September 2012

Readmissions Due to Hospital-Acquired Conditions (HACs):

Multivariate Modeling and Under-coding Analyses

Final Report

Prepared for

Susannah G. Cafardi, MSW, LCSW, MPH
Centers for Medicare & Medicaid Services
Rapid-cycle Evaluation Group
Innovation Center Mail Stop C3-19-26
7500 Security Boulevard
Baltimore, MD 21244-1850

Prepared by

Richard D. Miller, Jr., PhD
Terry Eng, RN, PhD (c)
Amy M.G. Kandilov, PhD
Jerry Cromwell, PhD
Nancy McCall, ScD
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709

RTI Project Number 0209853.231.002.128

Readmissions Due to Hospital-Acquired Conditions (HACs): Multivariate Modeling and Timing of Clinical Presentation Analyses

Draft Final Report

by Richard D. Miller, Jr., PhD
Terry Eng, RN, PhD (c)
Amy M.G. Kandilov, PhD
Jerry Cromwell, PhD
Nancy T. McCall, ScD, Project Director

CMS Project Officer: Susannah G. Cafardi, MSW, LCSW, MPH

RTI International

CMS Contract No. HHSM-500-2005-00029I

August 2012

This project was funded by the Centers for Medicare & Medicaid Services under Contract No. HHSM-500-2005-00029I. The statements contained in this report are solely those of the authors and do not necessarily reflect the views or policies of the Centers for Medicare & Medicaid Services. RTI assumes responsibility for the accuracy and completeness of the information contained in this report.

RTI International is a trade name of Research Triangle Institute.

ACKNOWLEDGMENTS

We would like to acknowledge assistance we received in conducting analyses related to hospital readmissions and preparing this report for submission. First, we would like to thank Merry Rabb, Matt Urato, and Arnold Bragg who provided valuable assistance in the construction of the episode-of-care linked file that made this analysis possible and in programming assistance through the analysis phase. Lastly, we would like to thank Loretta Bohn and Norma DiVito for assistance with preparation of this report.

This page intentionally left blank.

CONTENTS

List of Tables

SECTION 1
INTRODUCTION AND OVERVIEW OF RESEARCH APPROACH

1.1 Introduction and Findings from Previous Research

This report continues RTI's analysis of the effects of the hospital-acquired conditions-present on admission (HAC-POA) program on utilization, with a specific focus on readmissions. The HAC-POA program was designed to improve the quality of inpatient care to Medicare beneficiaries by providing a negative financial incentive, in which inpatient prospective payment system (IPPS) cases can no longer be assigned to higher-paying MS-DRGs on the basis of reasonably preventable complications or co-morbid (CC) conditions or major complications or co-morbid (MCC) conditions that are acquired during the hospital stay. The reimbursement effects are limited to the initial or index admission only. Thus, even though the hospital may not receive a higher rate of payment for index admissions in which a HAC occurred under the HAC-POA program, hospitals could receive additional payments from the Medicare program for care provided during readmissions related to the hospital-acquired condition. A recent study has found that an additional $103 million in payment would be withheld if Medicare expanded the non-payment policy to HAC-related readmissions (see McNair and Luft, 2012).

Previous research has shown to varying degrees that the likelihood of readmission is greater for patients who experience adverse events than for similar patients who have no such adverse events (Ashton et al., 1997; Herwaldt et al., 2006; Encinosa and Hellinger, 2008; Friedman et al., 2009; Friedman and Basu, 2004). Ashton and colleagues (1997) conducted a meta-analysis of the relationship between early readmission rates (31 days) and inpatient processes of care and concluded that substandard care was correlated with higher readmission rates; patients who were readmitted for unplanned reasons were 55% more likely to have had poor quality of care.

Encinosa and Hellinger (2008) studied the occurrence of seven categories of Agency for Healthcare Research and Quality patient safety indicators (PSIs) among 161,004 privately insured patients undergoing surgery. These seven groups of PSIs span the 10 HAC categories included in the HAC-POA program. Excessive 90-day readmission rates, calculated as the difference between the readmission rate estimated if all patients had the PSI and the readmission rate estimated if none of the patients had the PSI, were found for four of the seven PSI groups: infections (7.7%), pulmonary and vascular problems (3.4%), acute respiratory failure (4.3%), and metabolic problems (6.3%).

Infections after surgical procedures are an important reason for early readmissions and have been the focus of a number of recent studies. Herwaldt and colleagues (2006) studied postoperative nosocomial infections associated with general, cardiothoracic, and neurosurgical procedures in a large tertiary care medical center and associated VA hospital. They found that the risk adjusted odds ratio of being readmitted within 30 days of surgery ranged across the three surgical services from 2.15 to 5.62 for patients with a SSI compared with patients with no SSI.

Friedman and colleagues (2009) used an all payer data set of hospitalizations for surgical procedures from seven states and found that the relative risk of readmission was higher for patients experiencing at least one of nine PSIs. The unadjusted rate of 3-month readmission was

25% among patients with a positive PSI compared with 17% among those without a positive PSI. Risk adjustment reduced the 3-month readmission rate differences yet the rates remained statistically higher for patients with each of the nine PSIs.

The most recent literature points to a similar relationship between hospital-acquired conditions and readmissions. Morris et al. (2011) considered unplanned 30-day same-hospital readmissions among 1,808 surgical patients in an urban, tertiary hospital in FY 2009 and found that deep vein thrombosis significantly increased the probability of a readmission, with an odds ratio of 4.7. The reasons for readmission among these patients, however, did not seem to be related to the deep vein thrombosis.

1.2 Summary of Phase II Findings on Readmissions and Potential Estimation Bias

RTI completed a descriptive analysis of the relationship between the Medicare hospital-acquired conditions and readmissions earlier this year (see Kandilov et al., 2012). In that study, we examined the rates and reasons for all-cause readmissions among all discharges in FY 2009 and the first 10 months of FY 2010 in which a HAC was coded by the hospital and the patient was discharged alive. The rates of readmission varied considerably across the different HACs, with the lowest readmission rate for deep vein thrombosis or pulmonary embolism (DVT/PE) following certain orthopedic procedures and the highest readmission rate for blood incompatibility and surgical site infection (SSI) of mediastinitis following a coronary artery bypass graft (CABG) procedure. Readmission rates increased as the readmission window expanded from 7 days to 60 days.

Between FY 2009 and FY 2010, we did not discover any large changes in the readmission rates for any of the HACs, except for among the low-volume surgical site infections, where fluctuations in the readmission rate from year to year likely have more to do with small sample sizes than with actual changes in readmissions for this patient population. Septicemia and pneumonia were among the most common primary diagnoses for readmission across many of the HACs, and for the surgical site infections, post-operative infections were a common reason for readmission. Comparing FY 2009 and FY 2010 data, we did not detect any substantive changes in the reasons for readmission following the development of a HAC during the initial hospitalization.

To address the *incremental* effect of a HAC on readmissions for falls and trauma, vascular catheter-associated infections, and DVT/PE following certain orthopedic procedures, we developed comparison groups for each of the three HACs using a random sample of discharges matched to the HAC cases by key clinical and demographic characteristics. For all three HACs, we found large and statistically significant differences in the readmission rates between the HAC cases and the matched comparison groups. FY 2009 and FY 2010, readmission rates were 3 to 6 percentage points higher for discharges with falls and trauma, 6 to 7 percentage points higher for discharges with a vascular catheter-associated infection, and 2 to 3 percentage points higher for discharges with a DVT/PE following certain orthopedic procedures.

Although we found that readmission rates vary by key patient criteria, such as age, Medicaid status, disability status, and HCC scores, differences in readmission rates between discharges with the HAC and its respective comparison group persisted across most of these

stratifications. For patients with a fall or trauma, readmissions remained significantly higher than among the comparison group within all age groups, those with and without Medicaid, all eligibility groups (aged, disabled, ESRD), both genders, within two racial groups (white and other), within all levels of HCC score (low, medium, or high), and within those who were not institutionalized. Significant differences in readmissions also remained when we stratified the vascular catheter-associated infection patients and comparisons by these same categories, and additionally there was a significant difference in readmissions among the black patients. For HACs and comparisons in the DVT/PE group, the only patient characteristics where a significant difference in readmissions did not persist were within patients over 85, those enrolled in Medicaid, those with ESRD, those whose race was other, those who had medium or high HCC scores, and those who were institutionalized.

The significant differences in readmission rates also persisted when we stratify by important hospital characteristics such as Census division, urban location, teaching status, and bed size. For falls and trauma, the rate of readmissions was significantly higher for the HAC cases than for the control cases across all of these stratifications of hospital characteristics. For vascular catheter-associated infections, readmission rates for HAC cases were also significantly higher within all Census divisions, urban and rural hospitals, teaching and non-teaching hospitals, and for hospitals with 100-299 beds and hospitals with 300 or more beds.

While the rates of readmission for the beneficiaries who acquired one of the three conditions during their hospitalization were much higher than for comparison beneficiaries, we found many of the same reasons for readmission for these two groups across our two years of data. The primary exception was the "infection of a central venous catheter," which was one of the top five reasons for readmission among those with a hospital-acquired vascular catheter-associated infection, while it was not among the top reasons for readmission among the comparison group beneficiaries.

Finally, we created a separate study sample to conduct further investigations of mediastinitis following coronary artery bypass graft (CABG) surgery. The number of mediastinitis cases that were HACs is very small so we undertook this study to examine the possible degree of under-reporting of mediastinitis during the hospital period or clinical presentation of mediastinitis after discharge. The primary motivation for this study was to examine the degree to which readmission estimation bias may exist due to identification errors in the dependent variable because of either under-reporting of the HAC by the hospital or a delay in clinical presentation until after discharge.

The mediastinitis study sample included all discharges with a CABG procedure in either FY 2009 or FY 2010. We linked the MedPAR records for these discharges with all physician claims billed during the admission and all physician and hospital outpatient department claims for a 60-day follow-up period and explored the reporting of mediastinitis by physicians during the hospitalization and follow-up periods.

Of the 195 cases of mediastinitis identified during the index hospitalization using a hospital or physician diagnosis, 65% were coded only on the physician claims, and 21% were coded only on the hospital claims. The rate of agreement between hospital and physician coding of mediastinitis was poor, with only 14% of all mediastinitis cases identified in the hospital

coded on both hospital and physician claims. Most physician-reported diagnoses of mediastinitis occurred between day 9 and day 23 following the CABG surgery. The first physician diagnosis of mediastinitis was most likely to be made by an infectious disease specialist.

Overall, we found low rates of reporting of mediastinitis by physicians after discharge from the hospital. However, the rate of observed interactions between the patient and their primary surgeon post-discharge was extremely low; only 14 out of 149,395 Medicare beneficiaries had a follow-up appointment within 30 days. This low number is likely a reflection of the global billing payment policy. Thus, it would appear that the use of Medicare claims with the global billing convention may not be an adequate source of information to conduct post-discharge analyses for beneficiaries having major surgical procedures subject to the global surgical payment policy.

1.3 Overview of Phase III Research Questions and Analytic Approach

The readmission multivariate analyses presented in this report represent an extension of the descriptive analysis of readmissions that we completed in Phase II of the study. The Phase III research questions that we address in this study are:

- Does the likelihood of readmission differ between cases that report HACs and similar cases that do not report HACs?

- Does the likelihood of use of post-acute care (PAC) services differ between cases that report HACs and similar cases that do not report HACs?

We use a two stage estimation strategy for readmissions. The first stage is the estimation of a single period, mixed-effects level model where logistic regression is used to estimate the likelihood of having a readmission within 30 days of discharge. A dichotomous variable is included for the presence or absence of a HAC (1 = HAC; 0 = no HAC). We report the odds ratio (OR) on the presence of a HAC from the logistic regressions along with an indication of the level of statistical significance of the effect. Odds ratios greater than 1.0 indicate an increased likelihood of a readmission; odds ratios less than 1.0 indicate a decreased likelihood of a readmission.

In the second stage, we replicate the method of Encinosa and Hellinger (2008) and report the excess likelihood of readmission associated with HAC status and its associated standard error using the multivariate logistic regression models developed in the first stage. In general, the strategy is to use the results of the logistic regression models to estimate the likelihood of readmission assuming that all hospitalizations had an adverse event (HAC) and then estimate the likelihood of readmission assuming that all hospitalizations had no adverse event (no HAC). The difference between the two sets of predictions is the "excess" likelihood of readmission that can be attributed to the HAC after controlling for hospital- and patient-level characteristics, including co-morbidities.

To better understand the role of post-acute care services in observed readmission rates, we also estimate the single-period, multilevel model on the likelihood of any post-acute care services following the general estimation strategy for readmissions. We do not generate

estimates of the "excess" likelihood for PAC admissions, but do report the odds ratios from the logistic regressions. We also provide descriptive statistics regarding the relationship between two discharge destinations (PAC and home) and the likelihood of readmission. These analyses consider this relationship for patients both with and without HACs present.

We also conduct a special study which is an extension of last year's work to examine the degree to which readmission estimation bias may exist due to identification errors in the dependent variable because of either under-reporting of the HAC by the hospital or a delay in clinical presentation until after discharge. The Phase III research questions that we address in this special study are:

- What proportion of HAC cases are identified during the index hospitalization period from physician claims and what is the degree of concordance with the MedPAR claim diagnosis for these HACs?

