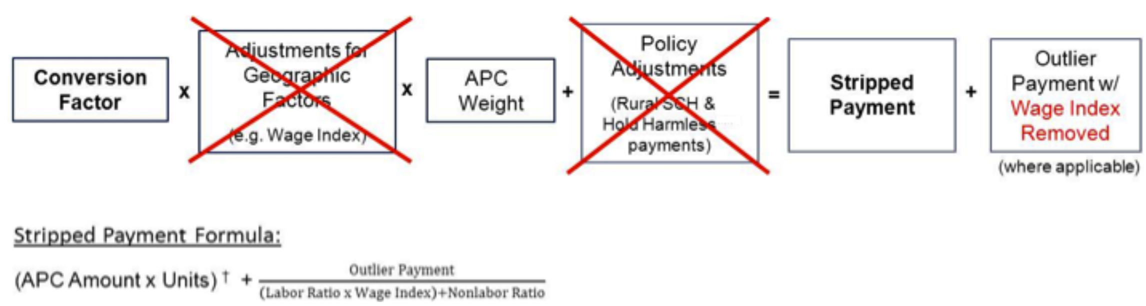
IRF denotes inpatient rehabilitation facilities; CMG, case-mix group; LOS, length of stay; ALOS, average length of stay for CMG.

Figure 4. Payment and standardization method for long term care hospitals.



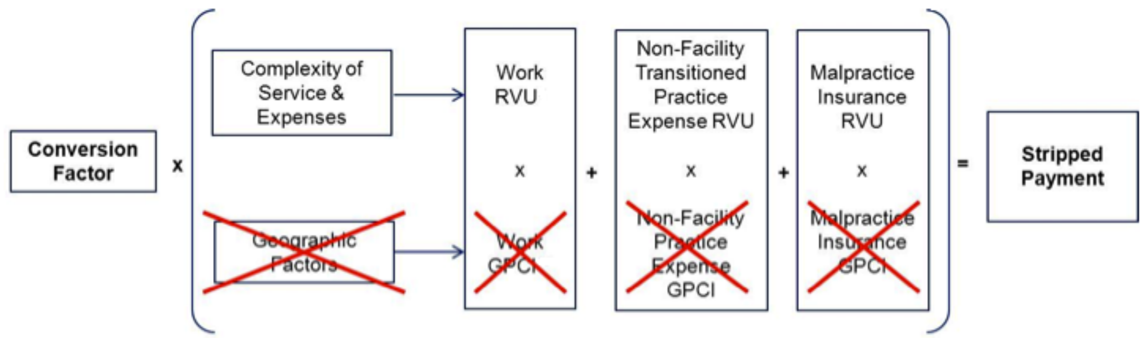
LTCH denotes long term care hospital; DRG, diagnosis related group; LOS, length of stay.

Figure 5. Payment and standardization method for hospital outpatient services and community mental health centers.



APC denotes ambulatory payment classification; SCH, sole community hospital. Note: APC measures resource requirements of services; Hold Harmless payments are additional payments to hospitals (i.e. cancer, children's, non-SCH rural with <100 beds) that experience losses under the outpatient prospective payment system compared to cost-based systems. † This amount is adjusted for any modifiers such as reduced or discontinued procedures.

Figure 6. Payment and standardization method for comprehensive outpatient rehabilitation facilities and outpatient rehabilitation facilities.

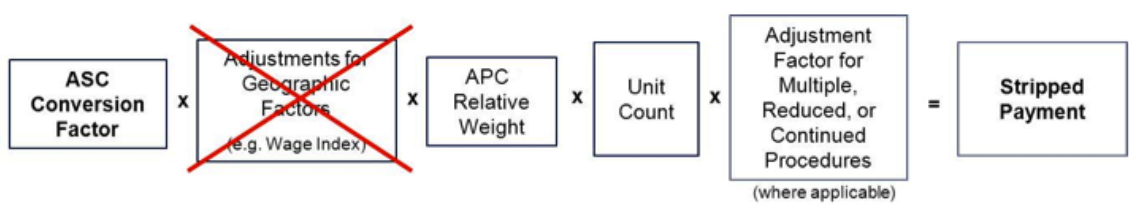


Stripped Payment Formula:

[Conversion Factor x (Work RVU + Non-Facility Transitioned Practice Expense RVU + Malpractice Insurance RVU)] x Units

RVU denotes relative value unit; GPCI, geographic practice cost index. Note: RVUs account for the relative costliness of the inputs used to provide services: clinician's work, practice expenses, and professional liability insurance expenses.

