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Analysis Report: Estimating the Incremental Costs of Hospital-Acquired Conditions (HACs)

Final Report

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ANALYSIS REPORT:
ESTIMATING THE INCREMENTAL COSTS OF HOSPITAL-ACQUIRED CONDITIONS

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EXECUTIVE SUMMARY

Introduction

Hospital-acquired conditions (HACs) can result in additional costs to patients, to third parties who pay for health care, and to the hospitals in which they occur. These costs can be generated both in the hospitalization in which the HAC occurs and in subsequent health care encounters that might not have been necessary, or might not have been as resource-intensive, if that patient did not have a HAC. In this report, we estimate the incremental effects of a HAC on Medicare Part A spending for inpatient services. We examine the effects on payments for the initial hospitalization where the HAC occurred and on subsequent admissions, and we consider both Medicare program outlays and beneficiary liabilities for Part A deductibles or coinsurance.

Empirical Approach

We began by identifying hospital claims paid under the inpatient prospective payment system (IPPS) and discharged in fiscal year (FY) 2009 that had one of the 10 selected HACs or one of the 8 previously considered candidate HACs; these were the "index" claims. We limited our sample to those claims in which the ICD-9 diagnoses associated with the HAC were coded as *not* being present on admission (POA indicator code is N or U). Using the unique beneficiary identifiers on the claims, we searched for any admissions into other inpatient sites of care—including other hospitals, long-term care hospitals (LTCHs), inpatient rehabilitation facilities (IRFs), inpatient psychiatric facilities (IPFs), and skilled nursing facilities (SNFs)—that were paid under Medicare Part A and that occurred within 90 days of the discharge from the index hospitalization. These claims were grouped as a single episode. We summed the Medicare Part A payments (including outlier payments) across all of the Medicare Provider Analysis and Review (MedPAR) claims in the episode as well as separately over each type of care facility. We also summed the beneficiary deductibles and coinsurance liabilities across all claims in the episode as well as separately for the different types of care facilities.

To create a comparable control group for our analysis, we performed a multivariable matching procedure. For each index HAC claim, we selected five IPPS claims with the same Medicare Severity diagnosis-related group (MS-DRG), sex, race, and age that did *not* have the HAC and that did not have any of the diagnosis codes related to the HAC present on admission. We used this matched control group for both our descriptive analysis and our multivariate analysis, where program cost measures were regressed on a 0/1 HAC indicator variable along with additional clinical, hospital, and geographic covariates.

We utilized bivariate (descriptive) analysis and multivariate analysis to examine the differences between the Medicare program costs and beneficiary out-of-pocket costs in (1) inpatient episodes of care for patients who had a HAC selected by the Centers for Medicare & Medicaid Services (CMS) or one that was a previously considered candidate HAC and (2) episodes for clinically comparable patients who did not have that HAC.

Our descriptive analysis presents the unadjusted differences between the Medicare program costs and beneficiary liabilities associated with a HAC and the costs associated with the matched non-HAC cases. All selected and candidate HACs were included in the analysis. We examined separately the impact of a HAC on episode payments, index payments, outlier payments, post-acute care payments, payments for acute transfers, and payments for readmissions.

In addition to the descriptive analysis, we also used a multivariate approach to analyze the matched samples. For each selected and candidate HAC chosen for the multivariate models, we estimated the incremental effect of individual HACs on two types of outcome variables: the natural log of Medicare inpatient episode payments and the actual level of beneficiary inpatient episode payments. Predictor variables included the indicator for the presence of the HAC as well as other measures capturing pre-existing patient conditions, hospital characteristics, an indicator for beneficiary death in the index admission, and state fixed effects.

Descriptive Results

Costs to the Medicare Program

For almost all of the selected and candidate HACs analyzed, the inpatient episode payments were significantly higher for the HAC episodes than for the comparable non-HAC episodes. Significant estimates of the incremental program cost attributable to the HAC ranged widely, from a low of $486 for iatrogenic pneumothorax to a high of more than $58,000 for the surgical site infection (SSI) for mediastinitis following coronary artery bypass graft (CABG).

Our measure of Medicare index payments included any outlier payments that were paid for the index IPPS hospitalization. When comparing Medicare index payments between HACs and matched comparisons, we found that either the HAC claims had statistically significantly higher index IPPS payments or there was no significant difference between the two. Among those with significantly higher payments, additional outlier payments for the HAC cases appear to be the source of most of the index payment difference. As we matched our comparison group on the basis of MS-DRGs, the only remaining differences in payments would be due to differences in hospital characteristics (such as wage index and teaching status), which affect payments. We further control for these characteristics in the multivariate analyses.

Follow-up episode payments include the payments for all inpatient sites of care that occur within 90 days of the IPPS index discharge, whether in general acute care hospitals, SNFs, LTCHs, IRFs, or IPFs. In nearly all of the selected and previously considered candidate HACs presented in this analysis, the payments for subsequent inpatient stays for the HAC cases were higher than those for the comparison non-HAC cases. Significantly higher payments for acute hospital transfers (defined as an admission to a general acute care hospital within 1 day of the index discharge date) were found for only two of the selected HACs—falls and trauma (fracture, dislocation, and intracranial injury) and SSI-mediastinitis following CABG—and for only one of the previously considered candidate HACs, *Staphylococcus aureus* septicemia. However, Medicare payments for acute readmissions were significantly higher among the HAC cases for most of the selected HACs and previously considered candidate HACs. For this study, "readmissions" included all other admissions to nonspecialty acute hospitals within 90 days of the index discharge date, regardless of the clinical reason for the admission.

Many of the selected and previously considered candidate HAC episodes had significantly higher payments for SNF admissions than did non-HAC episodes, and some had higher payments for LTCH admissions. Only a few of the HACs—falls and trauma (fracture, intracranial injury, burn, and electric shock), catheter-associated urinary tract infection (UTI), *Clostridium difficile*-associated disease, and ventilator-associated pneumonia—had significantly higher payments for other post-acute care (most of which was for IRF admissions). None of the studied HACs had significantly lower payments than the comparison episodes for any of the payment variables studied.

Beneficiary Liabilities

It was not uncommon for the beneficiaries in our sample to have no deductibles or coinsurance within the episodes of care that we built around index hospitalizations with a HAC. On average, beneficiaries who experienced a HAC in their index hospitalization faced larger deductible and coinsurance liabilities than did comparison beneficiaries who did not have a HAC. In particular, we found significant increases in liabilities for acute hospital readmissions, due largely to readmissions that triggered an additional deductible, and significant increases in liabilities for SNFs, due to increases in coinsurance days.

Multivariate Results

Multivariate modeling was limited to seven selected HACs and one previously considered candidate HAC with sufficient volume to produce reliable estimates. These HACs were

- stage III and IV pressure ulcers,
- falls and trauma: fractures,
- falls and trauma: intracranial injury,
- catheter-associated UTIs,
- vascular catheter-associated infections,
- SSIs following certain orthopedic procedures,
- deep vein thrombosis/pulmonary embolism (DVT/PE) following certain orthopedic procedures, and
- ventilator-associated pneumonia (previously considered candidate).

For each of these HACs, we estimated equations using log Medicare inpatient episode payments and (level) beneficiary inpatient episode liabilities as outcome variables. The outcome of interest was the coefficient on the indicator for the presence of the HAC in the index stay. Additional covariates included comorbidities (defined as secondary diagnoses that were coded as present on admission), hospital characteristics including Medicare payment factors, an indicator for beneficiary death in the index admission, and state fixed effects.

For each of the eight HACs used in the multivariate analysis, the models predicted Medicare episode payments to be higher for HAC cases than for non-HAC comparisons. The percentage difference in payments associated with the HAC ranged from 9 percent for ventilator-associated pneumonia to 36 percent for falls and trauma: fractures. Interpreting those coefficients at the sample mean within each HAC, we found that the estimates for the average incremental episode cost of a HAC to Medicare Part A ranged from $2,860 for DVT/PE following certain orthopedic procedures to $12,378 for vascular catheter-associated infections. Furthermore, all of the beneficiary payment models predicted liabilities for deductibles or coinsurance to be higher for the HAC episodes, and the differences were significant for all HACs except DVT/PE following certain orthopedic procedures. Estimates for the incremental beneficiary liability associated with having a HAC ranged from $700 (for ventilator-associated pneumonia) to just over $2,400 (for pressure ulcer stages III and IV), which from the descriptive analysis would seem to be largely due to additional coinsurance days in SNFs.

The bivariate (descriptive) results and the multivariate results were generally similar for both Medicare payments and beneficiary liabilities. For the eight HACs used in the multivariate analysis, the percentage difference in episode payments between HAC cases and non-HACs cases was typically smaller under the multivariate analyses, indicating that the other covariates included in the model are important and that matching of similar cases is not always sufficient to estimate incremental differences due to a HAC. In particular, risk factors based on the secondary diagnoses identified as present on admission provide further control for remaining differences between the HAC episodes and the comparison episodes within the matched sample.

Limitations

There are a few limitations to note concerning our results. Most of these limitations we plan to address in more detail in future reports for this task.

- The estimates of the incremental cost of some of the selected and candidate HACs are not statistically significantly different from zero, due in part to the very small number of these HACs. We are unable to say whether the costs of these HAC episodes are truly similar to those of non-HAC episodes or the individual analyses do not have sufficient statistical power to detect a difference.

- By matching on the final (for some of the HACs, reassigned) MS-DRG, our analysis does not reflect the possibility that the HAC diagnoses could be leading to other complications that determine the MS-DRG assignment. We thus consider our estimates to be lower bounds of the true incremental costs of these HACs. Future analyses will explore alternative approaches to the MS-DRG match to avoid this problem.

- Undercoding of true HAC events could cause us to understate the incremental cost of a HAC. HACs could be incorrectly coded as present on admission, they could appear in the later diagnosis codes that are not included in the MedPAR data, or they could be completely excluded. To partially address this issue, we remove from the comparison groups any episodes of care in which the HAC-related diagnoses appear as present on admission, either within the index hospitalization or in subsequent inpatient claims. Future analyses will explore alternatives for defining a HAC index stay that include certain subsequent clinical presentations, and they will test the sensitivity of our findings to this change.

Conclusions

Our multivariate analysis of seven of the selected HACs and one of the previously considered candidate HACs suggests that in FY 2009, CMS paid an additional $170 million across these episodes of care compared with what they would have paid if none of the HACs had occurred. This is somewhat smaller than the figure we obtain in our descriptive analysis, which estimates that the incremental cost of these eight more frequent HACs was $205 million.

For beneficiaries, the incremental liabilities associated with the HACs in our multivariate analysis were $19 million, only somewhat smaller than the $21 million suggested in the descriptive analysis. In our descriptive analysis, we see that hospital readmissions triggering additional deductibles and increased SNF utilization leading to additional coinsurance days were the primary sources of higher patient liabilities.

Preventable infections and other conditions that are hospital acquired create a significant financial burden for both the Medicare program and Medicare beneficiaries. Programs and policies that reduce the occurrence of these HACs have the potential to both improve health and reduce costs.

SECTION 1
INTRODUCTION AND REVIEW OF KEY RESEARCH ISSUES

1.1 Introduction

This report presents the initial analysis of Medicare program payments and beneficiary liabilities used to answer the following question identified in the project statement of work for Task 8.7: **"What is the incremental impact of an HAC (by each selected and candidate HAC) on CMS reimbursement, cost to the hospital, and cost to the beneficiary?"** In the Design Report prepared as Task 3 for this contract, RTI International interpreted these study questions as encompassing requests to estimate the incremental effects of a hospital-acquired condition (HAC) on each of the following:

- Centers for Medicare & Medicaid Services (CMS) reimbursement

  "CMS reimbursement" is defined as Medicare Part A program payments. Direct estimates of HAC program savings for each documented HAC (i.e., the *reductions* in Medicare program payments) are already addressed in the context of Task 4.1 of this evaluation, as part of the requested set of analytic tables used to support prospective payment system) rulemaking. In this report we address a different payment-related question, which is how to estimate the *increases* in Medicare payments for the additional services within the episode of care during which the HAC occurs that can be attributable to the HAC. We calculate Medicare program payments as the sum of Medicare payment amounts on the Medicaid Provider Analysis and Review (MedPAR) claims. These Medicare payments include the base diagnosis-related group (DRG) amount, any applicable DRG outlier amount, disproportionate share payments, indirect medical education, and total capital. We analyze Medicare payments for the initial inpatient prospective payment system (IPPS) hospital claim and for all subsequent inpatient Part A claims, including other IPPS hospitals, critical access hospitals and other non-IPPS hospitals, long-term care hospitals (LTCHs), skilled nursing facilities (SNFs), inpatient rehabilitation facilities (IRFs), and inpatient psychiatric facilities (IPFs).