- What is the typical timing to a physician diagnosis of a HAC-related condition during a hospitalization? And what proportions of patients with a HAC and without a HAC-related condition are diagnosed on a subsequent inpatient claim within 7, 15, or 30 days following hospital discharge?

- What evidence do we find of treatment for an infection among the outpatient department drug claims for patients at-risk of developing a HAC-related infection within 30 days following discharge?

To conduct further investigation of potential under-coding or post-discharge presentation of the more frequent HACs, we conducted a series of descriptive analyses. To analyze the potential degree of under-coding during the hospitalization, we compare the degree of concordance in coding a HAC between hospital claims and linked physician claims for the hospitalization period. We examined the timing between procedures that put patients at risk of developing a HAC and physician diagnosis of the HAC-related conditions in the hospital, and we also analyzed post-discharge presentation of the HAC-related conditions by linking hospital, SNF, IRF, and LTCH claims in the 30-days following the index hospitalization to the index hospital claim and reporting the 7-, 15-, and 30-day readmission rates for patients at risk of developing the HAC during the hospitalization and for those that have a HAC reported. We do not include physician or hospital outpatient department (OPD) claims in this analysis as the rate of follow-up for patients with a major surgical procedure that puts them at risk of developing a HAC is extremely low during the post-discharge period due to the Medicare global surgical payment policy that does not allow physicians to routinely bill for services within 90 days of the procedure that are related to follow-up care for the procedure. For the infection-related HACs, we also linked outpatient department drug claims within a 30-day period of discharge and report the percentage of beneficiaries who received antibiotics that would be appropriate for treatment of a HAC-related infection.

1.4 Organization of Report

Section 2 of this report describes the study sample, data, and methods to answer the first two research questions related to likelihood of readmission and likelihood of PAC transfer for

patients with a HAC and those at risk for development of a HAC but for whom no HAC is recorded during the hospital stay. ***Section 3*** provides results of the multivariate modeling of readmission. ***Section 4*** provides descriptive and multivariate analyses of likelihood of using PAC services. ***Section 5*** describes the study sample, data, methods, and presents the results of the special study of potential under-coding and time to clinical presentation for selected HACs. ***Section 6*** presents a summary of the findings.

SECTION 2
TECHNICAL APPROACH

2.1 Study Sample and Data

For the analysis of readmissions among patients with hospital-acquired conditions (HACs), we created our study sample by linking Medicare claims data to "index" HAC inpatient prospective payment system (IPPS) hospital claims. These "index" claims were defined as claims with the HAC-associated diagnoses coded as not present on admission (POA indicator = "N" or "U"). The index HAC claims were taken from MedPAR files for FY 2009 and the first ten months of FY 2010, to allow for a 60-day look-forward period. From these index HAC claims, we used a cross-referenced beneficiary identifier (HIC number) to look back 180 days prior to the index admission date in order to identify any Medicare claims (inpatient, outpatient, home health, and physician claims) for that patient within that period. The claims data for the look-backs came from FY 2008, FY 2009, and FY 2010, as needed. These look-back claims were used to calculate concurrent Hierarchical Condition Category (HCC) indicators for these patients, which were then used to generate indicators of pre-existing medical conditions as described in ***Section 2.7***. We then used the HIC number to look forward 30 days from the index discharge date for additional hospital admissions. If a patient was discharged from their index HAC hospitalization and admitted to another IPPS hospital within a day (with a discharge designation of an acute care transfer), then the 60-day follow up period began with the discharge date from that second transfer hospitalization.

The study sample was limited to beneficiaries who were residents of the U.S., who were enrolled in Medicare Parts A & B, who did not have Medicare as a secondary payer, and who were *not* enrolled in managed care during their HAC index claim, during the 180 days prior to the index admission, and during the 30-day period following the index discharge. The sample was also limited to patients who were discharged alive from their index hospitalization. These exclusions allowed us to focus on Medicare patients with HACs who could possibly have a readmission and whose readmission claims we would likely find using MedPAR claims data. For example, if a Medicare beneficiary with an index HAC admission switched to Medicare managed care during the 60-day follow-up period, any hospital readmissions they might have had would not be present in the MedPAR claims data. Including these beneficiaries in the sample could lead to an under-estimation of the readmission rates.

2.2 Defining Readmissions

For the statistics presented in this report, we use a measure of hospital all-cause readmissions and include all admissions to acute care hospitals that occur within 30 days of the index claim discharge date, regardless of the clinical reason for the admission. In addition to IPPS hospitals, an admission to a critical access hospital (CAH) or to another non-IPPS hospital that is paid under Medicare Part A (such as a Cancer hospital or a Children's hospital) following an index IPPS hospital discharge is considered a readmission. This measure of readmissions does not include admissions to an inpatient rehabilitation facility (IRF) or to a long-term care hospital (LTCH), which are included among our measure of post-acute care. Discharges from the index hospitalization to another acute care IPPS hospital, where the index discharge date is within one day of the next admission date and the discharge destination is a transfer, are treated

as transfer cases and so are not included as readmissions. The 30-day look-forward period begins with the discharge date of the transfer hospitalization, if there is one.

2.3 Defining Discharges to PAC Settings

For the analyses of post-acute care utilization, we created a measure based on the discharge destination variable in the MedPAR data. The following settings were included in our PAC definition: skilled nursing facilities, organized home health service organizations, intermediate care facilities, inpatient rehabilitation facilities, and long-term care hospitals.

2.4 Selection of the Three Study HACs

Based on our initial descriptive statistics produced for the Strategic Memo: Strategy to Estimate Readmissions Due to Hospital-Acquired Conditions (HACs), we selected three HACs from the current set of HACs for further analysis in this report. The primary criterion for our selection was that the chosen HACs have a sufficient volume to estimate statistically reliable descriptive statistics, allowing us to examine variation in readmission rates across beneficiary characteristics. Using this criterion, we selected the following three HACs for the Phase II report:

- ***Falls and trauma***, with 7,954 HAC-associated live discharges in FY 2009 and the first 10 months of FY 2010.

- ***Deep vein thrombosis or pulmonary embolism (DVT/PE)*** following certain orthopedic procedures, with 4,195 HAC-associated live discharges in FY 2009 and the first 10 months of FY 2010.

- ***Vascular catheter-associated infection*** with 5,167 HAC-associated live discharges in FY 2009 and the first 10 months of FY 2010.

We continue to analyze these three HACs in this Phase III report.

2.5 Comparison Group Matching Criteria

To develop a valid comparison group we selected discharges based on a small set of clinical or demographic characteristics held in common with the specific HAC cases, and then used a larger set of covariates in the outcome regressions. Matching is a common technique found among empirical studies on this topic. For the descriptive analysis in this report, we took a multivariable matching approach. Multivariable matching uses a limited number of specific characteristics and identifies controls that match on *all* of the variables.

To construct appropriate comparison groups for the three selected study HACs, we matched each index claim identified with a HAC to 10 IPPS claims without a HAC but with the same MS-DRG and demographic characteristics (sex, race, and age) as the HAC claim. In the cases where a 10:1 match was not obtainable, we reweighted the matches that were made to simulate a 10:1 match. Any claims with the HAC-associated diagnosis codes identified as present on admission (POA indicator equal to "Y" or "W") were excluded from the comparison

group, since conditions coded as present on admission could potentially be true HACs that were miscoded. Including true HACs in the comparison group could introduce bias in our results. Thus, the comparison group for each of the three HACs contained no index claims with the specified HAC-associated diagnoses.

No additional restrictions were placed on the comparison group for the falls and trauma HACs. For the DVT/PE following certain orthopedic procedures, the set of claims from which the comparison group was drawn was further limited to those claims containing the orthopedic procedure associated with this HAC. To better target the population who would be at risk for a vascular catheter-associated infection, we limited this comparison group to index claims that had one of two vascular catheter procedure codes (38.93 or 38.95). Note that among patients with the vascular catheter-associated infection HAC, 38% did not have a vascular catheter procedure code on their claims. The vascular catheter codes may have been coded after the fifth surgical procedure code, and thus not picked up by the MedPAR data, or may have been left off of the claim completely. Readmission rates were similar between the HAC claims that included the vascular catheter procedure codes and those that did not include the codes.

From these index comparison claims, we linked additional claims data both before and after the index comparison claim, as described in ***Section 2.1***, in order to calculate readmission rates and co-morbid conditions. The same sample exclusions – residents of the U.S., enrolled in Medicare Parts A & B, Medicare not the secondary payer, and not enrolled in managed care – were applied to the identified comparison groups to ensure analogous samples.

2.6 Multivariate Analyses

To estimate the impacts of each of the three study HACs on the likelihood of readmission within 30 days, we estimated mixed effects (or multi-level) logistic models. The mixed effects models are necessary due to the multi-level nature of the data being analyzed. The idea is to control for both patient- or discharge-level covariates such as co-morbid conditions and age as well as hospital-level covariates such as size (number of beds). Also, the discharges are clustered within hospitals, so it is necessary to model this clustering.

The mixed effects logistic model is derived through using the logistic function to model the probability of readmission based on the value of a latent variable Y_{ij}, where i indexes discharges within hospitals and j indexes hospitals.

$$Pr_{ij}(\text{Readmission}) = 1 / [1+\exp(-Y_{ij})]$$

The variable Y_{ij} can be thought of as a function of HAC status as well as other patient- or discharge-level characteristics (X) and an individual-level error term (r) as follows:

$$Y_{ij} = \beta_0 + \beta_1 HAC_{ij} + \beta_2 X_{ij} + r_{ij}$$

The mixed effects model is implemented by allowing the βs to vary across hospitals, which constitute a second level of data. We considered three different specifications for modeling the likelihood of readmission for each of the three HACs and the likelihood of discharge to a PAC setting. The first was a random intercept model. The second was a random

intercept model where we allowed the intercept to be a function of hospital-level covariates. The third was a model, which built upon the second model by estimating a random effect for the HAC indicator variable.

Model I

$$\text{Level 1: } Y_{ij} = \beta_{0j} + \beta_1 HAC_{ij} + \beta_2 X_{ij} + r_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + u_{0j}$$

In this case the intercept term is equal to an average intercept across all hospitals and a hospital-specific random error term (u_{0j}). The model may be re-written as one equation as follows:

$$Y_{ij} = \gamma_{00} + \beta_1 HAC_{ij} + \beta_2 X_{ij} + r_{ij} + u_{0j}$$

This model is composed of fixed effects (the γs and βs) and random effects (the random error terms).

Model II

$$\text{Level 1: } Y_{ij} = \beta_{0j} + \beta_1 HAC_{ij} + \beta_2 X_{ij} + r_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01} W_j + u_{0j}$$

In this case the intercept term is a function of hospital-level covariates (W_j) and a hospital-specific random error term (u_{0j}). The model may be re-written as one equation as follows:

$$Y_{ij} = \gamma_{00} + \gamma_{01} W_j + \beta_1 HAC_{ij} + \beta_2 X_{ij} + r_{ij} + u_{0j}$$

This model is composed of fixed effects (the γs and βs) and random effects (the random error terms).

Model III

$$\text{Level 1: } Y_{ij} = \beta_{0j} + \beta_{1j} HAC_{ij} + \beta_2 X_{ij} + r_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01} W_j + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

In this case the intercept term is a function of hospital-level covariates (W_j) and a hospital-specific random error term (u_{0j}). The coefficient on the HAC indicator is equal to the average value of the coefficient across all hospitals (γ_{10}) and a hospital-specific random error term (u_{1j}). The model may be re-written as one equation as follows:

$$Y_{ij} = \gamma_{00} + \gamma_{01} W_j + \gamma_{10} HAC_{ij} + \beta_2 X_{ij} + r_{ij} + u_{0j} + u_{1j}$$

This model is composed of fixed effects (the γs and βs) and random effects (the random error terms).

In each of the specifications, we control for the following discharge- or patient-level characteristics (the Xs): age, Medicaid enrollment, original eligibility status, gender, race, institutional status, and several co-morbid conditions (we discuss the measures for co-morbid conditions in ***Section 2.7***). In the Models II and III, we control for the following hospital-level characteristics (the Ws): whether the hospital is located in an urban area, number of beds, and whether the hospital is an academic medical center (teaching hospital).

2.7 Co-morbid Condition Measures

To control for co-morbid conditions in our models, we included a series of indicator variables suggested in a report to CMS by the Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (referred to as Yale for the remainder of this report). Based on several factors, the Yale team grouped CMS condition categories (CMS-CCs) into a series of 31 co-morbid risk variables.[1] The grouping of the CMS-CCs into the risk variables is presented in ***Table 2-1***.

Table 2-1
The Yale co-morbid condition measures

Co-morbid condition measure	CMS Co-morbid conditions included
Severe infection	1 HIV/AIDS 3 Central nervous system infection 4 Tuberculosis 5 Opportunistic infections
Other infectious disease	6 Other infectious disease 111 Aspiration and specified bacterial pneumonias 112 Pneumococcal pneumonia, emphysema, lung abscess 113 Viral and unspecified pneumonia, pleurisy
Metastatic cancer/acute leukemia	7 Metastatic cancer/acute leukemia
Severe cancer	8 Lung, upper digestive tract, and other severe cancers 9 Other major cancers
Other major cancers	10 Breast, prostate, colorectal and other cancers and tumors 11 Other respiratory and heart neoplasms 12 Other digestive and urinary neoplasms

(continued)

[1] See pages 29-30 of Horwitz et al. (2011) for a fuller description of the rationale for the creation of the comorbid risk variables.