Figure 7. Payment and standardization method for ambulatory surgical centers.



Stripped Payment Formula:

The amount equal to (ASC Conversion Factor x APC Relative Weight) is given on the ASC fee schedule.

(APC Fee Schedule Amount) x Unit Count x Adjustment Factor for Multiple, Reduced, or Continued Procedures

ASC denotes ambulatory surgical center; APC, ambulatory payment classification.

Figure 8. Payment for renal dialysis facilities.

Given that the 2008/2009 Renal Dialysis payment rates are adjusted by patient-specific body measurements which we do not have in our data, as well as capped at an amount equal to 3 dialysis sessions per week, we chose to remove the portion of the payment likely attributable to wages using the RDF wage index.

Stripped Payment Formula:

$$\frac{\text{Actual Payment} + \text{Co} - \text{Insurance} + \text{Deductible}}{(\text{Outpatient Labor Ratio x Wage Index}) + (1 - \text{Outpatient Labor Ratio})}$$

RDF denotes renal dialysis facility. Note: A Renal Dialysis Prospective Payment System was implemented in 2011.

Figure 9. Payment for rural health clinics and federally qualified health clinics.

RHCs:

Each year Congress determines a RHC per visit payment limit. We remove the portion of the payment likely attributable to wages using the SNF state rural wage index.

Stripped Payment Formula:

$$\frac{\text{Actual Payment} + \text{Co} - \text{Insurance} + \text{Deductible}}{(\text{Outpatient Labor Ratio x Wage Index}) + (1 - \text{Outpatient Labor Ratio})}$$

FQHCs:

FQHC payments are an all-inclusive per visit amount based on reasonable costs. Given the resources necessary to determine whether the FQHC is located in a rural or urban area, we did not adjust for wages in the current data.

Standardized Payment Formula:

Actual Payment + Co-insurance

RHC denotes rural health clinic; SNF, skilled nursing facility; FQHC, federally qualified health clinic. Note: A FQHC prospective payment system is scheduled to be implemented in 2014.

Figure 10. Payment for laboratory services.

Avg. Payment from State Clinical Diagnostic Laboratory Fee Schedule x Unit Count = **Standardized Payment**

Standardized Payment Formula:

Avg. Payment from State Clinical Diagnostic Laboratory Fee Schedule x Unit Count

Labs Under the Automated Multi-Channel Chemistry Code (AMCC) Payment Algorithm Standardized Payment Formula:

Actual Payment + Co-insurance + Deductible

Figure 11. Payment for ambulance services.

Avg. of Urban & Rural Mileage / Service Rate for Each State = (Avg. Mileage / Service Rate for Each State → National Avg. of All States' Mileage / Service Rate) x Unit Count = **Standardized Payment**

Standardized Payment Formula:

Step 1:

$$\frac{\text{Urban+Rural Mileage / Service Rates}}{2} = \frac{\text{Average Mileage}}{\text{Service Rate for Each State}}$$

Step 2:

$$\frac{\sum \text{Avg.Mileage / Service Rate for Each State}}{\text{\# of States}} = \frac{\text{National Average Mileage}}{\text{Service Rate}}$$

Step 3:

$$\frac{\text{National Average Mileage}}{\text{Service Rate}} \times \text{Unit Count}$$

Figure 12. Payment for Part B drugs.