- Beneficiary out-of-pocket costs

  "Cost to the beneficiary" is defined as direct costs incurred from increased liabilities for deductibles and coinsurance associated with increased services used that are attributed to the HAC. We recognize that substantial indirect costs of increased illness also occur, such as the cost associated with the lost productivity of the beneficiary and their informal caregivers, the cost associated with hiring formal care, and the burdens on informal caregivers, but estimation for these types of costs is outside the scope of this contract.

These questions will be directed at the 10 selected HACs that came under the new payment policy as of October 1, 2008 (***Table 1***), as well as the 8 previously considered candidate HACs that were originally identified as under consideration for the future (***Table 2***).

Table 1.
Definition and frequencies of CMS selected hospital-acquired conditions, FY 2009

Selected HAC	ICD-9-CM codes[1]	Number of discharges with this secondary diagnosis	Rate of discharges with secondary diagnosis per 1,000 at risk[2]	Number of discharges with this HAC[3]	HACs as a percentage of the discharges with this secondary diagnosis
1. Foreign object retained after surgery	998.4 or 998.7	541	<0.1	241	45%
2. Air embolism	999.1	36	<0.1	28	78%
3. Blood incompatibility	999.6	33	<0.1	13	39%
4. Pressure ulcer stages III & IV	707.23 or 707.24	110,859	10.7	1,282	1%
5. Falls and trauma	800-829 (fracture), 830-839 (dislocation), 850-854 (intracranial injury), 925-929 (crushing injury), 940-949 (burn), 991-994 (electric shock)	159,791	15.5	5,403	3%
6. Catheter-associated urinary tract infection	996.64 (4)	16,796	1.6	2,786	17%
7. Vascular catheter-associated infection	999.31	8,389	0.8	3,120	37%
8. Manifestations of poor glycemic control	250.10-250.13, 250.20-250.23, 251.0, 249.10-249.11, 249.20-249.21	15,654	1.5	424	3%
9a. SSI: mediastinitis following coronary artery bypass graft	519.2 in combination w/ any procedure codes 36.10 through 36.19	45	0.4	36	80%
9b. SSI: following certain orthopedic procedures	996.67 (CC) or 998.59 (CC) w/ any procedure codes: 81.01-81.08, 81.23-81.24, 81.31-81, 38, 81.83, 81.85	308	2.7	194	63%
9c. SSI: following bariatric surgery for obesity	Principal diagnosis of 278.01 w/ 998.59 w/ any procedure codes 44.38, 44.39, or 44.95	24	1.5	20	83%
10. Deep vein thrombosis & pulmonary embolism following certain orthopedic procedures	415.11, 415.19, 453.40-453.42 w/ any procedure codes 00.85-00.87, 81.51-81.52, or 81.54	3,624	8.5	2,743	76%

NOTES:

CC, complication or comorbidity; CMS, Centers for Medicare & Medicaid Services; HAC, hospital-acquired condition; ICD-9-CM, *International Classification of Diseases (9th ed.), Clinical Modification*; SSI, surgical site infection.

[1] The ICD-9 codes listed in this table conform to coding practices applicable for the FY 2009 year. Some coding will change in the FY 2011 implementation year as more specific disease categories are added.

[2] For HACs 1–8, "at risk" population includes all Medicare fee-for-service discharges subject to present-on-admission (POA) coding rules in FY 2009 file (N=10,329,361). For HACs 9(a-c) and HAC 10, "at risk" population includes only those discharges with specified surgical procedures: for SSI/mediastinitis, 104,334; for SSI/orthopedic, 112,570; for SSI bariatric, 16,391; for deep vein thrombosis and embolism/orthopedic, 426,568.

[3] "Hospital-acquired" identified as selected HAC codes with POA indicator values of N or U.

[4] Also excludes the following ICD-9-CM codes from acting as a CC or major complication or comorbidity (MCC): 112.2 (CC), 590.10 (CC), 590.11 (MCC), 590.2 (MCC), 590.3 (CC), 590.80 (CC), 590.81 (CC), 595.0 (CC), 597.0 (CC), 599.0 (CC).

Table 2.
Definition and frequencies of previously considered candidate hospital-acquired conditions, FY 2009

Previously considered candidate HAC[1]	ICD-9-CM codes[2]	Number of discharges with this secondary diagnosis	Rate of discharges with secondary diagnosis per 1,000 at risk[3]	Number of discharges with this HAC[4]	HACs as a percentage of the discharges with this secondary diagnosis
1. *Clostridium difficile* – associated disease (CDAD)	008.45	93,989	9.1	32,854	35%
2. Delirium	293.1	743	0.1	193	26%
3. Legionnaire's disease	482.84	429	<0.1	31	7%
4. *Staphylococcus aureus* septicemia	038.11, 038.12	25,850	2.5	5,741	22%
5. Methicillin-resistant *S. aureus* (MRSA)	041.12, V09.0	79,438	7.7	2,757	3%
6. Iatrogenic pneumothorax	512.1	23,972	2.3	20,836	87%
7. Ventilator-associated pneumonia	997.31	4,892	0.5	3,848	79%

NOTES:

CMS, Centers for Medicare & Medicaid Services; HAC, hospital-acquired condition; ICD-9-CM, *International Classification of Diseases (9th ed.), Clinical Modification*.

[1] Contrast-induced acute kidney injury was not included for the purposes of this report.

[2] The ICD-9 codes listed in this table conform to coding practices applicable for the FY 2009 year. Some coding will change in the FY 2011 implementation year as more specific disease categories are added.

[3] For candidate conditions 1, 2, and 4–8, “at risk” population includes all Medicare fee-for-service discharges subject to present-on-admission (POA) coding rules in FY 2009 file (N=10,329,361).).

[4] “Hospital-acquired” identified as codes with POA indicator values of N or U.

1.2 Cost From Whose Perspective?

The first issue to be addressed in designing any economic study related to HACs is that of perspective—that is, whose costs are being measured and over what time period (Graves, 2004; Stone, Larson, & Kawar, 2002). From a social perspective, the costs of preventable HACs include not only the value of resources consumed for HAC-attributable health care services (regardless of who is paying for the care) but also the value of lost productivity for patients and their informal caregivers. If considered over a short time horizon, the value of resources consumed can be captured by measuring the variable costs of added treatments; over a sufficiently long time horizon, however, all costs are variable, and total costs rather than variable costs could be appropriate. Resources can also be measured as the social or economic return on these health care dollars had they been spent on something other than excess services to address hospital-acquired illnesses.

Our perspectives for this report are not as broad as those of society, but they do include those of the payer and the patient. The outcome variables that we will use to study cost from the payer's perspective are summed from Medicare payments, and those to study costs from the beneficiary's perspective (given our limited interpretation that excludes lost income and informal caregiving) are the summed beneficiary cost-sharing amounts. These measures are straightforward and can be captured from Medicare claims. The central research design issues are thus not about metrics but about attribution—that is, how to identify the incremental portion of payments attributable to the HAC.

1.3 Key Issues in Study Design

Estimation of the impact of a HAC on payments is sensitive to a number of important specification and design decisions. These can be roughly divided into two groups: decisions regarding the comparison population and decisions regarding the estimation techniques.

With respect to appropriate comparison groups and estimation techniques to control for confounding, the key difficulty is how to design the empirical study so that observed differences in the outcome variables can be attributed to the HAC rather than to other patient or provider characteristics.

- What are the right comparison groups for each HAC? This is another way of asking, "Who belongs in the estimation sample?" For specific surgical site infections (SSIs), the comparison group should include those patients who are at risk because they have undergone the surgical procedure, but who have no SSI. For other HACs such as pressure ulcers or falls and trauma, the population at risk is technically any admitted patient, but the estimation sample could be restricted to patients at higher risk. The cost increment in all analyses should be estimated between patients with the HAC and those without the HAC-associated diagnoses at all—thus leaving out any cases where the condition is present on admission.

- What are the advantages of using different empirical strategies to control for confounding? Common approaches for identifying outcome differences between two groups in observational studies are single multivariate regression, two-stage propensity-weighted or stratified multivariate regression, two-stage multivariate regressions with instrumental variables, and a variety of matched analyses. Because HACs are rare, it can be more efficient to estimate outcome differences between two matched samples, but this is done at the expense of throwing out information on a large number of non-HAC cases that could have been informative.

- Are there significant potential endogeneity issues for some HACs, and if so, what are the modeling options to address them? For example, length of stay is a measure of exposure for certain HACs (e.g., pressure ulcers, falls, and vascular catheter-associated infections). Therefore length of stay is directly related to risk, and yet it is also strongly correlated with—in fact is often used as a proxy measure for—cost. Some studies conducted in individual facilities have access to additional data on the timing of a HAC. These data can be used to identify costs before or after the HAC and are invaluable for constructing a matching or control variable for exposure that is not also a proxy for the outcome measure. In population-based studies such as this one, unfortunately, this level of detail is rarely available.

- What is the appropriate follow-up period for capturing patient costs?[1] Anywhere from 30 to 80 percent of SSIs are said to be identified after the index stay for surgery (Yasunaga, Ide, Imamura, & Ohe, 2007), implying a clear need to collect episode-based data. From a payer or societal perspective, the relevant study period should include enough time to capture readmissions and post-acute care (PAC).

1.4 Recent Literature on the Cost of Adverse Events and Health Care-Acquired Conditions

A moderate body of clinical and economic literature addresses both prevalence and outcomes of adverse events in health care. Much of it was initially directed to the cost of adverse drug events, then later to the cost of hospital-acquired infections (HAIs). In this section we review findings from summary and review articles, as well as several empirical studies, on this topic. A selection of recent articles describing empirical work on variously defined adverse hospital events is provided in ***Appendix Table A***. The entries are divided into those using single-hospital data and those using population data (state, national, or insured). The articles are chosen to demonstrate typical approaches taken to estimate cost differences but are not intended to serve as a complete or systematic review of the literature.

After reviewing approaches found in the literature, we devote ***Section 2*** to describing our empirical approach to estimating the incremental cost of a HAC. We discuss the choices we made for identification and study design. In making our choices, we have incorporated findings from the literature review to identify study designs that are feasible for the analysis of Medicare administrative data that will (1) improve on previous population-based cost estimates and (2) exploit new research opportunities offered by the new present-on-admission data.

1 Recent rulemaking from CMS regarding value-based purchasing has a Medicare spending per beneficiary measure that captures patient costs 3 days before admission (which are inpatient costs per statute) through 30 days after discharge. CMS initially had proposed to capture 90 days after discharge but finalized 30.

1.4.1 *Findings From Methods Papers*

A consensus study from 2001 and a concept paper from 2004 provide a helpful framework for assessing the state of current research in this field. The consensus study stems from a workshop sponsored by the Centers for Disease Control and Prevention and convened to review best approaches for measurement and estimation of the economic impact of antimicrobial-resistant infections in hospitals (Howard et al., 2001). The article contains several recommendations for how to refine and standardize calculations of attributable costs of infection in order for the industry to be able to assess cost-effective strategies for prevention. While the conference focused on incremental costs of resistant infections rather than on any HAI, many of the design and methods issues apply to either study question. The conference group made the following observations and recommendations, which are directly relevant to RTI's task of estimating incremental costs of the selected and candidate HACs:

- Although most studies address only the cost perspective of the hospital, optimal decisions regarding investment in prevention need data analyzed from the perspective of payers, patients, and society. Both payer and patient perspectives need data on follow-up care.

- Cohort or case-control designs are appropriate if grouping or matching is based on type or risk of event or both. Studies must also incorporate control for underlying severity of illness using severity scoring systems such as the Charlson Co-morbidity Index, available from claims data, or Acute Physiology, Age, and Chronic Health Evaluation (APACHE), available from some clinical data.

- Preinfection length of stay may be a necessary variable to control for confounding between stays, risk of infection, and cost. In the absence of this information, instrumental variables need to be explored to identify risk of infection that is not correlated with cost or stays. For example, Howard and colleagues (2001) identified patient location within a hospital as a potential instrumental variable for an HAI, as patients located closer to infected areas of the hospital would have higher risk of developing an HAI.

- Sample sizes from single-site studies are generally too small to support the types of statistical techniques needed to control for heterogeneity in patients. Increased use of multicenter data and better designed analyses of larger administrative data are needed.[2]

1.4.2 *Empirical Studies: Examples of Methods Used to Identify Comparable Populations and Control for Confounding*

All of the studies included in Appendix Table A that address multiple HACs stratify their results by major type of condition. Nine of the 16 studies also used matching—either multivariable or propensity-score—as a technique to control for confounding. All of the

[2] See, for example, Encinosa and Hellinger (2008) and de Lissovoy et al. (2009).

matching studies matched on patient demographics (age, sex) and most also included risk factors for the adverse event, whether as specific comorbidities or as proxy measures like the Charlson Co-morbidity Index. Some studies have also matched on DRG or procedure to create more homogenous comparison groups, or they have used APACHE or nursing acuity scores. Some of the studies state their cost results as average differences in resource use between the matched samples without any further covariate control, but most of them use ordinary least squares or other multivariate techniques in their analysis of matched samples. This allows the study to match on the basis of demographics and HAC risk factors but then add hospital or market variables to control for other known cost drivers.