Table 2-1 (continued)
The Yale co-morbid condition measures

Co-morbid condition measure	CMS Co-morbid conditions included
Diabetes mellitus	15 Diabetes with renal manifestation 16 Diabetes with neurologic or peripheral circulatory manifestation 17 Diabetes with acute complications x 18 Diabetes with ophthalmologic manifestation 19 Diabetes with no or unspecified complications 20 Type I diabetes mellitus 119 Proliferative diabetic retinopathy and vitreous hemorrhage 120 Diabetic and other vascular retinopathies
Protein-calorie malnutrition	21 Protein-calorie malnutrition
End-stage liver disease	25 End-Stage Liver Disease 26 Cirrhosis of Liver
Other hematological disorders	44 Other hematological disorders
Drug and alcohol disorders	51 Drug/alcohol psychosis 52 Drug/alcohol dependence
Psychiatric comorbidity	54 Schizophrenia 55 Major depressive, bipolar, and paranoid disorders 56 Reactive and unspecified psychosis 58 Depression 60 Other psychiatric disorders
Hemiplegia, paraplegia, paralysis and functional disability	67 Quadriplegia, other extensive paralysis 68 Paraplegia 69 Spinal Cord Disorders/Injuries 100 Hemiplegia/hemiparesis 101 Diplegia (upper), monoplegia, and other paralytic syndromes 102 Speech, language, cognitive, perceptual 177 Amputation status, lower limb/amputation 178 Amputation status, upper limb
Seizure disorders and convulsions	74 Seizure disorders and convulsions
Congestive heart failure	80 Congestive heart failure

(continued)

Table 2-1 (continued)
The Yale co-morbid condition measures

Co-morbid condition measure	CMS Co-morbid conditions included
Coronary atherosclerosis or angina, cerebrovascular disease	81 Acute myocardial infarction 82 Unstable angina and other acute ischemic heart disease 83 Angina pectoris/old myocardial infarction 84 Coronary atherosclerosis/other chronic ischemic heart disease 89 Hypertensive heart and renal disease or encephalopathy 98 Cerebral atherosclerosis and aneurysm 99 Cerebrovascular disease, unspecified 103 Cerebrovascular disease late effects, unspecified 104 Vascular disease with complications 105 Vascular disease 106 Other circulatory disease
Specified arrhythmias	92 Specified heart arrhythmias 93 Other heart rhythm and conduction disorders
COPD	108 Chronic Obstructive Pulmonary Disease
Dialysis status	130 Dialysis status
Ulcers	148 Decubitus ulcer 149 Decubitus ulcer or chronic skin ulcer
Septicemia/shock	2 Septicemia/shock
Cardio-respiratory failure and shock	79 Cardio-respiratory failure and cardio-respiratory shock
Acute renal failure	131 Acute renal failure
Pancreatic disease	32 Pancreatic disease
Rheumatoid arthritis and inflammatory connective tissue disease	38 Rheumatoid arthritis and inflammatory connective tissue disease
Respirator dependence	77 Respirator dependence/tracheostomy status
Transplants	128 Kidney transplant status 174 Major organ transplant status
Hip fracture/dislocation	158 Hip fracture/dislocation

SOURCE: Horwitz et al. (2011)

This page intentionally left blank.

SECTION 3
MULTIVARIATE RESULTS FOR LIKELIHOOD OF READMISSION WITHIN 30 DAYS OF DISCHARGE

3.1 Choosing among Potential Model Specifications

We estimated three separate specifications or models to estimate the impact of HAC status on the likelihood of readmission, while controlling for patient and hospital characteristics. In this section, we provide a rationale for the choice of final specification that we made for each of the three HACs considered in this study. The results for the three specifications for each HAC can be found in ***Appendix Tables 1*** through ***3***.

Falls and Trauma. The result regarding the effect of having a HAC on the likelihood of readmission within 30 days is quite consistent across all three specifications. This is also true for the effect of the control variables. Including the hospital-level covariates has very little impact on the coefficients for the patient- or discharge-level covariates, although at least some of the hospital-level covariates are significant.

In all three models, the random effect on the intercept is significant. At the same time, only roughly 7% of the total variance is determined to be due to differences in readmission rates across hospitals. In Model III, the random effect on the HAC indicator is not significant and neither is the covariance between the intercept and the HAC indicator. Allowing for the random effect on the HAC indicator has no significant impact on the results. Based on these results, we report the results from Model II for falls and trauma.

Vascular Catheter-Associated Infection. Again, the result regarding the effect of having a HAC on the likelihood of readmission within 30 days is quite consistent across all three specifications. This is also true for the effect on the control variables. Including the hospital-level covariates has very little impact on the coefficients for the patient- or discharge-level covariates, although at least some of the hospital-level covariates are significant.

In all three models, the random effect on the intercept is significant. At the same time, only roughly 5% of the total variance is determined to be due to differences in readmission rates across hospitals. In Model III, the random effect on the HAC indicator is not significant and neither is the covariance between the intercept and the HAC indicator. Allowing for the random effect on the HAC indicator has no significant impact on the results. Based on these results, we report the results from Model II for vascular catheter-associated infection.

DVT/PE Following Certain Orthopedic Procedures. In this case, the result on the effect of having a HAC is quite different when allowing for a random effect on the HAC indicator in Model III. In addition, the random effect on the HAC indicator is quite significant. Based on the significance of the random effect on the HAC indicator, we report the results from Model III for DVT/PE.

3.2 Logistic Model Results

The results of the chosen mixed effects logistic model for each HAC are presented in ***Table 3-1***. The main finding is that the presence of each HAC has a significant positive impact

on the likelihood of readmission within 30 days. For the falls and trauma HAC and the DVT/PE HAC, the presence of the HAC is associated with a 21 to 23% increase in the odds of being readmitted within 30 days, respectively. The presence of the vascular catheter-associated infection HAC has an even greater impact on the likelihood of readmission. It is associated with a 33% increase in the odds of being readmitted within 30 days.

As far as the hospital-level covariates are concerned, larger hospitals tend to have higher readmission rates. For instance, in the falls and trauma sample, the odds ratio for the largest hospitals (those with 300 or more beds) is equal to 1.139, which indicates that the odds of a readmission are 14% higher for patients from these larger hospitals than for patients from hospital with fewer than 100 beds. The effect of hospital size is largest for patients in the DVT/PE sample, or almost 40% higher. There is no association between bed size and likelihood of readmission for patients at risk to develop a DVT or PE. Discharges from academic medical centers are also associated with a higher likelihood of readmission for patients at risk of a fall or trauma, 18%, and vascular catheter-associated infection, 22%. The results of the influence of level of urbanicity are mixed. Urbanicity has no correlation with the likelihood of readmission in the falls and trauma sample. At the same time, discharges from urban hospitals are associated with a higher likelihood of readmission in the vascular catheter-associated infection sample, 10%, and with a lower likelihood of readmission in the DVT/PE sample, 12%.

The results on patient age are also mixed. In the falls and trauma and DVT/PE samples, there is a positive relationship between age and the likelihood of readmission after controlling for other factors, including co-morbidities. In the vascular catheter-associated infection sample, there is to be a negative relationship. The effect of Medicaid enrollment is more consistent across the three samples. In each case, Medicaid enrollment is associated with a greater likelihood of readmission. In the DVT/PE sample, the odds of readmission is 35% higher for Medicaid enrollees than for non-enrollees, while for the falls and trauma and vascular catheter-associated infection samples, the odds of readmission among Medicaid enrollees are 20 and 15% higher, respectively.

Among the discharges in the falls and trauma and DVT/PE samples, original Medicare eligibility status and gender are important determinants of the likelihood of readmission. Patients who initially became eligible for Medicare due either to disability or ESRD status have a greater likelihood of readmission than patients who initially became eligible due to age. Women generally have a lower likelihood of readmission than men. In the falls and trauma sample, the odds of readmission were 9% lower for women than for men and in the DVT/PE sample, the odds of readmission were more than 20% lower. Generally, race and institutional status have no effect on the likelihood of readmission. Co-morbidities are very important determinants of the likelihood of readmission. In each sample, at least one-half of the Yale co-morbidity measures have significant odds ratios. In all cases where the odds ratios are significant, the odds ratio is greater than one, indicating that the co-morbidities are associated with a greater likelihood of readmission.

Table 3-1
Multivariate regression estimates of the likelihood of a 30-day readmission for selected hospital-acquired conditions (HAC)

Variable	Falls and trauma (n=78,827)	Vascular catheter-associated infection (n=44,981)	DVT/PE following certain orthopedic procedures (n=41,432)
HAC Indicator	**1.214****	**1.330****	**1.229****
Hospital-Level Covariates			
Urban	0.998	1.096*	0.875*
Number of beds (reference is "fewer than 100"			
100-299	1.112**	1.028	1.376**
300 or more	1.139**	1.097	1.393**
Academic medical center	1.175**	1.218**	1.109
Discharge-Level Covariates			
Age (reference is "less than 65")			
65-74	0.989	0.950	1.078
75-84	1.106*	0.893*	1.682**
85 and older	1.225**	0.779**	2.371**
Enrolled in Medicaid	1.197**	1.145**	1.346**
Original eligibility (reference is "aged")			
Disabled	1.092**	1.020	1.348**
ESRD	1.558**	1.080	2.091**
Gender: Female	0.910**	1.033	0.771**
Race (reference is "white")			
Black	0.960	0.960	0.984
Asian	0.891	1.018	0.876
Other	0.915	0.952	0.915
Institutionalized	0.778	0.823	0.400
Yale Comorbidity Measures			
Severe infection	1.089	1.222*	0.510
Other infectious disease	1.142*	1.059	1.122
Metastatic cancer/acute leukemia	1.286**	1.260**	1.662*
Severe cancer	1.235**	0.993	1.226
Other major cancers	1.039	0.967	0.876
Diabetes mellitus	1.182**	1.134**	1.132*
Protein-calorie malnutrition	1.152**	0.987	1.503**
End-stage liver disease	1.368**	0.953	2.346**
Other hematological disorders	1.404**	1.160**	1.099
Drug and alcohol disorders	1.410**	1.116	1.789**
Psychiatric comorbidity	1.121*	1.185**	1.148
Hemiplegia, paraplegia, paralysis and functional disability	1.175**	1.027	1.124
Seizure disorders and convulsions	1.100	1.121*	1.674**
Congestive heart failure	1.331**	1.113**	1.353**
Coronary atherosclerosis or angina, cerebrovascular Disease	1.147**	1.076*	1.222**
Specified arrhythmias	1.120**	1.053	1.101
COPD	1.328**	1.072*	1.381**

(continued)

Table 3-1 (continued)
Multivariate regression estimates of the likelihood of a 30-day readmission for selected hospital-acquired conditions (HAC)

Variable	Falls and trauma (n=78,827)	Vascular catheter-associated infection (n=44,981)	DVT/PE following certain orthopedic procedures (n=41,432)
Dialysis status	1.242**	1.181**	0.997
Ulcers	1.138**	0.973	1.389*
Septicemia/shock	1.127**	1.147**	1.282
Cardio-respiratory failure and shock	1.057	1.068	1.017
Acute renal failure	1.342**	1.230**	1.657**
Pancreatic disease	1.254**	1.217**	1.427
Rheumatoid arthritis and inflammatory connective tissue disease	1.178**	1.127**	1.314**
Respirator dependence	1.497**	1.074	5.516**
Transplants	1.560**	1.152	0.794
Hip fracture/dislocation	0.938	0.915	1.330**

NOTES:

* indicates statistically significant difference using negative binomial regression with $p<0.05$.
**indicates statistically significant difference using negative binomial regression with $p<0.01$.

SOURCE: falls_re_readmt_models.log, vcath_centered_xtmelogitJun20_2012.log, dvt_centered_xtmelogitJun20_2012.log

3.3 The Excess Likelihood of Readmission Attributable to Three Hospital-Acquired Conditions

In ***Table 3-2***, we present our multivariate regression results on the excess likelihood of readmission attributable to three selected HACs. We generated the excess likelihood by using the results of the logistic models to estimate the likelihood of readmission assuming that all hospitalizations had an adverse event (HAC) and then to estimate the likelihood of readmission assuming that all hospitalizations had no adverse event (no HAC). The difference between the two sets of predictions is the "excess" likelihood of readmission that can be attributed to the HAC after controlling for patient and hospital characteristics. We find that the falls and trauma HAC leads to an excess likelihood of readmission of 2.9 percentage points while the vascular catheter-associated infection HAC leads to an excess likelihood of readmission of 5.6 percentage points and the DVT/PE HAC leads to an excess likelihood of readmission of 1.8 percentage points. All of these results are statistically significant.

Table 3-2
Excess likelihood of readmission for selected hospital-acquired conditions

Hospital-acquired condition	Excess likelihood	Standard error
Falls and trauma	2.9%	0.5%
Vascular catheter-associated infection	5.6%	0.7%
DVT/PE following certain orthopedic procedures	1.8%	0.7%

NOTES: DVT/PE = Deep vein thrombosis or pulmonary embolism

SOURCE: DVT_predicted.xlsx, Vcath_predicted.xlsx, fall_readmt_predict.log

This page intentionally left blank.