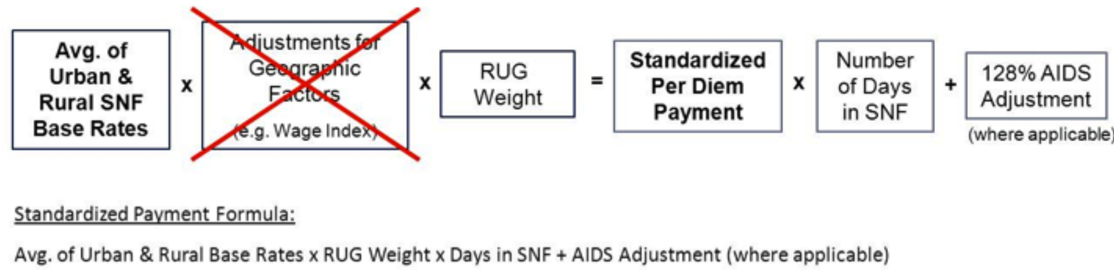
Part B Drugs National Fee Schedule Amount x Unit Count = **Standardized Payment**

The Part B Drug fee schedule is a national fee schedule (i.e. there is no variation from state to state). Thus, all Part B Drug claims were assigned the national fee schedule amount.

Standardized Payment Formula:

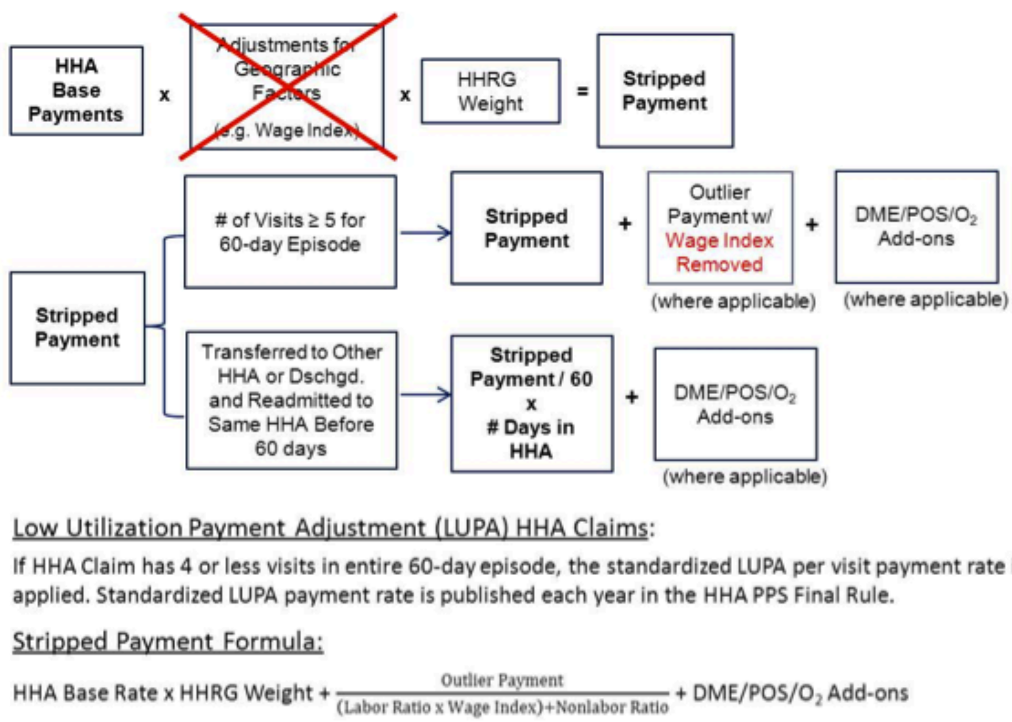
Part B Drugs National Fee Schedule Amount x Unit Count

Figure 13. Payment and standardization method for skilled nursing facilities.



SNF denotes skilled nursing facility; RUG, resource utilization group. Note: RUG includes therapy and service use, presence of certain medical conditions, and activity of daily living score.

Figure 14. Payment and standardization method for home health agencies.