Many variables that are typically used to capture severity of illness are both risk factors for the HAC as well as significant predictors of resource use. This is especially true for certain types of infections and for falls, for which risk is an increasing function of length of stay. A significant potential for endogeneity exists if these variables are used either for matching purposes or as covariates in the outcome models. To avoid endogenous variable bias, matching can be done only on severity-related variables that are present on admission, or on severity-related utilization measures (e.g., days in an intensive care unit [ICU]) that are measured before the HAC presents. Three of the 16 studies listed in Appendix Table A took pre- and postevent resource utilization into account: one used inpatient days before and after the documented date of an adverse drug event as a matching variable (#1); another used preoperative length of stay as a covariate in an ordinary least-squares estimate of cost differentials between risk-matched samples of infected and noninfected coronary artery bypass graft (CABG) patients (#3); and the third used a case series for central line infections, restricted the outcome variable to cost of postevent services only, using expert opinion to distinguish HAI-attributable costs from others (#6).

Matching is often mentioned as the preferred approach when comparing outcomes for rare events because it allows for a more even distribution of covariates across the sample of “exposed” and “unexposed” observations, although some analysts prefer to include all variables associated with the risk of the event and the cost outcome in a single regression in order to take advantage of the information in the full sample. Four studies in Appendix Table A (4, 5, 8, and 15) use multiple regression instead of matching to control for confounding, and three of the matching studies (7, 9, and 10) present results from both a matched and a nonmatched approach for comparison purposes. All three studies that published results from both approaches reported that the single regression results were similar to the matched analysis results.

1.4.3 Additional Findings From Review Articles

A number of recent review articles on the economics of HAIs have drawn conclusions about study quality that are relevant to this HAC-POA evaluation task. All have commented on the need to standardize cost measurement and improve statistical methods. A 2002 systematic review focused on studies that addressed both the attributable cost of nosocomial infections and the cost of preventive interventions (Stone et al., 2002). They found 55 articles with original estimates for both types of cost, but concluded that methods were generally poor, with many studies lacking comparison groups and using inconsistent cost measures. The same year, Frye published a review of the English-language research on costs of SSIs (Frye, 2002). He commented on lack of comparability in results due to the heterogeneity of the infections studied (by site as well as by superficial compared with deep SSIs) and the relatively small number of studies dealing with more serious orthopedic and cardiac SSIs. Only two studies captured data from follow-up care, and none addressed indirect costs to the patient or family. Broex, van Asselt, Bruggeman, and van Tiel (2009) noted that earlier reviews conclude that cost studies have been fundamentally incomparable because of variation in types of SSI studied, lack of information on SSI detection methods, and small sample sizes, as well as inconsistencies in cost measures and problems with design. The Broex team reviewed 16 articles published between 2004 and 2009. Five were based in the United States, and all appeared to be based at individual facilities. They noted that techniques of matching or sample restriction were generally used to control for heterogeneity due to type of infection, but few studies controlled for underlying acuity differences in the patients even though these can be assumed to have a large influence on costs. Estimates of the magnitude of SSI-attributable costs and length of stay in these review articles vary widely, both across conditions and across study type; all of the review articles, however, report at least one article with findings where costs and stays for the most serious infections are at least doubled.

SECTION 2
EMPIRICAL APPROACH

2.1 Study Questions

The incremental cost analysis focuses on the effect of HACs on costs to the Medicare program and to beneficiaries. The following research questions are addressed.

What are the incremental effects of a HAC on total Medicare program payments across the defined episode of care? In this report, we focus on inpatient Part A payments only. We analyze payment data from the initial (or index) admission during which the HAC is coded[3]; from any subsequent general acute hospital transfers or readmissions (all cause); and from any inpatient PAC admissions to SNFs, LTCHs, and other PAC sites (all cause) as identified from the episodes constructed as described below in ***Section 2.2***. We calculate Medicare program payments as the sum of Medicare payment amounts on the MedPAR claims. These Medicare payments include the base DRG amount, any applicable DRG outlier amount, disproportionate share payments, indirect medical education, and total capital.

What are the incremental effects of a HAC on beneficiary liabilities across the defined episode of care? In this report, we consider beneficiary deductibles and coinsurance liabilities that are associated with Part A inpatient episodes of care. We calculate beneficiary liabilities from the deductible and coinsurance amounts included on the MedPAR claims.

2.2 Episode Construction

HAC episodes used in this analysis were constructed by first identifying "index" HAC admissions, which are defined as IPPS claims in which the HAC-associated diagnosis codes were not present on admission (POA indicator code equal to N or U) and, if applicable, in which the relevant procedure codes were also reported. Using the beneficiary identifiers on these HAC claims, we looked forward 90 days from the discharge date of the index hospitalization to any future admission to an inpatient site of care (hospital, LTCH, SNF, etc.). The choice of a 90-day follow-up period was based primarily on the literature reviewed (Encinosa & Hellinger, 2008; McGarry, Engemann, Schmader, Sexton, & Kaye, 2004), although we acknowledge that the appropriate follow-up period from a clinical perspective likely varies across these HACs. To the extent that the follow-up period may be too long for some of the HACs, we do not expect that this choice of follow-up period will in any way bias the results, because our estimate of interest

[3] This could include diagnostic and related therapeutic charges up to 3 days before the date of admission and including the date of admission, although the definition of "related therapeutic" was very narrow and inconsistently applied by hospitals.

is the difference in payments between patients with HACs and similar patients who do not have HACs or HAC-related diagnoses that are present on admission. To the extent that 90 days may not be long enough to capture the full incremental costs associated with the HAC, our estimates will be the lower bounds of the true cost difference between HAC patients and similar non-HAC patients.

To create the comparison groups for each of the HACs, we also constructed these inpatient-only episodes using 100 percent of IPPS hospital claims in FY 2009 as "index" claims. These comparison groups were limited to index claims that did not have the HAC diagnosis codes, regardless of the value of the POA indicator, as we discuss in the following section.

2.3 Comparison Groups

2.3.1 Matching

One method for developing a valid comparison group involves selecting episodes on the basis of a small set of clinical or demographic characteristics held in common with the specific HAC cases and then using a larger set of covariates in the outcome regressions. As described in the literature review, matching is a common technique found among empirical studies on this topic. For both our descriptive analysis and our regression analysis, we took a multivariable matching approach. Multivariable matching uses a limited number of specific characteristics and identifies controls that match on *all* of these.

To construct appropriate comparison groups for the HAC cases, we matched each index claim identified with a HAC to five claims not identified with a HAC but with the same MS-DRG and demographic characteristics (sex, race, and age) as the HAC claim.[4] Any claims with the HAC-associated diagnosis codes identified as present on admission (POA indicator code equal to Y or W) were excluded from the comparison group, because 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. Also, index claims where subsequent claims in the 90-day follow-up period had the diagnosis codes associated with the relevant HAC were excluded from the comparison group over similar concerns about miscoding in the index claim.

If any of the claims within a defined episode had a negative payment amount, that episode was dropped from the analysis, whether it was a HAC episode or a non-HAC episode.

[4] In the few cases where a 5:1 match was not obtainable, we relaxed the criteria for matching on age and chose the matches who were closest in age to the HAC patient.

Negative payments may indicate CMS payment adjustments for previous claims, and so they are not appropriate for inclusion. Differences between the HAC counts in Tables 1 and 2 and the HAC counts in subsequent tables are due to this exclusion of episodes with negative payment amounts.

For the HACs that are related to specific surgical procedures—mediastinitis following CABG, SSI following certain orthopedic procedures, SSI following bariatric surgery for obesity, and deep vein thrombosis (DVT)/pulmonary embolism (PE) following certain orthopedic procedures—the comparison groups were limited to index hospital claims that had the relevant surgical procedures. For some of the other comparison groups, additional clinical criteria from the claims data were used to narrow the comparison group, depending on how well the clinical criteria were coded among the identified HACs. For example, we limited the comparison group for the foreign object retained after surgery HAC to index hospital claims with surgical MS-DRGs; we also limited the HAC population to those with surgical MS-DRGs. Among the claims identified with manifestation of poor glycemic control as a HAC, 95 percent had diabetes as a primary or secondary diagnosis, so index claims considered for the comparison group in this HAC were limited to those with a primary or secondary diagnosis of diabetes. For the ventilator-associated pneumonia HAC claims, 89 percent had either a ventilator MS-DRG (003, 004, 207, 208, 870, 871, or 933) or a ventilator ICD-9-CM procedure code (96.70, 96.71, or 96.72); the comparison group for this HAC was limited to claims with one of these MS-DRGs or procedure codes.

However, claims-based coding was not able to help in narrowing the comparison group for some HACs. Only 5 percent of the claims coded with catheter-associated urinary tract infection (UTI) as a HAC (POA = N or U) actually have any of the procedure codes for the insertion or replacement of an indwelling urinary catheter. The urinary catheter codes may have been coded after the fifth surgical procedure code, and thus not picked up by the MedPAR data, or they may have been left off of the claim completely. Therefore, we were unable to limit our comparison to those claims for which a urinary catheter was present. We faced a similar issue with the vascular catheter-associated infection HAC, and thus we relied only on the matching criteria (MS-DRG and demographic characteristics) to limit the comparison group.

2.3.2 Avoiding Endogeneity

When designing any approach to assess the incremental effect of a HAC, it is important to avoid matching on, or otherwise controlling for, any variable that is itself influenced by the HAC. For example, although the length of an ICU stay is possibly the strongest predictor of acquiring catheter- or ventilator-associated infections, once the infection takes hold then the length of stay becomes a function of the HAC. To address this particular endogeneity issue, we use an indicator variable to identify any ICU or coronary care unit (CCU) utilization by the patient in our multivariate regressions, as opposed to a continuous measure of days in the ICU or CCU. In a similar manner, overall length of stay is an important exposure variable in predicting many of the HACs. However, using length of stay as a predictor poses a considerable methods challenge for studies such as this one that do not have access to medical record data allowing information to be separated into pre- and post-HAC events.

The problem of endogeneity can be partially addressed in Medicare claims-based analyses by using principal diagnosis or principal procedure as a matching or control variable and by excluding some or all secondary diagnoses with POA indicators of N or U from any computed comorbidity control variables.

2.4 Outcome Variables

Payment-related outcome variables were constructed from payment fields in each of the MedPAR or standard analytic files used to construct the HAC-related episodes. In addition to variables for total index hospital payments and total episode payments, separate measures were constructed for IPPS outlier payments; follow-up payments (defined as episode inpatient payments minus index hospital payments); acute hospital transfer and acute hospital readmission payments; and inpatient post-acute payments for SNFs, LTCHs, and all other PAC facilities, including IRFs and IPFs. Beneficiary cost variables include liabilities for Part A deductibles and Part A coinsurance.

2.5 Outcome Models and Sample Output Tables

2.5.1 Descriptive (Tabular) Analyses

Our initial tabular analysis presents the unadjusted differences between the Medicare program costs and beneficiary liabilities associated with a HAC and the costs associated with the matched non-HAC cases. All selected and previously considered candidate HACs are included in each table, with one table for each payment outcome. The tables are discussed in ***Section 3.1*** and presented in full in Appendices B (Medicare program costs) and C (beneficiary liabilities).

2.5.2 Multivariate Modeling

In addition to the descriptive (bivariate) analysis, we also used a multivariate approach to analyze the matched samples. We used linear regressions to estimate the outcome differentials while controlling for other patient and facility covariates. In the models concerned with the incremental impact of a HAC on the Medicare episode payments or beneficiary liabilities, the outcome equations estimated had this basic structure:

$$\ln(Y_i) = \alpha + \beta 1 HAC_i + \varphi X_i + \gamma Z_k + (\mu_s + \varepsilon). \qquad (1)$$

In this specification, *i* subscripts the discharge, *k* subscripts the index hospital, and *s* subscripts the state in which the hospital is located. For Medicare episode payments, the outcome variable *Y* was log-transformed, as is standard practice in modeling data with strongly skewed distributions. Beneficiary liabilities remained in level (dollar) amounts because of the nontrivial number of beneficiaries with zero liabilities. In this specification, *HAC* is a dichotomous variable with a value of 1 if the HAC is recorded for that episode. *X* denotes a vector of beneficiary characteristics that are known risk factors for the HAC and are known exogenous cost drivers (i.e., cost drivers that are not also a function of the HAC status). These risk factors are HAC-specific and were derived from the clinical literature. Z_k is a vector of hospital characteristics that affect payments, including teaching status, rural or urban location, ownership, bed size, and wage index. State fixed effects μ_s account for variations in practice patterns across the United States, which can affect payments and referral patterns (e.g., use of LTCHs is greater in states where more LTCHs are located). The answer to the study question is identified by the re-transformed value of β1 for the main HAC effect on Medicare episode payments (computed as ($e^{\beta 1} - 1$) and as the coefficient β1 for the main HAC effect on beneficiary episode liabilities.