SECTION 4
DISCHARGE TO POST-ACUTE CARE SETTINGS

4.1 Descriptive Statistics on Discharge Destination

Table 4-1 presents descriptive statistics on the discharge destinations of patients in the HAC group and the comparison group. In the falls and trauma sample, 76.9% of the patients with the HAC were discharged to one of the PAC settings, while 57.4% of the patients in the control group were discharged to a PAC setting (statistically significant difference). On the other hand, patients with the HAC were significantly less likely to be discharged to home—13.7% compared to 33.7% among the controls. There is no significant difference in the likelihood of discharge to other settings between those patients with the falls and trauma HAC and the comparison group.

Table 4-1
Discharge destination for selected hospital-acquired conditions

Hospital-acquired condition	HAC group	Comparison group	Difference
Falls and trauma			
Discharged to PAC setting	76.9%	57.4%	19.5%**
Discharged home	13.7%	33.7%	-20.0%**
Other	9.4%	8.9%	0.5%
Vascular catheter-associated infection			
Discharged to PAC setting	67.9%	53.2%	14.7%**
Discharged home	25.0%	24.9%	0.1%
Other	7.1%	21.9%	-14.8%**
DVT/PE following certain orthopedic procedures			
Discharged to PAC setting	88.0%	81.8%	6.2%**
Discharge home	8.5%	13.9%	-5.4%**
Other	3.5%	4.3%	-0.8%**

NOTES: HAC = Hospital-acquired condition; PAC = Post-acute care; DVT/PE = Deep vein thrombosis or pulmonary embolism

**indicates statistically significant difference using negative binomial regression with $p<0.01$.

SOURCE: falls_pac_descriptive.log, vcath_pac_descriptive.log, dvt_pac_descriptive.log

In the vascular catheter-associated infection sample, 67.9% of the patients with the HAC were discharged to a PAC setting, compared with 53.2% of the patients in the control group (statistically significant difference) Patients with the HAC were discharged home at the same rate as patients in the control group, leaving a significant difference in the rate of discharge to other settings.

In the DVT/PE sample, there were significant differences between the HAC group and the comparison group for all discharge destinations, with the HAC group more likely to be

discharged to a PAC setting (88.0% vs. 81.8%) and less likely to be discharged home (8.5% vs. 13.9%).

4.2 Relationship between Discharge Destination and the Likelihood of Readmission

Table 4-2 illustrates the relationship between the likelihood of readmission and whether the patient was discharged to a PAC setting for patients in the HAC and comparison groups. The results indicate that patients discharged to PAC settings are more likely to be readmitted within 30 days than those patients who were not discharged to PAC settings.

Table 4-2
Relationship between discharge to a post-acute care (PAC) setting and the likelihood of readmission for beneficiaries in the hospital-acquired condition and comparison groups

Hospital-acquired condition	Likelihood of readmission: HAC group	Likelihood of readmission: Comparison group
Falls and trauma		
Discharged to PAC setting	23.7%	19.8%
Not discharged to PAC	19.7%	14.5%
Vascular catheter-associated infection		
Discharged to PAC setting	32.0%	30.0%
Not discharged to PAC	28.0%	16.6%
DVT/PE following certain orthopedic procedures		
Discharged to PAC setting	12.8%	9.8%
Not discharged to PAC	6.8%	5.2%

NOTES: HAC = Hospital-acquired condition; PAC = Post-acute care; DVT/PE = Deep vein thrombosis or pulmonary embolism

**indicates statistically significant difference using negative binomial regression with $p<0.01$.

SOURCE: falls_pac_descriptive.log, vcath_pac_descriptive.log, dvt_pac_descriptive.log

4.3 Probability of Discharge to a Post-Acute Care Setting

We estimated a series of mixed effect logistic models to predict the probability of discharge to a PAC setting. As we did for readmissions, we estimated each of the three models described in ***Section 2.6*** for each of the HACs. Based on the results of these models, we present the results of Model II for falls and trauma and vascular catheter-associated infection. We do this, because the random effect on the HAC indicator is insignificant for each of these HACs. We present the results of Model III for the DVT/PE sample, due to the fact that the random effect on the HAC indicator is significant for this HAC. The model results are reported in ***Table 4-3***.

Table 4-3
Multivariate regression models for the likelihood of discharge to a post-acute care setting

Variable	Falls and trauma (n=78,827)	Vascular catheter-associated infection (n=44,981)	DVT/PE following certain orthopedic procedures (n=41,432)
HAC Indicator	**2.668****	**1.943****	**1.393****
Hospital-Level Covariates			
Urban	1.311**	1.390**	1.891**
Number of beds (reference is "fewer than 100"			
100-299	1.320**	1.093	2.226**
300 or more	1.297**	1.042	2.585**
Academic medical center	0.858**	0.894*	1.110
Discharge-Level Covariates			
Age (reference is "less than 65")			
65-74	1.570**	1.453**	1.363**
75-84	2.074**	1.925**	2.550**
85 and older	2.630**	1.968**	3.009**
Enrolled in Medicaid	1.175**	1.180**	1.199**
Original eligibility (reference is "aged")			
Disabled	1.107**	1.144**	1.351**
ESRD	0.711**	0.740**	1.625
Gender: Female	1.368**	1.145**	1.533**
Race (reference is "white")			
Black	1.229**	0.948	1.321**
Asian	0.584**	0.925	1.249
Other	1.011	0.809**	1.032
Institutionalized	1.333	0.881	0.293
Yale Comorbidity Measures			
Severe infection	0.907	0.962	1.141
Other infectious disease	1.220**	1.081	0.810
Metastatic cancer/acute leukemia	0.701**	0.618**	0.833
Severe cancer	0.702**	0.835**	0.840
Other major cancers	0.912**	1.102*	1.074
Diabetes mellitus	1.105**	1.098**	1.149**
Protein-calorie malnutrition	1.276**	1.173**	1.512
End-stage liver disease	0.932	0.844*	1.068
Other hematological disorders	0.825**	0.537**	2.084*
Drug and alcohol disorders	0.852*	0.870*	1.616
Psychiatric comorbidity	0.938	1.061	1.405*
Hemiplegia, paraplegia, paralysis and functional disability	1.310**	1.564**	1.093
Seizure disorders and convulsions	1.055	1.070	1.303
Congestive heart failure	0.913**	0.944*	0.907
Coronary atherosclerosis or angina, cerebrovascular disease	0.956*	1.022	0.904
Specified arrhythmias	1.023	1.029	1.044
COPD	0.924**	1.026	1.237**

(continued)

Table 4-3 (continued)
Multivariate regression models for the likelihood of discharge to a post-acute care setting

Variable	Falls and trauma (n=78,827)	Vascular catheter-associated infection (n=44,981)	DVT/PE following certain orthopedic procedures (n=41,432)
Dialysis status	0.796**	0.740**	0.756
Ulcers	1.682**	1.360**	1.039
Septicemia/shock	1.328**	1.227**	1.182
Cardio-respiratory failure and shock	1.064	1.173**	0.856
Acute renal failure	1.018	0.976	1.142
Pancreatic disease	0.751**	0.796**	0.947
Rheumatoid arthritis and inflammatory connective tissue disease	1.137**	0.961	1.230*
Respirator dependence	1.585**	1.333**	1.369
Transplants	0.916	0.740**	1.047
Hip fracture/dislocation	2.395**	1.527**	1.299*

NOTES:

* indicates statistically significant difference using negative binomial regression with $p<0.05$.

**indicates statistically significant difference using negative binomial regression with $p<0.01$.

SOURCE: falls_pac_re_models.log, vcath_pac_re_models.log, DVT melogit Jun2012 Req2.log

The main finding is that the presence of each HAC is associated with a greater likelihood of discharge to a PAC setting. The odds of being discharge to a PAC setting is 2.7 times greater for patients with the falls and trauma HAC, two times greater for patients with the vascular catheter-associated infection HAC, and 40% greater for patients with the DVT/PE HAC than for similar patients without the HACs.

Among the hospital-level covariates, we find that patients discharged from teaching hospitals are generally less likely to be discharged to a PAC setting, while patients from medium and large hospitals (those with at least 100 beds) are more likely to be discharged to a PAC setting than patients from smaller hospitals (those with fewer than 100 beds). Patients from urban hospitals are more likely to be discharged to a PAC setting than patients from rural hospitals.

Among the discharge-level covariates, we find that women are more likely to be discharged to a PAC setting than men and that there is a positive relationship between age and the likelihood of being discharged to a PAC setting. Medicaid enrollees are more likely to be discharged to PAC settings than non-enrollees, while patients who were initially eligible for Medicare due to disability are more likely to be discharged to a PAC setting than patients who became eligible due to age. Interestingly, patients with a history of ESRD are less likely to be discharged to a PAC setting, at least in two of the samples (falls and trauma and vascular catheter-associated infection), although these sample sizes are quite small, 126 and 316 in the HAC groups, respectively.

The results on the co-morbidity measures are mixed. Several of the measures that are significant are associated with a greater likelihood of PAC admission, but about half are associated with a smaller likelihood of PAC admission. It is likely that these co-morbidities are related to discharge to other inpatient settings that are not included in our PAC measure.

This page intentionally left blank.

SECTION 5
SPECIAL STUDIES

5.1 Potential Under-Coding of Hospital-Acquired Conditions

5.1.1 Introduction

In the Phase II report for this task, "Readmissions Due to Hospital-acquired Conditions (HACs)," we developed a mathematical model of readmission estimation bias that can occur when there is error in the measurement of hospital-acquired conditions, particularly when HACs are not reported. This can occur when clinical manifestation of the HAC occurs after the initial hospital discharge, such as for a SSI, or under-reporting by hospital staff. In this section, we focus on under-reporting of HACs on hospital claims, and in ***Section 5.2***, we look more closely at post-discharge presentation of HAC-related conditions and post-discharge treatment that could be an indicator of a HAC-related condition.

The model demonstrates how one hospital can have a higher reported HAC rate if (a) it has more infections in general than average, and/or (b) if it has a higher likelihood of reporting its HACs. Conversely, a hospital with a lower-than-average HAC rate may truly have fewer HACs than other hospitals, or it may be under-reporting the incidence of HACs. Thus, two hospitals may have the same reported HAC rates but different readmission rates per admission leading to little correlation between the presence of a hospital-acquired condition and the likelihood of a readmission. It is also possible that one hospital has a lower reported HAC rate yet has a higher true infection readmission rate. The paradox is explained by the fact that the HAC rate calculated from claims data reflects two factors: the hospital's true, overall, HAC rate (once unreported, post-discharge, infections are accounted for) as well as the hospital's rate at which it reports HACs. The latter term may be both positive and negative; thus, an ambiguous net effect on the overall readmission rate. The reported or coded HAC rate can also vary positively or negatively with hospitals' overall infection rate. Thus, it is possible that a hospital has a high reported infection rate of all infections but a low readmission rate, thereby producing a zero correlation of reported HAC rates with readmission rates.

Model Implications. Conceptually, we would expect that the relationship between HAC rates and readmission rates to be positive; a HAC worsens a patient's health and could require multiple hospitalizations to treat. However, the "observed HAC" measure is imperfectly sensitive by failing to capture all true HACs. As a result, the observed relationship between HAC rates and readmission rates will not match the true relationship.

If the sensitivity is unrelated to the readmission rate and does not vary across providers, then this situation is analogous to the classic errors-in-variables regression problem, and the correlation between observed HAC rates and readmission rates will be lower than the true correlation. This biases the reported HAC coefficient in any readmission model towards zero, producing an under-estimate of the effect of true HACs on readmissions.

However, it is quite likely that the sensitivity of the observed HAC measure does vary systematically across providers (and type of HAC). To see this, consider two hospitals which differ only in their length of stay. One hospital tends to discharge patients as quickly as possible, whereas the second hospital tends to permit patients to stay in the hospital longer. In this

hypothetical situation, we assume that the procedure infection rates and other aspects of underlying quality are identical but only the lengths of stay differ. In the early-discharge hospital, the infection may not be identified until after the patient is discharged. The inpatient HAC rate for this hospital will be low, but the readmission rate will be high. In contrast, in the second hospital, since the underlying length of stay is longer, the HAC may be identified and treated in the hospital prior to discharge (even further lengthening that patient's stay length). Assuming the patient is discharged with the HAC fully treated, no readmission would be necessary. Thus, the second hospital's reported inpatient HAC rate will be high, but its readmission rate will be low.

This confounding relationship between observed inpatient HAC rates and readmission rates is due to the fact that hospitals vary on two dimensions. First, hospitals vary in their true HAC rates because of differences in their quality of care. Second, hospitals will vary in their lengths of stay (or any other factor that would impair the sensitivity of the HAC measure). To counteract the confounding length of stay effect, one option must be to extend the time window for measuring (recording) HACs into the post-discharge period. Using readmissions to enhance the measure of true HAC rates can significantly improve the sensitivity of the initial HAC measure and produce a higher, more accurate estimate of the HAC-readmission link. Care must be taken, however, in inferring a HAC when using readmission data. Infections not acquired during the earlier admission will likely be picked up in using readmission data and make the measure somewhat less specific. Readmission data will also be imperfect to the extent that infections and other late-appearing HACs are treated in an ambulatory setting without a subsequent readmission. The modeling suggests taking a careful look at the complex relationship between a very imperfectly measured estimate of hospital-acquired conditions and any subsequent readmission rates. The shorter the window, the greater the likelihood that a HAC had gone unreported during the earlier hospitalization. It also calls for using non-readmission claims to track ambulatory follow-up of HACs (e.g., physician and outpatient department bills).