HHA denotes home health agency; HHRG, home health resource group; DME, durable medical equipment; POS, prosthetics and orthotics; PPS, prospective payment system. Note: HHRGs are comprised of clinical, functional, and service utilization scores based on patient characteristics. HHA claims can include DME/Prosthetics/O2 as well. Payments for those claim lines are calculated according to the DME/POS payment formula.

Figure 15. Payment and standardization method for hospice.

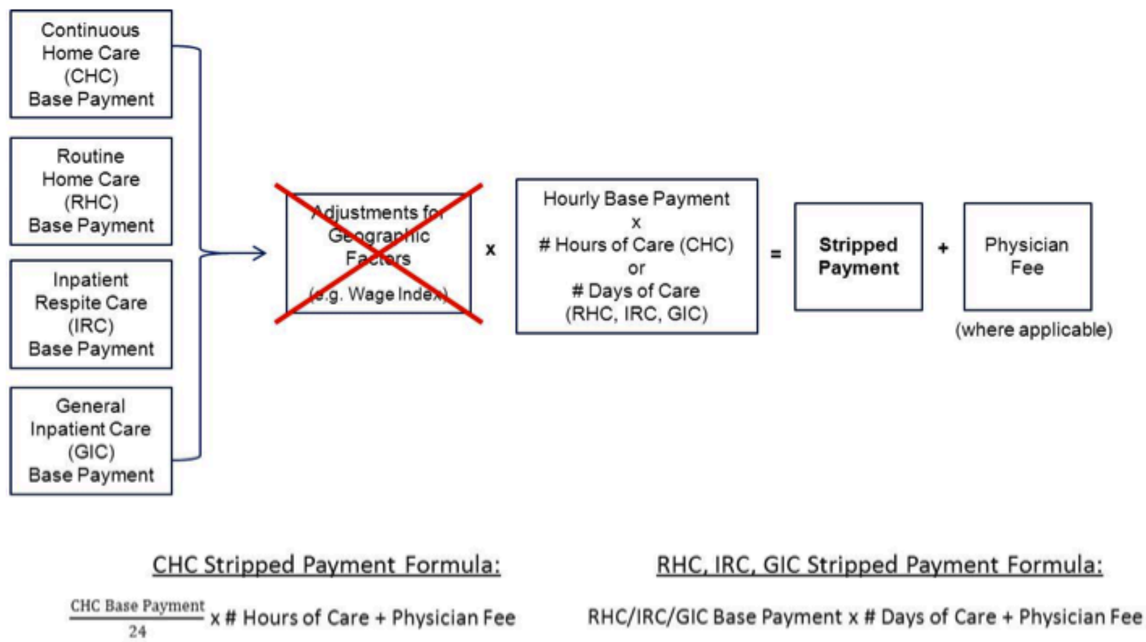
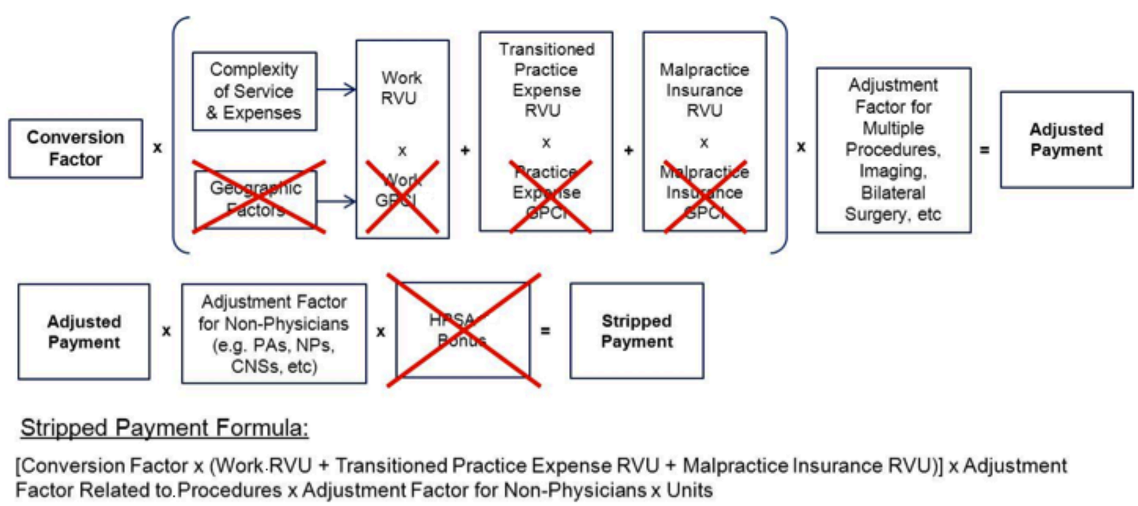