Example 1: Pressure ulcers stages III and IV

Risk of this HAC is related to patient demographics and clinical status, as well as to procedure and hospital characteristics. Several important patient factors influence payments and need to be included in a regression in order to compute an unbiased estimate of the effect attributed to the HAC, including the presence of a stage I or II pressure ulcer, nutritional deficiencies, sepsis, and stroke. The full list of risk factors included in the pressure ulcer regressions is shown in ***Appendix Table D1***.

Example 2: Catheter-associated UTI

Risk of this HAC is also related to patient demographics and clinical status, as well as to procedure and hospital characteristics. As we cannot determine from the claims data who has a urinary catheter, we use clinical factors such as ICU or CCU stay and surgical service to control for patients who are more likely to have had a urinary catheter. Other risk factors for this HAC include various bladder disorders and renal failure, all of which are included as controls in the multivariate regression if they are coded as present on admission (i.e., not hospital acquired). The full list of risk factors included in the catheter-associated UTI regressions is shown in ***Appendix Table D4***.

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SECTION 3
RESULTS AND DISCUSSION

3.1 Descriptive (Tabular) Results

In this section we present the differences between the Medicare program costs and beneficiary liabilities in (1) inpatient episodes of care for patients who have a CMS selected HAC or a previously considered candidate HAC and (2) episodes for clinically comparable patients who do not have that HAC. Clinically comparable non-HAC cases were matched to the HAC cases using the methodology described in ***Section 2.3.1***.

3.1.1 Costs to the Medicare Program

Episodes of care

Table 3 (also ***Appendix Table B1***) presents the differences in the Medicare program costs associated with the entire inpatient episode of care constructed for HAC and matched comparison patients. This inpatient episode includes the index hospitalization during which the HAC occurred, transfers and readmissions to general acute care hospitals, and subsequent post-acute admissions occurring within 90 days of the discharge from the index hospitalization. For almost all of the selected and candidate HACs analyzed, the inpatient episode payments are higher for the HAC episodes than for the comparable non-HAC episodes. Only among episodes with an air embolism and episodes with a crushing injury do the HAC episodes have smaller payments than the comparison episodes, but these samples sizes are very small and the differences are not statistically significant.

Among the selected HACs with higher episode costs, estimates of the incremental program cost attributable to the HAC range widely, from a low of $951 for the foreign-object retained after surgery HAC to a high of over $58,000 for SSI-mediastinitis following CABG. The five most costly selected or previously considered candidate HACs for the Medicare program, in terms of the incremental cost per episode of care, are

- SSI-mediastinitis following CABG ($58,416 average difference, episode payments of $80,598 for comparison group),
- SSI following bariatric surgery ($40,323 average difference, episode payments of $30,400 for comparison group),
- ventilator-associated pneumonia ($19,748 average difference, episode payments of $96,156 for comparison group),

Table 3.
Estimated average difference in total episode Medicare payments for selected and previously considered candidate hospital-acquired conditions and comparison cases

Selected or previously considered candidate HAC	Number with this HAC	Payments per episode without the condition ($)	Payments per episode with the condition ($)	Amount difference per episode ($)	Total increase in payments (thousand $)
1. Foreign object retained after surgery	225	30,874	31,825	951	214
2. Air embolism	28	37,220	27,249	−9,971	−279
3. Blood incompatibility	13	23,153	31,666	8,512*	111
4. Pressure ulcer stages III & IV	1,276	42,661	59,947	17,286*	22,057
5a. Falls and trauma: fracture	4,684	26,230	33,428	7,198*	33,715
5b. Falls and trauma: dislocation	28	28,503	32,189	3,686	103
5c. Falls and trauma: intracranial injury	679	25,510	33,142	7,632*	5,182
5d. Falls and trauma: crushing injury	1	37,123	1,940	−35,183	−35
5e. Falls and trauma: burn	40	43,215	52,854	9,639	386
5f. Falls and trauma: electric shock	11	22,416	24,563	2,146	24
6. Catheter-associated urinary tract infection	2,783	27,347	33,261	5,914*	16,458
7. Vascular catheter-associated infection	3,111	39,429	52,920	13,491*	41,969
8. Manifestations of poor glycemic control	424	28,488	33,195	4,707*	1,996
9a. Surgical site infection: mediastinitis following coronary artery bypass graft	35	80,598	139,014	58,416*	2,045
9b. Surgical site infection: following certain orthopedic procedures	194	50,089	61,260	11,172*	2,167
9c. Surgical site infection: following bariatric surgery for obesity	20	30,400	70,723	40,323*	806

(continued)

Table 3 (continued)
Estimated average difference in total episode Medicare payments for selected and previously considered candidate hospital-acquired conditions and comparison cases

Selected or previously considered candidate HAC	Number with this HAC	Payments per episode without the condition ($)	Payments per episode with the condition ($)	Amount difference per episode ($)	Total increase in payments (thousand $)
10. Deep vein thrombosis & pulmonary embolism following certain orthopedic procedures	2,742	23,355	26,257	2,902*	7,957
11. *Clostridium difficile* –associated disease (CDAD)	32,826	33,963	45,022	11,059*	363,017
12. Delirium	193	28,871	37,070	8,199*	1,582
13. Legionnaire's disease	31	38,793	41,766	2,973	92
14. *Staphylococcus aureus* septicemia	5,734	44,394	57,931	13,537*	77,621
15. Methicillin resistant *S. aureus* (MRSA)	2,752	29,359	35,285	5,926*	16,307
16. Iatrogenic pneumothorax	20,829	35,582	36,068	486*	10,122
17. Ventilator-associated pneumonia	3,845	96,156	115,904	19,748*	75,933

NOTES:

HAC, hospital-acquired condition.

Comparison episodes chosen by 5:1 multivariable matching using the characteristics of the index claims with HACs.

Episodes of care begin with an index inpatient prospective payment system (IPPS) hospitalization and include any subsequent inpatient admissions to an IPPS or non-IPPS hospital, a long-term care hospital, a skilled nursing facility, an inpatient rehabilitation facility, or an inpatient psychiatric facility that occur within 90 days of the index discharge date.

Medicare episode payments are the sum of all Medicare Part A payments for the index IPPS hospitalization, including outlier payments, and all subsequent inpatient claims in the 90-day follow-up period. All other Medicare payments are excluded.

Conditions 1–10 are the selected HACs. Conditions 11–17 are the previously considered candidate conditions.

*Indicates statistically significant different from 0, with $p<0.05$.

SOURCE: RTI analysis of FY 2009 Medicare Provider Analysis and Review (MedPAR) inpatient episodes of care data

- pressure ulcers stages III and IV ($17,286 average difference, episode payments of $42,661 for comparison group), and
- *Staphylococcus aureus* septicemia ($13,537 average difference, episode payments of $44,394 for comparison group).

Note, however, that two of these five conditions have 40 or fewer observations, meaning that their overall impact on Medicare payments may not be as high as some of the more common HACs with lower incremental costs. In terms of total financial impact on CMS payments (number with the HAC multiplied by amount difference per case), the most expensive from the selected HACs is vascular catheter-associated infection ($42 million in incremental payments), and the most expensive from the previously considered candidate HACs is *C. difficile*-associated disease ($363 million in incremental payments). Although CMS saved over $23 million in FY 2009 in reduced IPPS payments for the selected HACs, our descriptive analysis estimates that the incremental cost to CMS of these 10 selected HACs was nearly $135 million over the course of the episode of care.

Index payments and index outlier payments

Differences in Medicare payments for index inpatient claims and for index outlier claims are presented in ***Appendix Table B2*** and ***Appendix Table B3***, respectively. Recall that the index payments are defined as the total Medicare payment for the index claim, which includes outlier payments.

In Task 4.1 of the HAC-POA evaluation project, the descriptive tables presented actual savings to CMS from the HAC policy, defined as the difference between Medicare payment under the HAC-POA policy and what Medicare payment would have been without the HAC-POA policy for the index stay only. The results that we present under this task represent the difference in Medicare program payments between the index hospital admissions with HACs and Medicare program payments *for similar admissions without HACs*. Because CMS payment policy prevents HACs from acting as a complication or comorbidity (CC) or major complication or comorbidity (MCC) condition that results in a higher-paying MS-DRG, we expect that index claims with HACs and index claims for similar patients without HACs would have very similar base Medicare payments. However, as was reported in the Task 4.1 report and tables, one consequence of the HAC payment policy was an increase in outlier payments for some of the patients when the presence of a HAC led to reassignment to a lower-paid MS-DRG.[5] On the basis of that finding, we also expect to find higher outlier payments in the HAC index claims than in the claims for similar patients without HACs.

In Appendix Table B2, we see Medicare payments for index inpatient claims.[6] For most of the selected HACs and previously considered candidate HACs presented, there was a statistically significant difference between the index payments for the HAC cases and the non-HAC cases. When the difference between the HAC and non-HAC cases was statistically significant, the HAC case index payments were always higher. The percent difference in payments ranged from 2 percent for falls and trauma-dislocation up to 127 percent for SSI following bariatric surgery for obesity.

Appendix Table B3 presents the Medicare payments for index outlier claims. Most of the episodes of care analyzed were not outliers and therefore had no outlier payments. The sample averages produced in these descriptive statistics include observations both with and without outlier payments in the denominator. Nearly all of the selected and previously considered candidate HACs showed statistically significant differences between HAC outlier payments and non-HAC outlier payments. To qualify for outlier payments, a claim must have costs that exceed a certain fixed-loss level. Our measure of outlier payments comes directly from the outlier payments that are recorded in the MedPAR claims file.

By comparing the dollar differences per case in Appendix Table B2 and Appendix Table B3, we see that higher outlier payments account for a significant portion of the higher payments for the index stay. Consider, for example, the incremental costs of pressure ulcers. In Appendix Table B2, we see that Medicare payments are on average $10,224 higher for the HAC cases than for the non-HAC cases. Looking at the same condition figure in Appendix Table B3, we see that CMS spent $7,143 on additional outlier payments for each pressure ulcer HAC, meaning that about 70 percent of the higher index payment for the HAC was due to higher outlier payments. As we matched our comparison group on the basis of MS-DRG, the only remaining differences in payments would be due to differences in hospital characteristics (such as wage index and teaching status), which affect payments. We further control for these characteristics in the multivariate analyses.

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[5] CMS does not have authority to reduce outlier payments for HACs. The interactive effect of placing a HAC claim in a lower weighted MS-DRG can raise the outlier payment compared with the MS-DRG's not being reassigned by the HAC policy.

[6] The estimates are presented for each condition, with falls and trauma and SSIs broken out by their component conditions, and include previously considered candidate HACs.

Payments for follow-up care

Appendix Table B4 presents the difference in inpatient Medicare payments for subsequent admissions during the defined episode of care for HAC and comparison non-HAC cases. Follow-up payments include the payments for all inpatient sites of care—IPPS hospitals, non-IPPS hospitals such as critical access hospitals, SNFs, LTCHs, IRFs, and IPFs. Payments for these sites of care were also analyzed separately by facility type. Some of the episodes of care analyzed had no follow-up claims and therefore no follow-up costs. The sample averages produced in these descriptive statistics include observations both with and without follow-up costs in the denominator. For most of the selected HACs and previously considered candidate HACs examined, there was a statistically significant positive difference in follow-up payments between the HAC and non-HAC episodes of care. The follow-up payments for the HAC cases were higher than the payments for the non-HAC cases, indicating that the presence of a HAC leads to increased inpatient care in the 90 days following the index discharge.

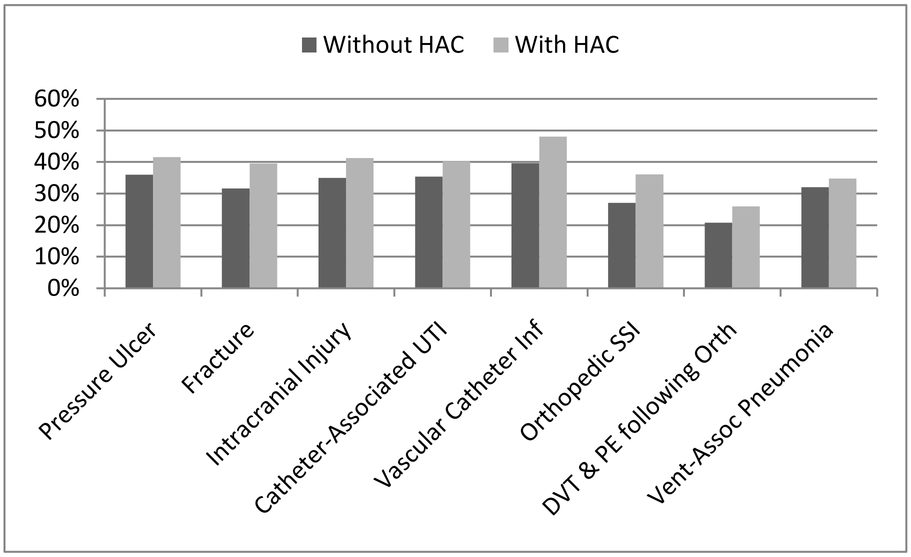
Acute transfers and acute readmission payments

We divided the payment for acute hospital admissions that followed the index admission into acute transfers and acute readmissions. An acute transfer was defined as an admission to a general acute care hospital within 1 day of the index discharge date. Readmissions included all other admissions to acute hospitals within 90 days of the index discharge date, regardless of the clinical reason for the admission. This could include readmission to a critical access hospital or to another non-IPPS hospital that is paid under Medicare Part A (such as a cancer hospital or a children's hospital). Some of the episodes of care analyzed had no acute transfer and readmissions and therefore no payments for this type of care. The sample averages produced in these descriptive statistics include observations both with and without transfer (readmissions) payments in the denominator.