5.1.2 Data and Methods

From the twelve hospital-acquired conditions included in the HAC-POA payment policy, we selected seven for this analysis. Foreign object retained after surgery, air embolism, and blood incompatibility were excluded due to their relative infrequency in the hospital claims data. For the remaining HACs – pressure ulcer stage III and IV, falls and trauma, catheter-associated urinary tract infection, vascular catheter-associated infection, manifestations of poor glycemic control, surgical site infections (included mediastinitis following CABG, SSI following certain orthopedic procedures, and SSI following bariatric surgery for obesity), and DVT/PE following certain orthopedic procedures – we constructed an episode of care file containing all IPPS hospitalizations in FY 2009 and FY 2010 with at least one of these conditions coded as hospital-acquired (POA indicator equal to "N" or "U"). In order to allow for a 30-day follow-up period after the initial (or "index") hospitalization, we excluded IPPS discharges that occurred on or after September 1, 2010 (approximately 4% of the initial sample).

For each of these HACs, we selected a comparison sample of IPPS hospitalizations that 1) did not have any of these HACs coded on the hospital claim, 2) did not have any of these HAC-related conditions coded as present on admission (POA indicators equal to "Y" or "W"), and 3) did not have any of these HAC-related diagnosis codes as the primary diagnosis on the claim. Since

all hospital patients are potentially at risk for hospital-acquired pressure ulcer or falls and trauma, we selected a 5% sample of all of the claims that met the above criteria. To look for evidence of the manifestations of poor glycemic control HAC, we used a comparison group of 5% of IPPS claims that had a principal diagnosis of diabetes (ICD-9_CM diagnosis codes 250.00 – 250.99), since diabetic patients would be those at most at risk for poor glycemic control.

The remaining HACs, being specific to particular procedures or surgeries, had comparison groups selected based on the presence of ICD-9_CM procedure codes on the hospital claim. To check for under-coding of catheter-associated UTI, we selected all IPPS claims with a urinary catheter procedure code (57.94 or 57.95); note that this procedure code greatly under-estimates the actual rate of urinary catheters among hospital patients, as evidenced by the fact that only 5% of IPPS claims with a catheter-associated UTI have one of the urinary catheter procedure codes. We looked for evidence of vascular catheter-associated infections among a 25% sample of IPPS index claims that had a vascular catheter ICD-9_CM procedure code (38.93 or 38.95). For the three SSIs considered, we used the entire set of claims with the specified surgical procedures as our comparison sample, and for DVT/PE following certain orthopedic procedures, we took a 50% sample of all total hip replacement and total knee replacement surgeries to use for the population at risk for a DVT/PE. The sampling that we chose allowed us to significantly reduce computational time of these analyses while maintaining large enough comparison samples to find evidence of HAC under-coding. When presented in the following tables and descriptions, all samples have been adjusted to reflect 100% of the population; for example, any frequencies for the comparison sample of diabetic patients have been multiplied by 20 to reflect their size in the entire at-risk population in the FY 2009 and FY 2010 MedPAR files.

After selecting the IPPS index claims with HACs and the at-risk comparison samples for each of the HACs, we then used the unique beneficiary identifiers and admission and discharge dates on the index hospital claims to link physician claims that occurred during the index hospitalization to the hospital claim. Approximately 2% of index hospital claims had no linked physician claims. For index hospital claims that were linked to physician claims, we examined the reported diagnosis codes on both types of claims to look for evidence of HAC-related conditions.

We also looked forward 30 days from the hospital discharge date to identify any hospital readmissions that occurred for the beneficiaries in our sample, in order to examine readmission rates for those with and without hospital- and physician-identified HAC-related conditions. This analysis was limited to the hospital-acquired infections (catheter-associated UTI, vascular associated-catheter infections, and SSIs) and DVT/PE following certain orthopedic procedures.

For our analysis of post-discharge clinical presentation of infections and DVT/PE, we linked inpatient and outpatient Medicare claims – hospital, SNF, IRF, LTCH, outpatient, and physician claims – that occurred within 30 days of the index hospital discharge—and report frequency of post-discharge reporting of the HAC-related conditions and rates of readmission within 30 days. We restrict the reporting to only institutional claims. Using the outpatient claims, we further examined claims with HCPCS codes for antibiotic administration, to examine post-discharge treatment consistent with HAC-related infections.

5.1.3 Correlation Between Hospital-Acquired Conditions Coded on Hospital Claims and Hospital-Acquired-Related Conditions Coded on Physician Claims

One way in which to determine the potential extent of under-coding of HACs on hospital claims is to compare the diagnosis codes on the hospital claims with the diagnosis codes on physician claims that were billed for the same patient during the hospitalization. In ***Table 5-1***, we show the frequencies of the HAC diagnosis codes on the hospital and the physician claims, for both the HAC populations and the at-risk comparison samples. In the first row, we present the number of index claims that had neither a hospital nor a physician diagnosis code of a HAC-related condition. The vast majority of claims in our analysis fall into this category. The second row shows, for each of the HACs in the analysis, the number of claims where the HAC is not coded on the index MedPAR hospital claim, but at least one physician claim linked to the index hospital claim has one of the HAC-related diagnosis codes. This is our set of potentially under-reported HACs.

Some of these HAC-related conditions identified on the physician claims but not on the hospital claim may have actually been coded on the hospital claim, but not picked up by the MedPAR file and used for determining payment. Prior to January 2012, hospitals were not required to submit claims using the 5010 electronic format, which captures up to 24 secondary diagnosis codes. The older system captured only 8 secondary diagnosis codes. So while the HAC-related diagnosis code may have actually been reported on the hospital claim, for the purposes of analysis using pre-2012 hospital claims data, these HACs go unreported.

Appendix Table 4 provides some evidence that HAC diagnosis codes were reported after the eighth secondary diagnosis code on the hospital claims. In this table, we show the rates of HAC coding in FY 2010, when only the first 8 secondary diagnosis codes on the claim were recorded, compared to the rates of HAC coding in FY 2011 for those hospitals that began using the 5010 electronic format earlier than January 2012 and could report up to 24 secondary diagnosis codes. We found that hospitals using the 5010 electronic format represented about 94% of claims in FY 2011. As we would expect, for almost all of the HACs,[2] pressure ulcer stages III and IV, catheter associated urinary tract infection(CAUTI), vascular catheter associated infection(CLABSI), surgical site infections(SSIs), mediastinitis, following coronary artery bypass graft surgery, following certain orthopedic procedures, following bariatric surgery for obesity, and manifestations of poor glycemic control, the HAC rates increase when more diagnosis codes are used in the FY 2011 data. For example, see the Number of Discharges Identified as a HAC per Thousand for pressure ulcers stage III and IV. In FY 2010, there were 0.14 discharges per thousand with a pressure ulcer HAC, while in FY 2011, among the claims where up to 24 secondary diagnosis codes could be reported, the rate increased to 0.20.

---

[2] Interestingly, HAC rates fall for both falls and trauma and DVT/PE following certain orthopedic procedures between FY 2010 and FY 2011, despite the fact that more diagnosis codes are used in FY 2011. This could reflect a significant, system-wide reduction in these HACs that is larger than the effect of the increased number of diagnosis codes. It could also reflect that these HACs have a greater likelihood of facing a payment penalty, and thus there is a greater incentive for under-reporting of these HACs. From Appendix 4, we see that more than one quarter of claims with a falls and trauma HAC face a payment penalty, and more than 40% of DVT/PE HAC claims face a payment penalty.

Therefore, some of the under-reporting we see in Table 5-1 is likely due to the limitation of 8 secondary diagnosis codes.

Table 5-1
Frequency of hospital and physician coding of selected hospital-acquired conditions

Hospital Diagnosis of HAC	Physician Diagnosis of HAC	Pressure Ulcer – Stages III & IV[1]	Falls and Trauma[2]	Catheter-Associated Urinary Tract Infection (CAUTI)[3]	Vascular Catheter - Associated Infection (CLABSI)[4]	Manifestation of Poor Glycemic Control[5]	Surgical Site Infection (SSI), Mediastinitis following Coronary Artery Bypass Graft (CABG)[6]	Surgical Site Infection (SSI) following Certain Orthopedic Procedures[7]	Surgical Site Infection Following Bariatric Surgery for Obesity[8]	Deep Vein Thrombosis or Pulmonary Embolism (DVT/PE) Following Certain Orthopedic Procedures[9]
No	No	17,742,320	17,392,660	151,795	1,365,324	4,683,940	156,114	203,780	29,679	673,928
No	Yes	1,720	35,380	117	4,148	14,340	126	849	163	3,622
Yes	No	2,508	3,103	6,175	6,534	655	41	227	24	1,511
Yes	Yes	60	7,064	81	488	226	28	151	8	3,740
—	Total	17,746,608	17,754,207	158,168	1,376,494	4,699,161	156,309	205,007	29,874	682,801

NOTES:

[1] 2.6% of MedPAR index admissions with no hospital diagnosis of pressure ulcer, and 2.2% of admissions with a pressure ulcer HAC, were excluded because they had no linked physician claims during the hospitalization period. 5% sample of hospital claims without the HAC multiplied by 20 to estimate the full population.

[2] Includes fracture, dislocation, intracranial injury, crushing injury, burn, and other injuries. 2.6% of MedPAR index admissions with no hospital diagnosis of falls and trauma, and 2.0% of admissions with a falls and trauma HAC, were excluded because they had no linked physician claims during the hospitalization period. 5% sample of hospital claims without the HAC multiplied by 20 to estimate the full population.

[3] 2.4% of MedPAR index admissions with no hospital diagnosis of CAUTI, and 2.0% of admissions with a CAUTI HAC, were excluded because they had no linked physician claims during the hospitalization period.

[4] 2.0% of MedPAR index admissions with no hospital diagnosis of CLABSI, and 2.4% of admissions with a CLABSI HAC, were excluded because they had no linked physician claims during the hospitalization period. 25% sample of hospital claims with vascular catheter procedure without the HAC multiplied by 4 to estimate the full population.

(continued)

[5] Includes diabetic ketoacidosis, nonketotic hyperosmolar coma, hypoglycemic coma, secondary diabetes with ketoacidosis, and secondary diabetes with hyperosmolarity. 2.6% of MedPAR index admissions with no hospital diagnosis of poor glycemic control, and 2.8% of admissions with a poor glycemic control HAC, were excluded because they had no linked physician claims during the hospitalization period. 5% sample of hospital claims with diabetes without the HAC multiplied by 20 to estimate the full population.

[6] 0.2% of MedPAR index admissions with no hospital diagnosis of mediastinitis, and 0.2% of admissions with a mediastinitis HAC, were excluded because they had no linked physician claims during the hospitalization period.

[7] Includes spine, neck, shoulder, and elbow surgeries. 2.4% of MedPAR index admissions with no hospital diagnosis of SSI, and 4.5% of admissions with an SSI following certain orthopedic procedures HAC, were excluded because they had no linked physician claims during the hospitalization period.

[8] Includes laparoscopic gastric bypass, gastroenterostomy, and laparoscopic gastric restrictive surgery. 2.4% of MedPAR index admissions with no hospital diagnosis of SSI, and 5.9% of admissions with an SSI following bariatric surgery HAC, were excluded because they had no linked physician claims during the hospitalization period.

[9] Includes total hip replacement and total knee replacement. 2.2% of MedPAR index admissions with no hospital diagnosis of DVT/PE, and 2.3% of admissions with a DVT/PE HAC, were excluded because they had no linked physician claims during the hospitalization period. 50% sample of orthopedic procedures without the DVT HAC multiplied by 2 to estimate the full population.

SOURCE: MedPAR hospital claims from FY 2009 and the first eleven months of FY 2010 linked to Medicare Part B physician claims during the hospitalization.

Additionally, some of these HAC-related conditions from the physician claims could have been present on admission; the large numbers of physician-identified falls and trauma and manifestations of poor glycemic control would seem to be more likely to reflect conditions that were present on admission rather than hospital-acquired. However, it seems less likely that the infections related to specific procedures or surgeries performed during the index hospitalization would be present on the admission before the procedure or surgery occurred, meaning that some of these physician-identified diagnoses could be truly un-reported HACs. For conditions such as mediastinitis following CABG, the 126 cases of mediastinitis identified only on the physician claims are likely to be true HACs. Regardless of the source of the under-reporting, the presence of true HACs among the hospital claims identified as not having HACs has the potential to bias our analysis of readmissions.

While the numbers of physician-identified HAC-related conditions are generally small relative to the entire sample examined, they are often large relative to the number of HACs identified on the hospital claims. For example, from the set of orthopedic surgery claims that did not have a DVT/PE coded on the hospital claim (the first two rows in the table), only about 0.5% had a DVT/PE coded on a linked physician claim (3,622 out of 677,550). But when we compare that to the total number of DVT/PE HAC claims (the last two rows of the table) – 5,251 – it seems to be a much more significant number. If all of the physician-identified DVT/PE claims are true HACs, then the total count of DVT/PE HACs across the two years of data would be about 70% higher, 8,873 instead of 5,251.