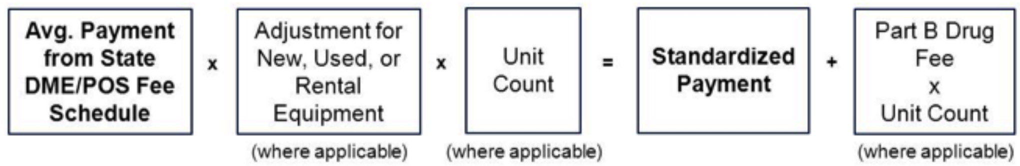
Figure 16. Payment and standardization method for physicians, physician extenders, social work services.



RVU denotes relative value units; GPCI, geographic practice cost index; HPSA, health professional shortage area.

Figure 17. Payment for durable medical equipment, prosthetics and orthotics, and parenteral and enteral nutrition.

DME/POS Claims:



DME/POS Standardized Payment:

Avg. Payment from State DME/POS Fee Schedule x Adjustment for New, Used, or Rental Equipment x Unit Count + (Part B Drug Fee x Unit Count)

PEN Claims:

The PEN fee schedule is a national fee schedule (i.e. there is no variation from state to state). Thus, all PEN claims were assigned the PEN fee schedule amount.

DME denotes durable medical equipment; POS, prosthetics and orthotics; PEN, parenteral and enteral nutrition. Note: Where applicable, Part B Drugs associated with DME claims were assigned the DME infusion limit amount from the Part B Drugs fee schedule.

Table 1. Example of included and excluded payments for a patient admitted on May 3 and discharged on May 8.

Claim Type	Claim Date	Admission Type	Primary ICD-9	Payment	Included in Model?	Payment Included in Model	Comments
Carrier	5/2-5/3	N/A	410.91	$255.61	N	$0.00	Starts prior to the index admission and ends within the analytic period.
Inpatient	5/3-5/4	Admission	410.71	$1,109.49	Y	$1,109.49	This inpatient AMI (410.71) admission defines the index admission date (5/3).
Inpatient	5/4-5/8	Transfer	410.71	$8,008.15	Y	$8,008.15	This inpatient AMI (410.71) discharge defines the discharge date (5/8).
Carrier	5/3-5/3	N/A	785.0	$367.20	Y	$367.20	N/A
Carrier	5/3-5/3	N/A	428.0	$6.59	Y	$6.59	N/A
Carrier	5/3-5/8	N/A	410.71	$350.52	Y	$350.52	N/A
Carrier	5/5-5/5	N/A	414.01	$225.75	Y	$225.75	N/A
Carrier	5/7-5/7	N/A	296.30	$148.39	Y	$148.39	N/A
Inpatient	5/30-6/3	Re-admission	410.71	$4,262.13	Y (prorated)	$3,409.70	Payment is prorated based only on days in the 30-day post-admission period. The amount includes: ($4262.13/5) x 4 = $3409.70. This second AMI (410.71) admission does not count as an index admission, but as a readmission.
Skilled Nursing Facility	6/3-6/21	Transfer	428.0	$1,652.28	N	$0.00	Starts after the 30-day post-admission period.
			TOTAL	**$16,386.11**		**$13,625.79**	

AMI denotes acute myocardial infarction.