From ***Appendix Table B5***, we see that the highest HAC-related incremental average Medicare payments for the acute transfers were for the fall and trauma HACs. Dislocations had the highest average payments for acute transfers ($3,653), and intracranial injuries had the second highest ($2,028). However, most of the selected HACs and previously considered candidate HACs were not associated with significantly higher payments for acute hospital transfers.

Figure 1 shows the proportion of index claims that had at least one hospital readmission during the 90-day follow-up period for eight of the larger selected and candidate HACs and their matched comparison groups. A higher proportion of the index claims identified as HACs (POA=N or U) than the comparison groups without HACs had at least one hospital readmission. Overall, hospital readmissions were highest for the vascular catheter-associated infection group and lowest for the DVT/PE following certain orthopedic procedures.

Figure 1.
Percentage with one or more all-cause readmissions within 90 days



NOTES: All differences graphed between episodes with hospital-acquired conditions (HACs) and those without HACs are statistically significantly different from zero, with $p<0.05$.

Comparison episodes chosen by 5:1 multivariable matching using the characteristics of the index claims with HACs.

Readmissions defined as all hospital admissions that occurred within 2–90 days after the index hospital discharge.

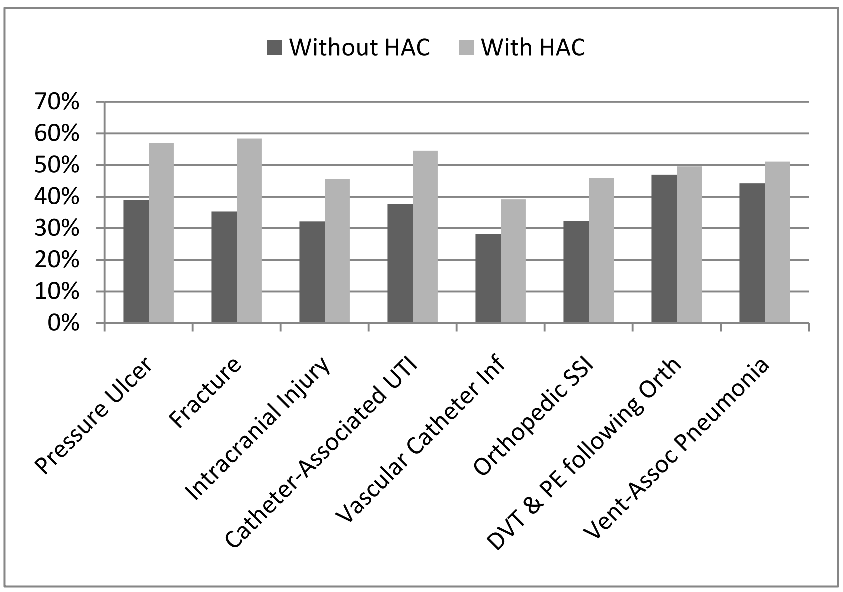
SOURCE: RTI analysis of FY 2009 Medicare Provider Analysis and Review (MedPAR) inpatient episodes of care data

In ***Appendix Table B6***, we see that Medicare payments for acute readmissions were significantly higher among the HAC cases for most of the selected HACs and previously considered candidate HACs. SSI-mediastinitis following CABG and SSI following bariatric surgery for obesity had the highest average incremental payments for acute readmissions; the Medicare program paid an average of more than $6,000 more for the readmissions in these HAC episodes than for the episodes of similar patients who did not have the HACs.

Skilled nursing facilities, long-term care hospitals, and other post-acute payments

For this analysis, post-acute inpatient care is subdivided into SNF, LTCH, and other PAC (mostly IRF but also including IPF). The average Medicare payment for each of these types of facilities where HAC episodes occurred is compared with average Medicare payment for the similar non-HAC episodes of care. Some of the episodes of care analyzed had no PAC claims and therefore no PAC payments. The sample averages produced in these descriptive statistics include observations both with and without PAC payments in the denominator. From ***Figure 2***, we see that, for eight of the more frequently occurring selected and previously considered candidate HACs, utilization of PAC is considerably higher among HAC episodes of care than among the comparison non-HAC episodes. Falls and trauma-fracture, pressure ulcer, and catheter-associated UTI cases have the highest proportions of patients with some type of PAC utilization.

Figure 2.
Percentage with any post-acute care utilization



NOTES: All differences graphed between episodes with hospital-acquired conditions (HACs) and those without HACs are statistically significantly different from zero, with p<0.05.

Post-acute care includes long-term care hospitals, skilled nursing facilites, inpatient rehabilitation factilies, and inpatient psychiatric facilities.

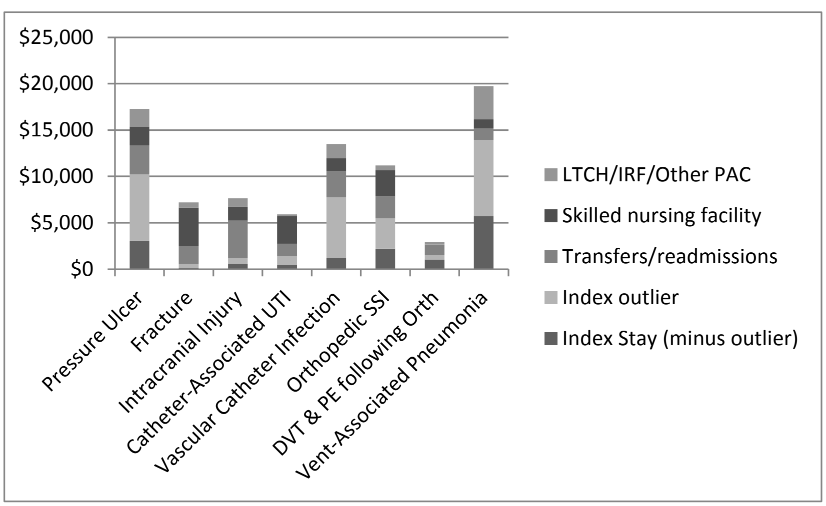
SOURCE: RTI analysis of FY 2009 Medicare Provider Analysis and Review (MedPAR) inpatient episodes of care data.

Appendix Table B7 details the payments made to SNFs for HAC-associated episodes of care and comparison non-HAC episodes. The largest differences in SNF payments due to a HAC are found among patients with falls and trauma-electric shock, SSI-mediastinitis following CABG, falls and trauma-fractures, and catheter-associated UTI. For LTCH payments (***Appendix Table B8***), patients with ventilator-associated pneumonia have the largest differences in payments between HAC and non-HAC episodes, followed by pressure ulcers and vascular catheter-associated infections. The largest differences in other PAC payments are attributable to falls and trauma patients with burns and electric shocks (***Appendix Table B9***).

Impact of different sites of care

For the seven HACs with the largest financial impact on the Medicare program (pressure ulcers, falls and trauma-fractures, falls and trauma-intracranial injuries, catheter-associated UTIs, vascular-catheter associated infections, SSIs following certain orthopedic procedures, DVT/PE following certain orthopedic procedures) and one of the previously considered candidate HACs (ventilator-associated pneumonia), ***Figure 3*** summarizes the contributions of the different sites of care to the incremental cost of a HAC. Across these HACs, we see different patterns of incremental payments arising from the different sites of care. PAC sites contribute modestly to the Medicare payments for most of the HACs in Figure 3. However, for falls and trauma-fractures and SSIs following certain orthopedic procedures, SNF payments contribute a relatively larger amount; for ventilator-associated pneumonia, LTCHs, IRFs, and other PAC contribute a relatively larger amount to the incremental Medicare payment. Furthermore, Figure 3 shows that index outlier payments contribute the largest portion to the incremental cost of a HAC for pressure ulcers, vascular-catheter infections, SSIs following certain orthopedic procedures, and ventilator-associated pneumonia but are relatively less important for the other four HACs included in the figure.

Figure 3.
Incremental Medicare Part A payments due to hospital-acquired conditions



NOTES: Comparison episodes chosen by 5:1 multivariable matching using the characteristics of the index claims with hospital-acquired conditions (HACs).

LTCH, long-term care hospital; IRF, inpatient rehabilitation facility; PAC, post-acute care (in this case, inpatient psychiatric facilities).

Transfers defined as all hospital admissions that occurred within 0–1 day after the index hospital discharge.
Readmissions defined as all hospital admissions that occurred within 2–90 days after the index hospital discharge.

SOURCE: RTI analysis of FY 2009 Medicare Provider Analysis and Review (MedPAR) inpatient episodes of care data.

3.1.2 Beneficiary Liabilities

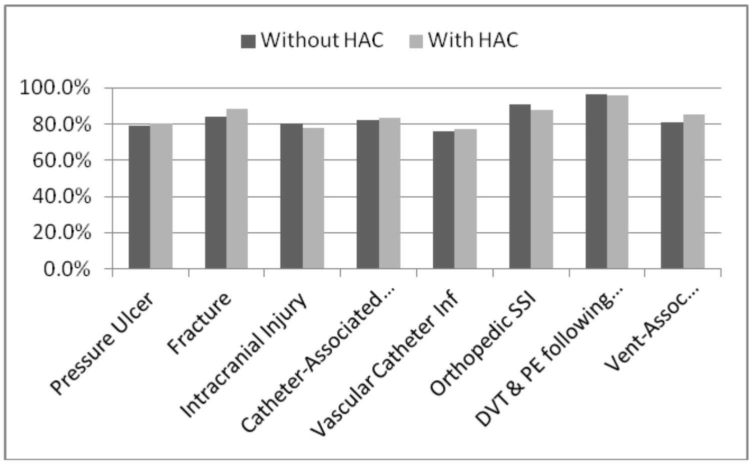
As we shift from our descriptive analysis of Medicare payments to our descriptive analysis of beneficiary liabilities, it is important to note that quite a few of the beneficiaries in our sample have no deductibles or coinsurance within the episodes of care that we built around index hospitalizations with a HAC. By definition, all of our episodes of care have nonzero Medicare payments. Beneficiaries with zero out-of-pocket liabilities are those who have met their deductibles before their index admission and are not responsible for Part A coinsurance within the episode interval that we have defined.

In ***Figure 4***, we show the proportion of beneficiaries included in the HAC group and comparison non-HAC group who have positive liabilities. The figure is limited to data for seven of the selected HACs that were among those with the largest total incremental beneficiary liabilities attributable to the HAC and for one of the previously considered candidate HACs. More than 90 percent of beneficiaries with the DVT/PE following certain orthopedic procedures had positive (nonzero) liabilities, whereas fewer than 80 percent of the beneficiaries with vascular catheter-associated infections or falls and trauma-intracranial injuries had positive liabilities. There is not necessarily a consistent relationship between the presence of a HAC and the proportion of the population that has positive beneficiary liabilities. For some HACs, the beneficiaries with the HAC are more likely to have nonzero liabilities; for others, the comparison beneficiaries are more likely to have nonzero liabilities. However, the only significant differences in the proportion of beneficiaries with nonzero liabilities are seen with falls and trauma: fractures, catheter-associated UTIs, and ventilator-associated pneumonia; in all three of these HACs, the beneficiaries with the HACs are significantly more likely to have positive liabilities.

Episodes of care

Appendix Table C1 presents the differences in the dollar amount of beneficiary Part A liabilities associated with the entire inpatient episode of care constructed for HAC and matched non-HAC patients. For most of the selected and candidate HACs analyzed, the beneficiary liabilities are higher for the HAC episodes than for the non-HAC episodes. Eight of the conditions have smaller episode patient liabilities for the HACs, but these differences are small and not statistically significant. Among the HACs with higher episode costs, there is a wide range in the estimates of the incremental beneficiary cost of the HAC, from $385 for the falls and trauma-intracranial injury HAC to $2,803 for SSI following bariatric surgery for obesity. All liability amounts reported for episodes of care and for the subsequent types of facilities below

Figure 4.
Proportion with any beneficiary liabilities within the episode of care, with and without hospital-acquired conditions



NOTES: Comparison episodes chosen by 5:1 multivariable matching using the characteristics of the index claims with hospital-acquired conditions (HACs).