The physician claims for mediastinitis also point to potential under-reporting of HACs. From the MedPAR data, a total of 156,309 Medicare claims for CABG surgery were identified and linked to at least on physician claim during the period of hospitalization. Of those claims, 69 (.04%) had a diagnosis of mediastinitis on the hospital claim. In addition to these 69 hospital-reported mediastinitis HACs, there were 126 physician claims linked to hospital claims for CABG surgeries with a physician diagnosis code for mediastinitis. If all of these 126 physician-identified cases of mediastinitis were true HACs, then this data suggests that approximately 65% of mediastinitis HACs were unreported.[3]

The third row of the table counts the claims where the HAC diagnosis code was on the hospital claim but not on the physician claim, and the fourth row shows the claims where both hospital and physician claims report the HAC. The rate of agreement between hospital and physician coding of these HACs is poor. Except for falls and trauma and DVT/PE following certain orthopedic procedures, there are more hospital-identified HACs without an accompanying physician diagnosis of the HAC than there are claims with both hospital and physician claims report the HAC. It would appear that neither hospital claims nor physician claims are fully coding all of the HACs that are occurring in the hospital.

[3] 126 physician-identified mediastinitis cases + 69 mediastinitis HACs = 195 cases of mediastinitis. 126 physician-identified mediastinitis cases ÷ 195 mediastinitis cases = .646.

5.1.4 Under-Coding of Hospital-Acquired Conditions and the Effect on Readmission Rates

Having identified a set of potentially under-coded HACs, we now examine how these under-coded HACs could affect measures of readmission rates. In ***Tables 5-2a*** through ***5-2c***, we present the 7-day, 15-day, and 30-day all-cause readmission rates for hospital claims with and without HACs, linked to physician claims with and without the HAC-related diagnosis codes. The rates presented calculate the number of discharges per 100 discharges that had at least one hospital readmission within the specified window. We limit this analysis of readmission rates to catheter-associated urinary tract infections, vascular catheter-associated infections, the three subsets of SSIs, and DVT/PE following certain orthopedic procedures.

For four of the HACs in the 7-day readmission window, and for all of the HACs in the 15-day and 30-day readmission windows, the lowest readmission rates are seen for the claims with neither a hospital- nor a physician-identified a HAC-related condition. When considering discharges with a physician-identified (but no hospital-identified) HAC-related condition, the second row in each series of 4 rows, the readmission rates are typically more similar to those of the hospital-identified HACs than to those with no HAC-related diagnoses. For example, consider the final column where we report the readmission rates for claims with certain orthopedic procedures (total hip replacement and total knee replacement), with and without a diagnosis of a DVT/PE. The readmission rate within 7 days is 3.3 per 100 discharges for surgical patients with no DVT/PE-related diagnosis code, 9.2 per 100 discharges for those with DVT/PE diagnosis code reported on the physician claim only, 7.2 per 100 discharges for those with DVT/PE diagnosis code reported on the hospital claim only, and 7.1 per 100 discharges for those with both a hospital and physician reported DVT/PE. The readmission rate for orthopedic surgery patients with no DVT/PE diagnosis is half or less than half of the readmission rate for patients with a DVT/PE diagnosis, regardless of whether the DVT/PE is coded on the physician claim or the hospital claim or both.

Table 5-2a
Readmission rates per 100 discharges for 7-day readmission window for selected hospital-acquired conditions (HACs) identified from hospital and or physician claims and for comparisons with discharges with no reported HAC

Hospital Diagnosis of HAC	Physician Diagnosis of HAC	Catheter-Associated Urinary Tract Infection (CAUTI)[3]	Vascular Catheter -Associated Infection (CLABSI)[4]	Surgical Site Infection (SSI), Mediastinitis following Coronary Artery Bypass Graft (CABG)[6]	Surgical Site Infection (SSI) following Certain Orthopedic Procedures[7]	Surgical Site Infection Following Bariatric Surgery for Obesity[8]	Deep Vein Thrombosis and Pulmonary Embolism (DVT/PE) Following Certain Orthopedic Procedures[9]
No	No	9.0	10.3	8.5	4.0	5.3	3.3
No	Yes	7.7	12.4	15.9	9.9	14.7	9.2
Yes	No	9.1	12.4	14.6	9.3	4.2	7.2
Yes	Yes	11.1	13.5	11.1	7.3	12.5	7.1

Table 5-2b
Readmission rates per 100 discharges for 15-day readmission window for selected hospital-acquired conditions (HACs) identified from hospital and or physician claims and for comparisons with discharges with no reported HAC

Hospital Diagnosis of HAC	Physician Diagnosis of HAC	Catheter-Associated Urinary Tract Infection (CAUTI)[3]	Vascular Catheter -Associated Infection (CLABSI)[4]	Surgical Site Infection (SSI), Mediastinitis following Coronary Artery Bypass Graft (CABG)[6]	Surgical Site Infection (SSI) following Certain Orthopedic Procedures[7]	Surgical Site Infection Following Bariatric Surgery for Obesity[8]	Deep Vein Thrombosis and Pulmonary Embolism (DVT/PE) Following Certain Orthopedic Procedures[9]
No	No	14.7	16.8	13.6	6.7	8.2	4.9
No	Yes	17.1	22.5	22.2	17.7	21.5	12.3
Yes	No	15.8	20.8	22.0	13.7	12.5	9.9
Yes	Yes	16.0	22.5	18.5	11.9	25.0	10.6

Table 5-2c
Readmission rates per 100 discharges for 30-day readmission window for selected hospital-acquired conditions (HACs) identified from hospital and or physician claims and for comparisons with discharges with no reported HAC

Hospital Diagnosis of HAC	Physician Diagnosis of HAC	Catheter-Associated Urinary Tract Infection (CAUTI)[3]	Vascular Catheter -Associated Infection (CLABSI)[4]	Surgical Site Infection (SSI), Mediastinitis following Coronary Artery Bypass Graft (CABG)[6]	Surgical Site Infection (SSI) following Certain Orthopedic Procedures[7]	Surgical Site Infection Following Bariatric Surgery for Obesity[8]	Deep Vein Thrombosis and Pulmonary Embolism (DVT/PE) Following Certain Orthopedic Procedures[9]
No	No	21.7	24.8	18.9	9.6	11.6	6.9
No	Yes	28.2	33.2	28.6	24.7	30.1	15.6
Yes	No	24.2	30.0	34.1	22.0	20.8	13.2
Yes	Yes	18.5	34.4	29.6	22.5	37.5	14.5

NOTES:

See Table 5-1 for frequencies for each cell, and see notes on Table 5-1 for further details on the sample

SOURCE: MedPAR hospital claims from FY 2009 and the first eleven months of FY 2010 linked to Medicare Part B physician claims during the hospitalization and linked to MedPAR inpatient claims up to 30 days after the hospital discharge.

5.2 Timing to Clinical Presentation of Selected Conditions

5.2.1 Time to Physician Diagnosis of Conditions During Hospitalization

For catheter-associated urinary tract infections, vascular catheter-associated infections, SSIs, and DVT/PE following certain orthopedic procedures that were identified on physician claims linked to the hospital claim, we looked at the dates of the relevant procedures on the hospital claim and compared them to the dates on the first physician claim with a HAC-related diagnosis, to show the amount of time that passes between the procedure and the HAC-related condition. We combined data from the physician-identified HAC-related conditions that were identified as HACs on the hospital claim with those who were not identified as HACs on the hospital claim, such that the sample sums the second and fourth rows of Table 5-1. In ***Table 5-3***, we report the time to a physician diagnosis of a HAC-related condition.

In the second row, we report the number and percent of hospitalizations (for HACs and those at risk for HACs who had a physician diagnosis of the HAC-related condition) where the physician diagnosis code of the HAC-related conditions occurred prior to the catheter insertion or surgery data. These diagnoses occurring prior to procedure could be error in coding, either of the diagnosis or procedure dates, or they could also represent conditions that were POA. CAUTI and CLABSI are more likely to occur before the procedure date, with 22.5% of physician-identified CAUTI diagnoses, and 45.9% of physician-identified CLABSI diagnoses, occurring prior to the hospital procedure date for the catheter insertion. This could be caused by a catheter being replaced (and coded) after the discovery of the infection.

Time to physician diagnosis of CAUTI and DVT/PE following certain orthopedic procedures is typically much faster than the timing to the other HAC-related infections. For CAUTI, 60% of physician-identified cases occur within 3 days of the catheter insertion procedure, and 77.5% of DVT/PE cases diagnosed by a physician occur within 3 days of the orthopedic surgery. In contrast, more than half of two of the SSIs are first diagnosed more than a week after the relevant surgical procedures. For example, for all cases of mediastinitis following CABG surgery identified on a physician claim, 35.7 % were first diagnosed between 8 and 15 days after the surgery and 44.8 % were first diagnosed 16 or more days after the surgery.

We also examined the physician specialty type for patients who had a physician-identified HAC-related condition, whether or not the HAC was coded on the hospital claims, to see what physician specialties might be potential indicators for the HAC-related conditions. In ***Table 5-4***, we present the top five physician specialties for the first physician claim linked to the hospital claim with a HAC-related diagnosis code. Infectious disease specialists were the most likely type of physician to make the initial diagnosis of the HAC-related condition for four of the five infection conditions (CAUTI, CLABSI, mediastinitis following CABG, and SSI following certain orthopedic procedures), accounting for more than 20% of initial diagnoses for these conditions. For SSI following bariatric procedures, infectious disease specialists first diagnosed 18% of HAC-related conditions.

Table 5-3
Time to presentation of selected conditions from physician claims during initial hospitalization, all claims with a physician diagnosis of selected hospital-acquired conditions

Time to Presentation	Catheter-Associated Urinary Tract Infection (CAUTI)	Vascular Catheter-Associated Infection (CLABSI)	Surgical Site Infection (SSI), Mediastinitis following Coronary Artery Bypass Graft (CABG)	Surgical Site Infection (SSI) following Certain Orthopedic Procedures	Surgical Site Infection Following Bariatric Surgery for Obesity	Deep Vein Thrombosis or Pulmonary Embolism (DVT/PE) Following Certain Orthopedic Procedures
Hospital claim with procedure linked to physician claim with HAC diagnosis codes						
Freq.	120	4,442	154	1,000	171	7,362
Percent	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Physician diagnosis of HAC-related condition prior to date of procedure						
Freq.	27	2,039	12	72	21	292
Percent	22.5%	45.9%	7.8%	7.2%	12.3%	4.0%
Physician diagnosis of HAC-related condition 0 to 3 days after procedure						
Freq.	72	1,469	8	400	33	5,708
Percent	60.0%	33.1%	5.2%	40.0%	19.3%	77.5%
Physician diagnosis of HAC-related condition between 4 and 7 days after procedure						
Freq.	9	334	10	219	24	1,160
Percent	7.5%	7.5%	6.5%	21.9%	13.8%	15.8%
Physician diagnosis of HAC-related condition between 8 and 15 days after procedure						
Freq.	10	332	55	207	63	168
Percent	8.3%	7.5%	35.7%	20.7%	36.8%	2.3%

(continued)

Table 5-3 (continued)
Time to presentation of selected conditions from physician claims during initial hospitalization, all claims with a physician diagnosis of selected hospital-acquired conditions

Time to Presentation	Catheter-Associated Urinary Tract Infection (CAUTI)	Vascular Catheter-Associated Infection (CLABSI)	Surgical Site Infection (SSI), Mediastinitis following Coronary Artery Bypass Graft (CABG)	Surgical Site Infection (SSI) following Certain Orthopedic Procedures	Surgical Site Infection Following Bariatric Surgery for Obesity	Deep Vein Thrombosis or Pulmonary Embolism (DVT/PE) Following Certain Orthopedic Procedures
Physician diagnosis of HAC-related condition between 16 days or more after procedure						
Freq.	2	268	69	102	30	34
Percent	1.7%	6.0%	44.8%	10.2%	17.5%	0.5%

NOTES:

1. Excludes 78 CAUTI HAC claims that did not have a urinary catheter procedure coded.
2. Excludes 194 CLABSI HAC claims that did not have a vascular catheter procedure coded.

See notes on Table 5-1 for further details on the sample

SOURCE: MedPAR hospital claims from FY 2009 and the first eleven months of FY 2010 linked to Medicare Part B physician claims during the hospitalization.

Table 5-4
Physician specialty from the first diagnosis of HAC-related condition, among all hospital claims linked to a physician claim with a HAC-related diagnosis code

Physician Specialty	Catheter-Associated Urinary Tract Infection (CAUTI)	Vascular Catheter-Associated Infection (CLABSI)	Surgical Site Infection (SSI), Mediastinitis following Coronary Artery Bypass Graft (CABG)	Surgical Site Infection (SSI) following Certain Orthopedic Procedures	Surgical Site Infection Following Bariatric Surgery for Obesity	Deep Vein Thrombosis or Pulmonary Embolism (DVT/PE) Following Certain Orthopedic Procedures
Number of physician-identified HAC-related diagnosis linked to hospital claim	198	4,636	154	1,000	171	7,362
Most common physician specialty (Percent)	Infectious disease specialist (31%)	Infectious disease specialist (21%)	Infection disease specialist (24%)	Infectious disease specialist (24%)	General surgery (21%)	Diagnostic radiology (46%)
Second most common physician specialty (Percent)	Ambulance service supplier (22%)	Diagnostic radiology (15%)	Plastic surgeons (14%)	Anesthesiology (22%)	Diagnostic radiology (19%)	Internal medicine (19%)
Third most common physician specialty (Percent)	Internal medicine (17%)	Internal medicine (14%)	Internal medicine specialists (12%)	Orthopedic surgery (15%)	Infectious disease specialist (18%)	Vascular surgery (6%)
Fourth most common physician specialty (Percent)	Urology (7%)	General surgery (13%)	Cardiac surgeons (9%)	Neurosurgery (9%)	Anesthesiology (11%)	Pulmonary disease (5%)
Fifth most common physician specialty (Percent)	Diagnostic radiology (5%)	Anesthesiology (8%)	Thoracic surgeons (8%)	Internal medicine (6%)	CRNA (7%)	Cardiology (5%)

NOTES:

See notes on Table 5-1 for further details on the sample

SOURCE: MedPAR hospital claims from FY 2009 and the first eleven months of FY 2010 linked to Medicare Part B physician claims during the hospitalization.

Internal medicine physician are often the first to diagnose many of the HAC-related conditions. Urologists are among the top 5 physician types for diagnosing CAUTI, and orthopedic surgeons are the third common physician specialty to diagnose an SSI following certain orthopedic procedures. Interestingly, 22% of CAUTI conditions are diagnosed by ambulance service suppliers. Recall from Table 5-3 that just over 22% of CAUTI diagnoses on the physician claims occur before the date of the insertion of a urinary catheter on the hospital claim. It is likely, then, that these infections identified by ambulance service suppliers occurred in another healthcare setting (or at home) and are coded during ambulance transfer to the hospital.

For those beneficiaries who had a DVT/PE coded on the physician claims linked to a hospital claim for certain orthopedic surgeries, the most common first physician specialty type coded was diagnostic radiology (46%), followed by internal medicine (19%), vascular surgery (6%), pulmonary disease (5%), and cardiology (5%). It is not surprising that diagnostic radiology was the most frequently coded first physician specialty and internal medicine was the next most common physician specialty as patients are referred to diagnostic radiology for testing to confirm the presence or absence of a DVT or PE, often by an internal medicine physician's assessment of a possible DVT or PE.

5.2.2 Post-Discharge Diagnosis of Conditions in Inpatient Settings

In ***Table 5-5***, we consider the sample of index claims that had neither a hospital- nor a physician-identified hospital-acquired condition, and we look for subsequent inpatient claims with diagnosis codes that are used to identify hospital-acquired conditions. We do not include any of the follow-up hospital claims where the relevant diagnosis codes are identified as being hospital-acquired (POA indicator equal to "N" or "U"), since we are looking specifically for evidence of the conditions that stem from the procedure or surgery in the index hospital claim. We also do not include any of the conditions that can occur due to poor care in any inpatient setting (pressure ulcer stages III or IV, falls and trauma, and manifestations of poor glycemic control).

The number and percent of inpatient claims (hospital, SNF, LTCH, IRF, and other inpatient claims) within the 7-day, 15-day, and 30-day window following the index hospital discharge that have the relevant diagnosis codes for each group are presented. Note that we do not refer to these as hospital-acquired conditions, because the first evidence from the claims data that these conditions occurred comes after the index hospital discharge, and thus we cannot determine if the conditions were actually acquired in the index hospitalization. Instead, we use the term "HAC-related" to refer to diagnosis codes/conditions that are considered HACs when they are coded as not present on admission (POA indicator equal to "N" or "U") in an IPPS hospital, but can present themselves in any health care setting. Some of these may have been uncoded HACs in the index hospital setting, but many may be HAC-related conditions whose clinical presentation did not occur until after the index discharge. As we saw in Table 5-3, the time to presentation for many of these HAC-related conditions, particularly the surgical site infections, can be more than 1 or 2 weeks. Short hospital stays increase the likelihood that an infection will not clinically present and be reported until after the initial hospital discharge.

Table 5-5
Time to presentation of selected conditions on inpatient claims following index hospital discharge with no hospital or physician diagnosis of selected hospital-acquired conditions

Time to Presentation	Catheter-Associated Urinary Tract Infection (CAUTI)	Vascular Catheter-Associated Infection (CLABSI)	Surgical Site Infection (SSI), Mediastinitis following Coronary Artery Bypass Graft (CABG)	Surgical Site Infection (SSI) following Certain Orthopedic Procedures	Surgical Site Infection Following Bariatric Surgery for Obesity	Deep Vein Thrombosis or Pulmonary Embolism (DVT/PE) Following Certain Orthopedic Procedures
Index hospital claim with procedure code, without HAC diagnosis codes, and linked to physician claims without HAC diagnosis codes						
Freq.	151,795	1,365,324	156,114	203,780	29,679	673,928
Percent	100%	100%	100%	100%	100%	100%
7-day window: any inpatient claim with HAC-related diagnosis codes						
Freq.	230	5,728	132	1,620	243	4,314
Percent	0.2%	0.4%	0.1%	0.8%	0.8%	0.6%
15-day window: any inpatient claim with HAC-related diagnosis codes						
Freq.	436	8,088	238	2,942	364	5,404
Percent	0.3%	0.6%	0.2%	1.4%	1.2%	0.8%
30-day window: any inpatient claim with HAC-related diagnosis codes						
Freq.	715	11,504	329	4,062	465	6,718
Percent	0.5%	0.8%	0.2%	2.0%	1.6%	1.0%

NOTES:

See notes on Table 5-1 for further details on the sample

SOURCE: MedPAR hospital claims from FY 2009 and the first eleven months of FY 2010 linked to Medicare Part B physician claims during the hospitalization and linked to MedPAR inpatient claims up to 30 days after the hospital discharge.

Within the 7-day follow-up window, about half of the claims identified with a HAC-related condition are readmissions to a hospital, which illustrates the strong relationship between post-discharge presentation of these conditions and hospital readmissions. Although a readmission to a hospital is the primary source of post-discharge diagnosis of these HAC-related conditions overall, DVT/PE is more likely to be found on a SNF claim and vascular catheter-associated infection is more likely to be found on an LTCH claim.

Even though the rates of these conditions are fairly low within our samples, the frequencies are often sizable relative to the number of hospital- and physician-identified conditions. For example, among SSI following certain orthopedic procedures, there were 1,620 cases of surgical site infections identified on inpatient claims that occurred within 7 days of the discharge from the index hospital claim where the surgery was performed, compared to 378 infections identified on the hospital claims and 849 infections identified on the physician claims only (see Table 5-1).

As these are cumulative frequencies and rates, the numbers of these conditions identified on inpatient claims increases as the follow-up window increases. Hospital readmissions are responsible for an even larger percentage of these HAC-related diagnoses in the 15-day window, around two thirds of the total, with other post-acute settings playing a less prominent role. After hospitals, vascular catheter-associated infections, mediastinitis following CABG, and SSI following bariatric surgery are most likely to be diagnosed in an LTCH, while SSI following orthopedic surgery is most likely to be diagnosed in an IRF and DVT/PE following certain orthopedic procedures is most likely to be diagnosed in a SNF.

At the 30-day window, there are more of HAC-related conditions diagnosed on the follow-up inpatient claims than on the index hospital claims alone, except for catheter-associated UTI; with the further exception of DVT/PE following certain orthopedic procedures, there are more of these conditions diagnosed on the follow-up claims than on index hospital and physician claims combined. While these may or may not have been true HACs, the presence of these conditions post-discharge is leading to more readmissions and resource use.

5.3 Post-Discharge Use of Outpatient Department Drugs for Infection Treatment

In this portion of the analysis, we used outpatient department (OPD) drug claims in the 30 days after a hospital discharge to examine post-discharge treatment consistent with HAC-related infections. We looked at four HAC-related conditions – CAUTI, SSI-mediastinitis after CABG surgery, SSI following bariatric surgery, and SSI following certain orthopedic procedures – to identify potential under-reporting of these conditions during the hospital period or clinical presentation of infections after discharge. As with the previous analyses, our initial sample contained all IPPS claims with one of these four HACs, and also those beneficiaries who did not have a reported HAC on their hospital claims, but who were identified as being at risk for a HAC due to the surgery (CABG, bariatric surgery, or orthopedic surgery) or procedure (placement of urinary catheter) that was performed during the index hospitalization. Our population of interest was the sample of beneficiaries who had at least one OPD drug claim that contained one of the Healthcare Common Procedure Coding System (HCPCS) procedure codes for antibiotics known to treat these infections.

We identified specific medications used to treat the HAC-related infections a priori through peer-reviewed literature, drug-related websites, drug reference books, and limited validation with physicians. We also identified the drugs that were used in the OPD data to treat beneficiaries with a reported HAC and compared them to the a priori list of antibiotics to ensure that these medications were included in our analysis. It should be noted that the HCPCS antibiotic codes included in this analysis are specific to antibiotics that are administered intramuscularly or intravenously. The OPD file provides a count of the number of occurrences of the antibiotic HCPCS codes at the revenue center on a claim. This means that an individual beneficiary may have multiple OPD drug claims for a specific antibiotic treatment plan that includes one or more administrations within the 30 day period. The outcome of interest in our analysis is the presence of at least one OPD drug claim for one of the specified antibiotics. In this section of the report, we present a summary of our findings for all of the four studied HACs.

In ***Table 5-6***, we present a summary of OPD drug claims 30 days after hospital discharge, for beneficiaries with and without one of the studied HACs. The first row gives the total number of hospital discharges with the HAC or at risk for the HAC. The second and third rows report the number and percent of hospital discharges with a 30-day post-discharge OPD drug claim for antibiotic treatment. The fourth row reports the most frequently administered OPD antibiotics and the percent of the total among those with OPD antibiotics.

Using mediastinitis following CABG as an example, there are a total of 156,612 discharges with CABG procedures (ICD-9_CM procedure codes 36.10-36.19) without a diagnosis code for mediastinitis on the hospital claim, and 71 discharges with CABG procedures and a hospital-acquired diagnosis of mediastinitis. Among the 156,612 discharges without a reported HAC that were at risk for mediastinitis, there are 2,401 discharges (1.5%) with OPD antibiotic drug claims appropriate for the treatment of mediastinitis. The ratio of at-risk discharges with an OPD antibiotic drug claim to reported hospital-based mediastinitis discharges is 34-to-1.

There are at least five potential reasons 2,401 CABG patients are reporting anti-infective drug use within 30 days after discharge. First, some patients may have already had an infection of another origin when admitted for the procedure and so are continuing antibiotic treatment after discharge. Second, some patients may have been infected after discharge from poor adherence to post-discharge instructions. Third, some patients could have been treated for a post-discharge infection unrelated to the surgery. Fourth, patients may have contracted a sternal wound infection that advanced to mediastinitis post-discharge. And fifth, the hospital might not have reported a mediastinitis infection during the CABG hospitalization.

Table 5-6
Outpatient department (OPD) drug claims within 30 days of hospital discharge, for patients with and without a HAC

OPD Drug Claims	Catheter-Associated Urinary Tract Infection (CAUTI): HAC group	Catheter-Associated Urinary Tract Infection (CAUTI): At-risk group	Surgical Site Infection (SSI), Mediastinitis following Coronary Artery Bypass Graft (CABG): HAC group	Surgical Site Infection (SSI), Mediastinitis following Coronary Artery Bypass Graft (CABG): At-risk group	Surgical Site Infection (SSI) following Certain Orthopedic Procedures: HAC group	Surgical Site Infection (SSI) following Certain Orthopedic Procedures: At-risk group	Surgical Site Infection Following Bariatric Surgery for Obesity: HAC group	Surgical Site Infection Following Bariatric Surgery for Obesity: At-risk group
Total of hospital claims	6,382	155,726	71	156,612	396	209,569	34	30,573
Number with 30-day post-discharge OPD drug claim for antibiotic treatment	124	3,500	2	2,401	16	2,143	0	513
Percent with 30-day post-discharge OPD drug claim for antibiotic treatment	1.9%	2.2%	2.8%	1.5%	4.0%	1.0%	0%	1.7%
Most frequently observed OPD drugs/ Percent of most frequently observed OPD drugs	Cefazolin/ 28.6% Vancomycin/ 25% Levofloxacin/ 21.4% Unclassified drugs/10.7% Ceftriaxone/ 3.6%	Vancomycin/ 26.1% Ceftriaxone/ 16.2% Cefazolin/ 12.5% Gentamicin/ 8.0% Levofloxacin/ 7.9% Unclassified Drugs/ 7.2%	Daptomycin/ 93.3% Cefazolin/ 6.7%	Vancomycin/ 37.4% Daptomycin/ 10.7% Ceftriaxone/ 10.1% Cefazolin/ 8.9%	Daptomycin/ 41.4% Vancomycin/ 26.7% Ertapenem/ 15.2%	Vancomycin/ 31.5% Daptomycin/ 21.3% Ceftriaxone/ 16.5% Cefazolin/ 8.2% Ertapenem/ 4.7%	N/A	Cefazolin/ 19.63% Vancomycin/ 15.5% Unclassified Drugs/ 13.9% Ertapenem/ 10.7% Ceftriaxone/ 10.3%

SOURCE: MedPAR hospital claims from FY 2009 and the first eleven months of FY 2010 linked to Medicare OPD drug claims up to 30 days after the hospital discharge.