SOURCE: RTI analysis of FY 2009 Medicare Provider Analysis and Review (MedPAR) inpatient episodes of care data.

are averaged across all beneficiaries who have HACs or across all comparison beneficiaries who do not have HACs. Beneficiaries with zero liabilities for the episode of care or for particular types of facilities are included in all reported averages.

Index liabilities

Differences in beneficiary liabilities for index inpatient claims are presented in ***Appendix Table C2***. For more than half of the HACs presented, there was no statistically significant difference between the index beneficiary liabilities for the HAC cases and the non-HAC cases. When the difference between the HAC and non-HAC cases was statistically significant, the HAC case index liabilities were higher. Among the HACs with significantly higher index costs, the difference in liabilities ranged from $26 for the iatrogenic pneumothorax cases up to $2,102 for SSI following bariatric surgery for obesity.

Follow-up liabilities

Appendix Table C3 presents the difference in inpatient follow-up beneficiary liabilities for HAC and comparison non-HAC cases. Follow-up care includes both hospitalizations and PAC that occur within 90 days of the index discharge. The difference in inpatient follow-up beneficiary liabilities for the HAC cases compared with the non-HAC cases was significant for about half of the selected HACs and previously considered candidate HACs. When the difference between the HAC and non-HAC cases was statistically significant, the HAC case index liabilities were higher.

Acute transfers and acute readmission liabilities

From ***Appendix Table C4***, we see that the HAC-related incremental beneficiary liabilities for the acute transfers were small. Most of the selected and previously considered candidate HACs did not have payments that were significantly different from those for acute transfers without HACs. The significant differences were typically less than $50, with the largest difference being $171. In ***Appendix Table C5***, we see that beneficiary liabilities for acute readmissions were significantly higher for the HAC cases for many of the selected HACs and previously considered candidate HACs. The significant differences in liabilities for readmissions range from $29 for DVT/PE following certain orthopedic procedures to $568 for vascular catheter-associated infection. These differences in acute readmission liabilities are largely due to additional deductibles beneficiaries must pay for a hospitalization once they have been out of the hospital for at least 60 days.

Skilled nursing facilities, long-term care hospitals, and other post-acute care liabilities

The average beneficiary liabilities for SNFs, LTCHs, and all other inpatient PAC in HAC episodes is compared with beneficiary liabilities for similar non-HAC episodes. As with the readmissions, these averages include in the denominator observations both with and without PAC. ***Appendix Table C6*** presents the differences in beneficiary liabilities associated with the entire inpatient episode of care constructed for HAC and matched non-HAC patients for SNF care. The difference in beneficiary liabilities is significant for about half of the selected HACs and previously considered candidate HACs, and the significant differences were higher for the HAC cases. The difference in average liabilities for LTCHs (***Appendix Table C7***) is significantly higher for only a few of the presented HACs and not significantly different for the rest compared with non-HAC cases. Last, ***Appendix Table C8*** shows that for only a few of the selected HACs and previously considered candidate HACs, the beneficiary liabilities for other PAC settings are significantly higher for HAC cases than for non-HAC cases, but these liability differences are small. PAC difference in beneficiary liabilities seems to be driven by differences in SNF liabilities, due to increased coinsurance days for the HAC episodes of care.

3.2 Multivariate Results

In this section, we describe the results from our multivariate analyses. Multivariate modeling was limited to the following seven selected HACs and one previously considered candidate HAC with sufficient volume to make such modeling relevant:

- stage III and IV pressure ulcers
- falls and trauma: fractures
- falls and trauma: intracranial injury
- catheter-associated UTI
- vascular catheter-associated infection
- SSI following certain orthopedic procedures
- DVT/PE following certain orthopedic procedures
- ventilator-associated pneumonia (previously considered candidate HAC)

For each selected and candidate HAC considered in the analysis, we estimated our equations using log Medicare inpatient episode payments and (level) beneficiary inpatient episode liabilities. The results of these regressions are reported in full in ***Appendix D***.

3.2.1 Costs to the Medicare Program

The first columns in ***Appendix Table D1*** through ***Appendix Table D8*** present the results for the multivariate analysis with log Medicare inpatient episode payments as the dependent variable. As described in ***Section 2.5.2***, the regressions were estimated separately for each condition and included an indicator for the HAC, risk factors for the conditions that were present on admission, hospital characteristics, an indicator for beneficiary death in the index admission, and state fixed effects.

For each of the eight HACs used in the multivariate analysis, the models predicted episode payments to be higher for HAC cases than for non-HAC comparisons. The coefficients on all of the HAC indicators (the first independent variables listed in the tables in ***Appendix D***) were statistically significant. The percent difference in payments associated with the HAC ranged from 9 percent for ventilator-associated pneumonia to 36 percent for falls and trauma: fractures.[7] In ***Table 4***, we compare the percent difference in Medicare episode payments from

[7] The models regress the log of Medicare payments on the HAC indicator and other variables. The expected percent change in the outcome variable associated with a binary dependent variable is obtained by

the bivariate (descriptive) analysis with the percent difference estimated in the multivariate analysis.

Table 4.
Percent differences in Medicare payments for inpatient episodes of care

Selected or previously considered candidate HAC	Number with this HAC	Percent difference between HACs and matched non-HACs	Percent difference between HACs and matched non-HACs, multivariate regression results
4. Pressure ulcer stages III & IV	1,276	41%	26%
5a. Falls and trauma: fracture	4,684	27%	36%
5b. Falls and trauma: intracranial injury	679	30%	34%
6. Catheter-associated urinary tract infection	2,783	22%	24%
7. Vascular catheter-associated infection	3,111	34%	30%
9b. Surgical site infections: following certain orthopedic procedures	194	22%	14%
10. Deep vein thrombosis & pulmonary embolism following certain orthopedic procedures	2,742	12%	12%
17. Ventilator-associated pneumonia	3,845	21%	9%

NOTES: HAC, hospital-acquired condition.

All differences are statistically significantly different from 0, with $p<0.05$

Comparison episodes chosen by 5:1 multivariable matching using the characteristics of the index claims with HACs. Multivariate results control for patient and hospital characteristics that affect payment.

Conditions 4–7 and 9–10 are from the selected HACs. Condition 17 is one of the previously considered candidate conditions.

SOURCE: RTI analysis of FY 2009 MedPAR inpatient episodes of care data

For the eight HACs used in the multivariate analysis, the percentage difference in Medicare episode payments between HAC and non-HAC cases is generally similar, as seen in Table 4. Two HACs showed relatively large differences between the two methods: pressure ulcers stages III and IV and ventilator-associated pneumonia. For these two HACs, the percentage difference was much less in the multivariate analysis. For five of the eight HACs, the difference estimated in the multivariate analyses was smaller than or equal to the difference observed in the bivariate analysis. This indicates that the other covariates included in the model are important and that matching of similar cases is not always sufficient to estimate incremental differences due to the HAC. In particular, risk factors based on the diagnosis codes that were

exponentiation of the coefficient on the binary dependent variable and subtracting one, or in these examples, $(\exp(\beta_{HAC}))-1$.

coded as present on admission appear to control for some of the difference in matched Medicare episode payments.

In ***Table 5*** we compare the incremental episode cost of the eight HACs across our different analyses. We find that the incremental cost is more similar when measured using the matched HAC and non-HAC cases and multivariate regression results than when using all non-HAC cases. In the column "Difference between HACs and all non-HACs," we calculate the average difference in episode costs between each of the HACs and all appropriate non-HACs.

Table 5.
Difference in Medicare payments for inpatient episodes of care

Selected or previously considered candidate HAC	Number with this HAC	Difference between HACs and all non-HACs	Difference between HACs and matched non-HACs	Difference between HACs and matched non-HACs, multivariate regression results
4. Pressure ulcer stages III & IV	1,276	$40,080	$17,286	$12,023
5a. Falls and trauma: fracture	4,684	$13,434	$7,198	$10,011
5b. Falls and trauma: intracranial injury	679	$13,130	$7,632	$8,971
6. Catheter-associated urinary tract infection	2,783	$13,279	$5,914	$6,913
7. Vascular catheter-associated infection	3,111	$32,891	$13,491	$12,378
9b. Surgical site infections: following certain orthopedic procedures	194	$30,389	$11,172	$7,169
10. Deep vein thrombosis & pulmonary embolism following certain orthopedic procedures	2,742	$5,651	$2,902	$2,860
17. Ventilator-associated pneumonia	3,845	$77,342	$19,748	$9,076

NOTES: HAC, hospital-acquired condition.

All differences are statistically significantly different from 0, with $p<0.05$

Comparison episodes chosen by 5:1 multivariable matching using the characteristics of the index claims with HACs. Multivariate results control for patient and hospital characteristics that affect payment.

Conditions 4–7 and 9–10 are from the selected HACs. Condition 17 is one of the previously considered candidate conditions.

SOURCE: RTI analysis of FY 2009 MedPAR inpatient episodes of care data

In this column, the non-HAC figure used to calculate the difference is the average episode payment for all episodes of care with an index claim in FY 2009; for the SSIs following certain orthopedic procedures, the DVT/PE following certain orthopedic procedures, and the ventilator-associated pneumonia, we further limit the non-HAC comparison group on the basis of the relevant procedures. In this comparison, the incremental episode cost of a HAC ranges from $5,651 for DVT/PE to $77,342 for ventilator-associated pneumonia. In the next column, "Difference between HACs and matched non-HACs," we use the incremental costs of the HACs produced in our descriptive analysis using a 5:1 match on MS-DRG and demographic characteristics. Matching significantly reduces the estimated incremental cost of the HACs for all eight of the HACs analyzed, and the range in incremental episode costs is now from $2,902 for DVT/PE to $19,748 for ventilator-associated pneumonia. In the final column of Table 5, we translate the percent differences produced in the multivariate analysis to incremental cost amounts by multiplying the percent change in episode payments (see Table 4) for each HAC by the average episode payments among both the HAC and non-HAC episodes. For five of the eight HACs, we see further reduction in the estimated incremental cost of the HAC compared with our descriptive analysis, although many of the figures are of similar magnitude. Vascular catheter-associated infection is now estimated to be the costliest from among these eight HACs, with an incremental episode cost of $12,378.

3.2.2 Beneficiary Liabilities

We performed similar analyses on the beneficiary episode Part A liabilities, using the actual dollar amount as the dependent variable instead of the log of beneficiary episode liabilities. The second columns in Appendix Table D1 through Appendix Table D8 present the results for the multivariate analysis, with beneficiary inpatient episode liabilities as the dependent variable. For seven of the eight HACs used for multivariate analysis, the models predicted liabilities to be higher for the HAC cases. The higher liabilities were significant for all HACs except for DVT/PE following certain orthopedic procedures. The incremental cost of a HAC ranged from $701 for ventilator-associated pneumonia to $2,447 for pressure ulcer stages III & IV. ***Table 6*** summarizes the results of our multivariate analysis and compares them with the differences in beneficiary episode liabilities from the bivariate (descriptive) tables. For the eight selected and previously considered candidate HACs in the analysis, the difference between HAC and non-HAC cases for beneficiary episodes liabilities was generally similar under both methods.

3.3 Limitations

Many of the estimates of the incremental cost of particular HACs are not statistically significantly different from zero in our descriptive analyses (***Appendices B and C***), due in part to the very small number of these HACs that are present in the claims data. These small sample sizes limit the specificity of the estimates of the incremental costs associated with these HACs.

We are unable to say whether the costs of these HAC episodes are truly similar to those of similar non-HAC episodes or whether the individual analyses do not have sufficient statistical power to detect a difference.

Table 6
Difference in beneficiary Part A liabilities for inpatient episodes of care

Selected or previously considered candidate HAC	Number with this HAC	Difference between HACs and all non-HACs	Difference between HACs and matched non-HACs	Difference between HACs and matched non-HACs, multivariate regression results
4. Pressure ulcer stages III & IV	1,276	$3,602	$2,678	$2,447
5a. Falls and trauma: fracture	4,684	$1,311	$1,124	$1,125
5b. Falls and trauma: intracranial injury	679	$657	$385	$482
6. Catheter-associated urinary tract infection	2,783	$1,411	$989	$938
7. Vascular catheter-associated infection	3,111	$2,160	$1,689	$1,546
9b. Surgical site infections: following certain orthopedic procedures	194	$1,310	$890	$979
10. Deep vein thrombosis & pulmonary embolism following certain orthopedic procedures	2,742	$117	−$72	$36
17. Ventilator-associated pneumonia	3,845	$3,162	$1,169	$701

NOTES: HAC, hospital-acquired condition.

All differences are statistically significantly different from 0, with $p<0.05$, except for the figures for (10) Deep vein thrombosis & pulmonary embolism following certain orthopedic procedures.

Comparison episodes chosen by 5:1 multivariable matching using the characteristics of the index claims with HACs. Multivariate results control for patient and hospital characteristics that affect payment.

Conditions 4–7 and 9–10 are from the selected HACs. Condition 17 is one of the previously considered candidate conditions.

SOURCE: RTI analysis of FY 2009 Medicare Provider Analysis and Review (MedPAR) inpatient episodes of care data.