The most frequently observed OPD antibiotic drugs across these four HACs are similar between both the reported and at-risk groups for each of the conditions as well as across all four HACs. This is most likely attributed to the bacterial origin of the infection and the specific antimicrobial therapy as all of these HACs have either a surgical or invasive procedure component that places patients at higher risk for an infection. For example, vancomycin, a glycopeptides antibiotic used for prophylaxis as well as treatment of infections caused by Gram-positive bacteria, is observed in all four at-risk groups and two of the three HAC groups with OPD antibiotic drug claims. (There are no observed OPD antibiotic drug claims for the 34 reported SSIs following bariatric surgery.) Gram-positive bacteria include such organisms as *Staphylococcus aureus* and *Staphylococcus epidermis*. Vancomycin is also used in the treatment of methicillin-resistant *S. aureus* (MRSA) infections that are resistant to other antibiotics. The use of vancomycin across all HACs is highest among the CABG patients who are at risk for mediastinitis (37.4% of those with OPD antibiotics received vancomycin) and lowest in the at-risk group for SSIs following bariatric surgery (15.5%). Daptomycin, a newer Gram-positive antibiotic, is used to treat skin and soft tissue infections as well as MRSA. Daptomycin claims are present in both the reported and at-risk groups for mediastinitis and SSIs following orthopedic surgery. Prescriptions for Daptomycin were not observed in OPD drug claims for SSI following bariatric surgery nor CAUTI. Clinical trials are ongoing to test the efficacy of Daptomycin in treating urinary tract infections.

When combined there are a total of 553,319 discharges used in this analysis, with only 6,883 reported HACs. Among the 552,480 discharges that are at risk but without a reported HAC, there are 8,557 discharges with one or more OPD drug claims for antibiotics appropriate for treatment of one or more of the hospital-acquired conditions. Some of these 8,557 discharges could potentially have been true HACs that were not reported by the hospital.

We observed diverse rates of potentially unreported HACs based on outpatient drug claims for CAUTI and SSIs for orthopedic, bariatric surgery, and CABG. The ratio of at-risk patient with outpatient antibiotic treatment to reported HACs ranged from .55-to-1 for CAUTI to 34-to-1 for mediastinitis following CABG. Among the studied conditions, CAUTI had the highest number of discharges with the HAC (6,382) as compared to the other three HACs. The at-risk group for CAUTI had 3,500 discharges with an OPD antibiotic claim, which was higher both in frequency terms and in percentage terms than the other three HACs. This difference may be attributed to the fact that patients with urinary catheters are at higher risk for infection due to the hospital environment and their own co-morbidities. Another explanation may be that CAUTI infections are more readily identified when they do occur in the hospital due to the recent national attention and success in implementing evidence –based procedures to prevent urinary catheter infections. Or, they manifest clinically earlier than other infections, as we saw in Table 5-3.

There are a number of limitations to using drug data to identify potentially unreported healthcare-acquired infections. One is that many of the drugs used to treat a specific HAC, such as mediastinitis, are also used to treat other infections. For instance Cefazolin may be used to treat infections related to CABG surgery, but it is also used to treat the other three HACs, as observed in our analysis. Antibiotics are prescribed based on the presenting bacterial pathogen and the results of bacterial blood cultures and drug sensitivity testing rather than the specific condition. A beneficiary with mediastinitis may present with the pathogen staphylococcus

aureus and be treated with a specific antibiotic for that pathogen and a different drug, like daptomycin for a more serious infection like MRSA. Third, beneficiaries may have more than one site at risk for infection. For example, a beneficiary undergoing a CABG procedure is at risk for both a sternal infection, mediastinitis, as well as an infection at the surgical site where the vein was harvested for the bypass graft (saphenous or internal mammary artery); these infections may be treated with different antibiotics depending on the presenting pathogen.

OPD drug claims for administered antibiotics for patients without a reported HAC provide some additional evidence that HACs related to infections are potentially unreported. Limiting the observation period for a hospital-acquired condition to just the hospitalization period may be too narrow, given the presence of these conditions in later inpatient claims and evidence of antibiotic treatment post-discharge.

SECTION 6
SUMMARY AND CONCLUSIONS

In this report, we have investigated the impact of three different HACs on the likelihood of readmission within 30 days and on the likelihood of discharge to a PAC setting. We used mixed effect logistic modeling to control for various other characteristics that may explain the likelihood of readmission and to account for the clustering of discharges within hospitals. The results suggest a very strong relationship between the presence of a HAC and the likelihood of both readmission and discharge to a PAC setting.

The relationship between the presence of a HAC and the likelihood of readmission within 30 days varied across the three HACs included in our analyses. For the falls and trauma HAC and the DVT/PE HAC, the presence of the HAC is associated with a 21 to 23% increase in the odds of being readmitted within 30 days. The presence of the vascular catheter-associated infection HAC has an even greater impact on the likelihood of readmission. It is associated with a 33% increase in the odds of being readmitted within 30 days.

The relationship between the presence of a HAC and the likelihood of discharge to a PAC setting also varied across the three HACs. The odds of being discharged to a PAC setting are 2.7 times greater for patients with the falls and trauma HAC, two times greater for patients with the catheter-associated infection HAC, and 40% greater for patients with the DVT/PE HAC compared to similar patients without the HACs. Discharge to a PAC setting does not appear to be mutually exclusive with a hospital readmission within 30 days. In fact, patients who were discharged to PAC settings were more likely to be readmitted within 30 days. This was true for patients with each of the HACs as well as for patients in our control groups.

And lastly, we examined the degree to which readmission estimation bias may be present in the Medicare claims data due to the presence of unreported HACs in the claims, using both physician claims linked to the hospital claim, and also 30 days of follow-up claims. We found that significant numbers of HAC-related conditions were reported on physician claims linked to hospital discharges where no HAC (or POA) was coded. These potentially unreported HACs could create bias in readmission estimations. There was fairly poor correspondence between HACs coded on the hospital claims and HAC-related conditions coded on the linked physician claims.

We examined physician claims linked to the hospital claims for the infection HACs and DVT/PE following certain orthopedic procedures, and found that, particularly for the SSIs, the time to clinical presentation of the infection can be more than a week, longer than the typical hospital stay for some of these surgical procedures. However, physician claims from infectious disease specialists identifying HAC-related conditions are common across many of the conditions studied during the hospitalization and could signal the presence of the infection where it is not otherwise identified on the hospital claim.

Significant numbers of HAC-related conditions are identified on inpatient claims within the 30 days following a hospitalization with the relevant HAC-related procedure or surgery. Outpatient claims data for administered antibiotics also points to potentially unreported HACs, or HAC-related conditions that manifest after the initial hospitalization.

This page intentionally left blank.

BIBLIOGRAPHY

Ashton, C.M., DelJunco, D.J., Souchek, J., et al.: The association between the quality of inpatient care and early readmission: a meta-analysis of the evidence. Med. Care 35(10):1044-1059, October 1997.

Averill, R.F., McCullough, E.C., Hughes, J.S., et al.: Redesigning the Medicare Inpatient PPS to Reduce Payments to Hospitals with High Readmission Rates. Health Care Financ. Rev. 30(4):1-15, Summer 2009.

Baser, O., Supina, D., Sengupta, N., & Kwong, L. (2010). Impact of postoperative venous thromboembolism on Medicare recipients undergoing total hip replacement or total knee replacement surgery. *American Journal of Health-Systems Pharmacy,* 67, 1438-1445.

Beckman, M., Hooper, C., Critichley, S., & Ortel, T. (2010). Venous thromboembolism a public health concern. *American Journal of Preventive Medicine,* 38, S495-S501.

Carter, K., (2010). Identifying and managing deep vein thrombosis. *Primary Health Care,* 20, 30-39.

Encinosa, W.E., and Hellinger, F.J.: The impact of medical errors on ninety-day costs and outcomes: an examination of surgical patients. HSR: Health Serv. Res. 43(6):2067-2085, December 2008.

Friedman, B., and Basu, J.: The rate and cost of hospital readmissions for preventable conditions. Med. Care Res. Rev. 61(2):225-240, June 2004.

Friedman, B., Encinosa, W., Jiang, J.H., et al.: Do patient safety events increase readmissions? Med. Care 47(5):583-590, May 2009.

Fuji, T., Takahiro, O., Shigeo, N., et al. (2008). Prevention of postoperative venous thromboembolism in Japanese patients undergoing total hip or knee arthroplasty: two randomized, double-blind-placebo-controlled studies with three dosage regimens of enoxaparin. *Journal of Orthopaedic Science*, 13, 442-451.

Geerts, W., Bergqvist, D., Pineo, G. et al. (2008). Prevention of venous thromboembolism: American College of Chest Physicians evidence-based clinical practice guidelines (8th edition).*Chest*, 133 (6), (suppl): 381S-453S.

Goldfield, N.I., McCullough, E.C., Hughes, J.S., et al.: Identifying potentially preventable readmissions. Health Care Financ. Rev. 30(1):75-91, Fall 2008.

Haines, S. (2010). Improving the quality of care for patients at risk for venous thromboembolism. *American Journal of Health-System Pharmacy*, 67, S3-S8.

Herwaldt, L.A., Cullen, J.J., Scholz, D., et al.: A prospective study of outcomes, healthcare resource utilization, and costs associated with postoperative nosocomial infections. Infect. Control Hosp. Epidemiol. 27(12):1291-1298, December 2006.

Horwitz, L., Partovian, C., Lin, Z., et al.: *Hospital-Wide (All Condition) 30-Day Risk-Standardized Readmission Measure: Draft Measure Methodology Report.* Contract no. HHSM-500-2008-0025I/HHSM-500-T0001, Modification No. 000005. New Haven, Conn.Yale New Haven Health Service Corporation/Center for Outcomes Research & Evaluation (YNHHSC/CORE), August 2011.

Huang S.S., Placzek H., Livingston J., et al. Use of Medicare claims to rank hospitals by surgical site infection risk following coronary artery bypass graft surgery. Infect. Control Hosp. Epidemiol. 2011 Aug;32(8):775-83.

Jencks, S.F., Williams, M.V., and Coleman, E.A.: Rehospitalizations among patients in the Medicare fee-for-service program. N. Engl. J. Med. 360(14):1418-1428, April 2009.

Kandilov, A., McCall, N., Dalton, K., and Miller, R.D. February 2012. *Readmissions Due to Hospital-Acquired Conditions (HACs).* Report prepared for Centers for Medicare and Medicaid Services Office of Research, Development, and Information under Contract no. HHSM-500-2005-000291. Research Triangle Park, NC: RTI International.

Kim, E., & Bartholomew, J. Venous Thromboembolism. Retrieved November 5, 2010 from http://www.clevelandclinicmeded.com/medicalpubs/diseasemanagement/cardiology/

Kohut, K. Guide for the Prevention of Mediastinitis Surgical Site Infections Following Cardiac Surgery. Association for Professionals in Infection Control and Epidemiology. 2008.

Lip, G., & Tse H. (2007). Management of atrial fibrillation. *Lancet*, 370, 604-618.

McNair, P. D., & Luft, H. S.: Enhancing Medicare's hospital-acquired conditions policy to encompass readmissions. Medicare Care & Medicaid Res. Rev. 2012; 2(2), E1-E15.

Morris, D.S., Rohrbach, J., Rogers, M., Sundaram, L.M.T., Sonnad, S., Pascual, J., Sarani, B., Reilly, P., and Sims, C.: The Surgical Revolving Door: Risk Factors for Hospital Readmission. Journal of Surgical Research, January 2011.

National Nosocomial Infections Surveillance (NNIS) System Report, data summary from January 1992 through June 2004, issued October 2004. Am. J. Infect. Control 2004; 32:470-85.

Rosenbaum, P.R., and Rubin, D.B.: The central role of the propensity score in observational studies for causal effects. Biometrika 70:41-55, 1983.

Peterson, E., Coombs, L., Ferguson, T., Shroyer, A., DeLong, E., Grover, F.,& Edwards, F., (2002). Hospital variability in length of stay after coronary artery bypass surgery: results from the Society of Thoracic Surgeons' National Cardiac Database. *Annals of Thoracic Surgery*, 74, 464-473.

Swenne, C.L., Linholm, C., Borowiec, J., Carlsson, M.: Surgical-site infections within 60 days of CABG, J. Hosp. Infect. (2004); 57(1):14-24 - Reported .5 - 5% within 60 days post discharge.

Wells, P., Borah, B., Sengupta, N., Supina, S., McDonald, H., & Kwong, L. (2010). Analysis of venous thromboprophylaxis duration and outcomes in orthopedic patients. *The American Journal of Managed Care*, 16, 857-866.

Zierler, B., Wittkowsky, A., Peterson, G., Lee, J., Jacobsen, C., Glenny, R., Wolf, F., Robins, L., Mitchell, P., Wolpin, S., Payne, T., Hendrie, P., Han, G., & Oh, H. (2008). Venous thromboembolism safety toolkit: a systems approach to patient safety. Retrieved June 26, 2012 from http://www.ahrq.gov/downloads/pub/advances2/vol3/Advances-Zierler_81.pdf.