By matching on the final (for some of the HACs, reassigned) MS-DRG, our analysis does not reflect the possibility that the HAC diagnoses could be leading to other complications that determine the MS-DRG assignment. For example, about 17 percent of the index cases with mediastinitis as a HAC are assigned MS-DRG 3 (ECMO [extracorporeal membrane oxygenation] or tracheostomy with mechanical ventilation 96+ hours with major operating room procedure). Without medical record review, we are unable to determine whether or not the mediastinitis led to the need for a tracheostomy among these patients. For purposes of our analysis, we assume that the two conditions are unrelated, and we match the mediastinitis HAC claims with MS-DRG 3 to other claims with MS-DRG 3 and the relevant CABG procedures. This choice in our matching algorithm means that we may be underestimating the true incremental costs of some of the HACs, particularly the ones like mediastinitis where the HAC could be leading to other complicating conditions that affect the MS-DRG assignment and thus affect the selection of the comparison group. We thus consider our estimates to be lower bounds of the true incremental costs of these HACs. Future analyses will explore alternative approaches to the MS-DRG match to avoid this problem.

Another limitation relates to the accuracy with which these hospital-acquired events are coded. If true HAC events are undercoded, then these HACs have the potential to appear in the non-HAC comparison groups, leading to bias in the estimate of the cost difference. HACs could be incorrectly coded as present on admission, or they could appear in the later diagnosis codes that are not included in the MedPAR data, or they could be completely excluded.[8] One way in which we address this issue is to remove from the comparison groups any episodes of care in which the HAC-related diagnoses appear as present on admission, either within the index hospitalization or in subsequent inpatient claims.

By removing all episodes with any HAC coding from the analysis, we have explicitly sidestepped the issue of timing of the clinical presentation of a HAC. This issue may be of particular importance among the SSI HACs, where the average index hospitalization may not be long enough for the SSI to appear. Consider the information presented in ***Table 7***. For each of the SSIs, we report the number of relevant surgical procedures performed in FY 2009, as well as the average length of stay for these hospitalizations. Note that the average length of stay for all but the CABG procedures is less than 1 week. We then report the number of SSI diagnoses that appear on the index claims (both for those that are hospital-acquired and those that are present on admission) and the number of SSI diagnoses that occur in subsequent inpatient claims, categorized by the number of days between the index (surgical) discharge and the admission date of the claim with the SSI. For both mediastinitis following CABG and SSIs following certain orthopedic procedures, significantly more infections are found on inpatient claims that occur within 15 days of the index discharge than are recorded as HACs in the index admission. For example, there are 211 cases of mediastinitis discovered within 15 days of index discharge, compared with only 35 that are HACs in the index (surgical) hospitalization. Among SSIs following certain orthopedic procedures, almost 2,000 infections are present within 15 days of

[8] It will be important to re-examine the incremental costs of a HAC in the future when Medicare claims data will include additional diagnosis codes.

index (surgical) discharge, compared with the 194 that are recorded as HACs within the index (surgical) hospitalization.

Because the attribution of the SSI to the index hospital becomes problematic once the patient is discharged (i.e., the SSI could be due to poor adherence to postsurgical instructions on the part of the patients as opposed to poor-quality care by the hospital), for this report we chose to remove these episodes with later presentation of SSIs from the analysis. Additional analyses on the timing of the SSIs and the effect on CMS and beneficiary costs may be informative.

Table 7.
Time to presentation of surgical site infections

Episode characteristics	Mediastinitis following CABG	SSI following certain orthopedic procedures	SSI following bariatric surgery
Number of surgical procedures performed in FY 2009	101,008	111,910	16,237
Mean index length of stay in days	11	4	5
Number of index hospital claims with this hospital-acquired condition	35	194	20
Number of index hospital claims with this diagnosis present on admission	9	110	4
Number of episodes with this condition first reported within 15 days of index discharge	211	1,932	1
Number of episodes with this condition first reported from 16 to 30 days of index discharge	54	621	0
Number of episodes with this condition first reported from 31 to 60 days after index discharge	30	332	0
Number of episodes with this condition first reported from 61 to 90 days after index discharge	7	109	0

NOTE. CABG, coronary artery bypass graft; SSI, surgical site infection.

SOURCE: RTI analysis of FY 2009 Medicare Provider Analysis and Review (MedPAR) inpatient episodes of care data.

3.4 Conclusions

This report analyzed the incremental cost associated with a HAC on Medicare and beneficiary episode costs. "Medicare costs" were measured as Medicare program costs and defined as Medicare program payments. "Beneficiary costs" were defined as direct beneficiary liabilities for deductibles and coinsurance. We estimated the increases in Medicare payments and beneficiary liabilities for the additional services within an episode of care during which a

HAC occurs that can be attributable to the HAC. Both bivariate and multivariate analyses were performed on data representing the entire inpatient episode of care constructed for HAC and matched non-HAC patients. This inpatient episode includes the index hospitalization, transfers and readmissions to general acute care hospitals, and subsequent inpatient PAC occurring within 90 days of the discharge from the index hospitalization.

The bivariate analyses included separate analyses of index inpatient, index outlier, all follow-up inpatient care, hospital transfer, hospital readmission, SNF, LTCH, and all other PAC payments (which included IRF and IPF). Each component played a role in contributing to the overall incremental cost of a HAC to the Medicare program. However, the contribution of each component differed by HAC. Outlier payments and readmission payments were often the largest contributors to the incremental costs of a HAC to the Medicare program. Index inpatient payments were generally not a significant contributor to the episode incremental cost of a HAC. These findings regarding the outlier and index inpatient payments are consistent with the work performed under Task 4.1.

In both the bivariate and multivariate analyses for almost all of the selected and candidate HACs analyzed, the inpatient episode payments are higher for the HAC episodes than for the non-HAC episodes. The highest incremental costs, from the bivariate analyses, were associated with SSIs for mediastinitis following CABG, adding on average over $58,000 to Medicare payments and $2,600 to beneficiary liabilities. The Medicare payments for inpatient episodes of care were 133 percent higher ($40,323) for SSI following bariatric surgery for obesity, and beneficiary liabilities were 176 percent higher ($2,803). The multivariate analyses (of seven selected HACs and one previously considered candidate HAC) were consistent with the bivariate results, and the incremental cost associated with a HAC was generally lower when our analysis controlled for patient risk factors and hospital characteristics that could affect costs.

The costliest of the selected HACs in terms of total CMS payments are vascular catheter-associated infections and falls and trauma: fractures. From the multivariate (bivariate) analysis, we estimate that vascular catheter-associated infections result in incremental Medicare Part A payments of $38.5 million ($42.0 million), and falls and trauma: fractures result in an additional $46.9 million ($33.7 million), in Medicare payments. Incremental beneficiary liabilities for these selected HACs are estimated to be around $5 million each. From the candidate HACs, *C. difficile*-associated disease has the highest incremental costs—CMS paid $367 million more in FY 2009 for these episodes of care, and the affected beneficiaries had $51 million more in liabilities.

Our multivariate analysis of seven of the selected HACs and one of the previously considered candidate HACs suggests that in FY 2009, CMS paid an additional $170 million across these episodes of care compared with what they would have paid if none of the HACs had occurred. This is somewhat smaller than the figure we obtain in our descriptive analysis, which estimates that the incremental cost of these eight more frequent HACs was $205 million.

For beneficiaries, the incremental liability associated with the HACs in our multivariate analysis was $19 million, only slightly smaller than the $21 million suggested in the descriptive analysis. In our descriptive analysis, we see that hospital readmissions triggering additional deductibles and increased SNF utilization leading to additional coinsurance days were the primary sources of higher patient liabilities.

Preventable infections and other conditions that are hospital acquired create a significant financial burden for both the Medicare program and Medicare beneficiaries. Programs and policies that reduce the occurrence of these HACs have the potential to both improve health and reduce costs.

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REFERENCES

Bates, D., Spell, M., Cullen, D., Burdick, E., Laird, N., Petersen, L. A., et al. (1997). The costs of adverse drug events in hospitalized patients. *JAMA, 277,* 307–311. doi:10.1001/jama.1997.03540280045032

Broex, E. C. J., van Asselt, A. D. I., Bruggeman, C. A., & van Tiel, F. H. (2009). Surgical site infections: How high are the costs? *Journal of Hospital Infection, 72,* 193–201. doi:10.1016/j.jhin.2009.03.020

Classen, D., Pestotnik, S., Evans, R. S., Lloyd, J. F., & Burke, J. P. (1997). Adverse drug events in hospitalized patients: Excess length of stay, extra costs, and attributable mortality. *JAMA, 277,* 301–306. doi:10.1001/jama.1997.03540280039031

de Lissovoy, G., Fraeman, K., Hutchins, V., Murphy, D., Song, D., & Vaughn, B. B. (2009). Surgical site infection: Incidence and impact on hospital utilization and treatment costs. *American Journal of Infection Control, 37,* 387–397. doi:10.1016/j.ajic.2008.12.010

Encinosa, W., & Hellinger, F. (2008). The impact of medical errors on 90-day costs and outcomes: An examination of surgical patients. *Health Services Research, 43,* 2067–2085. doi:10.1111/j.1475-6773.2008.00882.x

Frye, D. (2002). The economic costs of surgical site infection. *Surgical Infections, 3*(Suppl.), s37–s43. doi:10.1089/sur.2002.3.s1-37

Fuller, R. L., McCullough, E. C., Bao, M. Z., & Averill, R. F. (2009). Estimating the costs of potentially preventable hospital-acquired complications. *Health Care Financing Review, 30*(4), 17–32.

Graves, N. (2004). Economics of preventing hospital-acquired infection. *Emerging Infectious Diseases, 10,* 561–566. doi:10.3201/eid1004.020754

Graves, N., Halton, K., Doidge, S., Clements, A., Lairson, D., & Whitby, M. (2008). Who bears the cost of healthcare-acquired surgical site infection? *Journal of Hospital Infection, 69,* 274–282. doi:10.1016/j.jhin.2008.04.022

Hollenbeak, C., Murphy, D. M., Koenig, S., Woodward, R. S., Dunagan, W. C., & Fraser, V. J. (2000). The clinical and economic impact of deep chest surgical site infections following coronary artery bypass graft surgery. *Chest, 118,* 397–402. doi:10.1378/chest.118.2.397

Howard, D., Cordell, R., McGowan, J., Packard, R. M., Scott, R. D., & Solomon, S. L. (2001). Measuring the economic costs of antimicrobial resistance in hospital settings: Summary of the Centers for Disease Control and Prevention-Emory Workshop. *Healthcare Epidemiology, 33,* 1573–1578.

McGarry, S., Engemann, J., Schmader, K., Sexton, D. J., & Kaye, K. S. (2004). Surgical-site infection due to *Staphylococcus aureus* among elderly patients: Mortality, duration of hospitalization, and cost. *Infection Control and Hospital Epidemiology 25,* 461–467.

Olsen, M., Chu-Ongsakul, S., Brandt, K. E., Dietz, J. R., Mayfield, J., & Fraser, V. J. (2008). Hospital-associated costs due to surgical site infection after breast surgery. *Archives of Surgery, 143,* 53–60.

Peng, M., Kurtz, S., &Johannes, R. S. (2006). Adverse outcomes from hospital-acquired infection in Pennsylvania cannot be attributed to increased risk on admission. *American Journal of Medical Quality, 21*(6 Suppl.), 17S–28S. doi:10.1177/1062860606294632

Pennsylvania Health Care Cost Containment Council. (2009). *Hospital-acquired infections in Pennsylvania, data reporting period 2006 & 2007*. Harrisburg: Author. Retrieved from http://www.phc4.org/reports/hai/07/docs/hai2007report.pdf

Roberts, R., Hota, B., Ahmad, I., Scott, D., Foster, S., Abbasi, F., et al. (2009). Hospital and societal costs of antimicrobial-resistant infections in a Chicago teaching hospital: Implications for antibiotic stewardship. *Clinical Infectious Diseases, 49*, 1175–1184. doi:10.1086/605630

Roberts, R. R., Scott, R. D., Cordell, R., Solomon, S. L., Steele, L., Kampe, L. M., et al. (2003). The use of economic modeling to determine the hospital costs associated with nosocomial infections. *Clinical Infectious Diseases, 36,* 1424–1432. doi:10.1086/375061

Shannon, R. P., Patel, B., Cummins, D., Shannon, A. H., Ganguli, G., & Lu, Y. (2006). Economics of central-line associated bloodstream infections. *American Journal of Medical Quality, 21*(6 Suppl.), 7S–16S. doi:10.1177/1062860606294631

Stone, P., Larson, E., & Kawar, L. N. (2002). A systematic audit of economic evidence linking nosocomial infections and infection control interventions: 1990–2000. *American Journal of Infection Control, 30,* 145–152. doi:10.1067/mic.2002.121099

Yasunaga, H., Ide, H., Imamura, T., & Ohe, K. (2007). Accuracy of economic studies on surgical site infection. *Journal of Hospital Infection, 65,* 102–107. doi:10.1016/j.jhin.2006.07.008

Zhan, C., Friedman, B., Mosso, A., & Pronovost, P. (2006). Medicare payment for adverse events under the prospective payment system: Building the business case for investing in patient safety improvement. *Health Affairs, 25,* 1386–1393. doi:10.1377/hlthaff.25.5.1386

Zhan, C., & Miller, M. (2003). Excess length of stay, charges, and mortality attributable to medical injuries during hospitalization. *JAMA, 290,* 1868–1874. doi:10.1001/jama.290.14.1868

Appendix Table A-1
Selected Empirical Studies Addressing Resource Utilization Attributable to Hospital-Acquired or Preventable Events
Institution-based

Author/Title/Journal	Population Studied	Outcome Utilization Measure	Adverse Event Measure	Study Design and Estimation Methods	Cost Findings
1. Bates, D., Spell, M., Cullen, D., Burdick, E., Laird, N., Petersen, L., Small, S., Sweitzer, B., Leaped, L. The Costs of Adverse Drug Events in Hospitalized Patients. JAMA 277(4):307-311. Published: January 1997.	Admissions to medical and surgical units of two hospitals (6 months in1993; N=4,108).	Post-event length of stay and resource use by routine, ICU and ancillary service areas, initial hospitalization only. Costs defined as CCR-adjusted charges	ADEs, as self reported or identified by chart review	Nested case-control within prospective cohort. Controls matched by pre-event length of stay and ICU use, within hospital units. Incremental effect of adverse event estimated by multivariate regression with controls for demographics, DRG weight, Charlson comorbidity scores and acuity scores.	All ADEs (n=190): associated increase of 2.2 days (12.6 vs. 10.4) and $3,244 ($15,580 vs. $13,336). Preventable ADEs (n=90): associated increase of 4.6 days (15.8 vs. 11.2) and $5,857 ($22,792 vs. $16,937).
2. Classen, D., Pestotnik, S., Evans, R. S., Lloyd, J., Burke, J. Adverse Drug Events in Hospitalized Patients: Excess Length of Stay, Extra Costs, and Attributable Mortality. JAMA 277(4):301-306. Published: January 1997.	Admissions to a single hospital over four years (1990 – 1993)	Days and cost for initial hospitalization, using facility micro-costing system.	ADEs as identified from electronic surveillance system	Case control w/ multivariable matching by DRG, nursing acuity score, admit year and sex (1,580 cases to 20,197 controls). Attributable days and costs identified through OLS with additional covariates and indicators for matched sets.	Average ADE-attributable days of 1.91 w/ range from 0.72 to 5.49 depending on type of event. Average ADE-attributable costs of $2,013 w/ range from $677 to $9,022.
3. Hollenbeak, C., Murphy, M., Koenig, S., Woodward, R., Dunagan, W., Fraser, V. The Clinical and Economic Impact of Deep Chest Surgical Site Infections Following Coronary Artery Bypass Graft Surgery. Chest 118(2):397-402. Published: August 2000.	CABG patients at a single hospital	Days and costs for initial hospitalization plus 1 year follow-up, using facility micro-costing system.	Deep chest SSI, from prospective surveillance	Prospective case control, with 41 cases and 4:1 non-infected match. Attributable costs identified by OLS with covariates for age, comorbidities, selected SSI risk factors and pre-op LOS..	Unadjusted difference of 20.1 days (27.5 vs. 7.0) and $20,012 ($34,218 vs. $14,206). Attributable cost difference from OLS model of $18,938.

(continued)

Appendix Table A-1 (continued)
Selected Empirical Studies Addressing Resource Utilization Attributable to Hospital-Acquired or Preventable Events
Institution-based

Author/Title/Journal	Population Studied	Outcome Utilization Measure	Adverse Event Measure	Study Design and Estimation Methods	Cost Findings
4. Roberts, R., Scott, D., Cordell, R., Solomon, L., Steele, L., Kampe, L., Trick, W., Weinstein, R. The Use of economic Modeling to Determine the Hospital Costs Associated with Nosocomial Infections. Clinical Infectious Diseases 36(11):1424-1432. Published: June 2003.	Adult admissions to a single hospital over one year (1998).	Total costs for initial hospitalization, using facility micro-costing system.	HAIs, as identified by medical record abstraction	Retrospective cohort sample of 164 observations w/>=6 secondary dx, of which 17 confirmed and 8 suspected HAI cases. OLS regression with covariates for APACHE scores and ICU use	Unadjusted HAI cost difference of $19,712 for confirmed HAIs ($27,050 vs. $7,338) and $15,298 ($22,636 vs. $7,338) for suspected HAIs. Attributable cost difference after OLS of $15,275 for confirmed HAIs and $6,767 for suspected.
5. McGarry, S., Engemann, J., Schmader, K., Sexton, D., Kaye, K. Surgical-Site Infection Due to *Staphylococcus aureus* Among Elderly Patients: Mortality, Duration of Hospitalization, and Cost. Infection Control and Hospital Epidemiology 25(6):461-467. Published: June 2004.	Patients undergoing surgery at an academic and an affiliated community hospital over six years (1994-2000)	Post-operative days, post-infection days and total charges, for hospitalization plus 90-day follow-up.	SSIs, identified from electronic surveillance	Nested cohort with sub-analysis for patients age >=70. Elderly study sample=96 cases and 59 controls. OLS with controls for comorbidities and acuity.	Median unadjusted differences of 15 post-surgery days (22 vs. 7); 13 post-infection days; and $53,625 in total charges ($85,648 vs. $32,023). Median attributable differences from OLS model of 12 post-surgery days and $41,117 in total charges.
6. Shannon, R.P., Patel, B., Cummins, D., Shannon, A. H., Ganguli, G., & Lu, Y. Economics of Central-Line Associated Bloodstream Infections. American Journal of Medical Quality 21(6 Suppl):7S-16S. Published: November/December 2006.	ICU patients from single hospital (N=54)	Costs for initial hospitalization;, using attributable fixed & variable costs per facility's micro-costing system	HAI for central line associated blood stream infections	Case series and nested case-control. Expert review of services attributable post-infection services	HAI cost increment range from 21% to 71%, by underlying condition w/average of 43%,. Average attributable cost $per case of $40k.

(continued)

Appendix Table A-1 (continued)
Selected Empirical Studies Addressing Resource Utilization Attributable to Hospital-Acquired or Preventable Events
Institution-based

Author/Title/Journal	Population Studied	Outcome Utilization Measure	Adverse Event Measure	Study Design and Estimation Methods	Cost Findings
7. Olsen, M., Chu-Ongsakul, S., Brandt, K. E., Dietz, J. R., Mayfield, J., Fraser, V. J. Hospital-Associated Costs Due to Surgical Site Infection After Breast Surgery. Archives of Surgery 143(1) 53-60. Published: January 2008.	Single university system cohort, all breast surgeries 1999-2002	Days and costs for initial hospitalization plus follow-up (1 yr), using facility micro-costing system.	SSIs as identified by facility's electronic surveillance system	Average outcome differences after propensity score matching on p(SSI), by type of surgery procedure. Alternative method uses OLS and FGLS with control for type procedure, patient demographics, comorbidities and grouping by hospital.	Unadjusted median difference of 4.9 days and $$10,759 in cost. Mean cost difference between propensity-matched samples was $3,492. Alternative regression-adjusted attributable cost difference was $4,091
8. Graves, N., Halton, K., Doidge, S., Clements, A., Lairson, D., Whitby, M. Who Bears the Cost of Healthcare-Acquired Surgical Site Infection? Journal of Hospital Infection 69:274-282. Published: June 2008.	Conceptual paper illustrated using data from 1,640 surgical admissions from two hospitals in Australia	Days and costs for initial hospitalization and 8-month follow-up period including estimate of opportunity cost per bed day.	SSIs	Cost simulations per 10,000 surgical cases, using output from multiple regression with control for patient demographics, prior health use and comorbidities.	Average increase of 2.51 days per SSI, with estimated variable costs of (Australian)$134/day and opportunity cost of (Australian)$699/lost bed-day. Total additional cost per case for SSI diagnosed in hospital of (Australian)$2,047. Post-discharge period accounted for 33% of modeled additional costs.

(continued)

Appendix Table A-1 (continued)
Selected Empirical Studies Addressing Resource Utilization Attributable to Hospital-Acquired or Preventable Events
Institution-based

Author/Title/Journal	Population Studied	Outcome Utilization Measure	Adverse Event Measure	Study Design and Estimation Methods	Cost Findings
9. Roberts, R., Hota, B., Ahmad, I., Scott, D., Foster, S., Abbasi, F., Schabowski, S., Kampe, L., Ciavarella, G., Supino, M., Naples, J., Cordell, R., Levy, S., Weinstein, R. Hospital and Societal Costs of Antimicrobial-Resistant Infections in a Chicago Teaching Hospital: Implications for Antibiotic Stewardship. Clinical Infectious Diseases 49:1175-1184. Published: October 2009.	Random sample of patients from an urban teaching hospital in 2000	Days and cost for initial hospitalization, using facility micro-costing system.	Antimicrobial-resistant infections	Both OLS regression models and propensity score matching used to compare average costs and days in the hospital. Additional controls included surgery, ICU use, APACHE scores, modified Charlson score, and the development of HAIs.	Mean cost difference for propensity matched samples, controlling for HAI, was $21,018, and length of stay was 6.7 days longer. Similar results from the multivariate regressions.

Appendix Table A-2
Selected Empirical Studies Addressing Resource Utilization Attributable to Hospital-Acquired or Preventable Events
Population-based

Author/Title/Journal	Population Studied	Outcome Utilization Measure	Adverse Event Measure	Study Design and Estimation Methods	Cost Findings
10. Zhan, C., Miller, M. Excess Length of Stay, Charges and Mortality Attributable to Medical Injuries During Hospitalization. JAMA 290(14):1868-1873. Published: October 2003.	HCUP/NIS (2000)	Days and charges for initial hospitalization	AHRQ Patient Safety Indicators (PSIs)	Average differences between samples matched on hospital, DRG, age, sex and race; alternate approach using multilevel regression (GLIMM by hospital and DRG)	Range from 2 to 10 day incremental stay, with largest effect in sepsis and selected post-op infections. Matched study results similar to multilevel regression.
11. Zhan, C., Friedman, B., Mosso, A., Pronovost, P. Medicare Payment for Adverse Events Under the Prospective Payment System: Building the Business Case for Investing in Patient Safety Improvement. Health Affairs 25:1386-1393. Published: September/October 2006.	HCUP NIS (2002)	DRG payments	AHRQ Patient Safety Indicators (PSIs)	Payment simulations on claims run through grouper without PSI-related diagnoses	No additional DRG payments to cover additional costs in 48% of post-op sepsis and 80% of decubitus ulcers, implying strong business case for investment in prevention independent of HAC-POA penalties.
12. Encinosa, W., Hellinger, F. The Impact of Medical Errors on 90-Day Costs and Outcomes: An Examination of Surgical Patients. Health Services Research 43(6):2067-2085. Published: December 2008.	Enrollees in a large private insurance data base (2001-2002)	Claims payments, for initial hospitalization plus 90-day follow-up plus physician.	PSI/PPEs, as identified from claims coding	1:1 propensity-score matching on 4,140 event cases, w/ p(PSI) estimated using comorbidities and DRG groups. Multivariate regression on matched sample	Significant portion of excess costs occur in post-discharge period. Total excess payments highest for respiratory failure ($28k, accounting for 52% of total pmts, of which 15% is post-discharge). Second highest for infections ($19k, accounting for 42% of total pmts of which 28% post-discharge).

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Appendix Table A-2 (continued)
Selected Empirical Studies Addressing Resource Utilization Attributable to Hospital-Acquired or Preventable Events
Population-based

Author/Title/Journal	Population Studied	Outcome Utilization Measure	Adverse Event Measure	Study Design and Estimation Methods	Cost Findings
13. Pennsylvania Health Care Cost Containment Council. Hospital-Acquired Infections in Pennsylvania, Data Reporting Period 2006 & 2007. Harrisburg: Author. Retrieved from http://www.phc4.org/reports/hai/07/docs/hai2007report.pdf Published: January 2009.	State-mandated data base, PA (2007). All-payer discharges age 18+	Days and charges for initial hospitalization	HAIs as identified by MediQual (Atlas) electronic surveillance system	Raw outcome differences between HAI and non-HAI discharges, stratified by hospital within hospital peer group	Unadjusted median state-wide difference in stays of 12 days (15 vs. 3) and in charges of $68k ($188k vs. $20k) Median differences by peer group: --most complex: 14 days and $115k --least complex: 4 days and $16k.
14. Peng, M., Kurtz, S., Johannes, R. S. Adverse Outcomes From Hospital-Acquired Infection in Pennsylvania Cannot Be Attributed to Increased Risk on Admission. American Journal of Medical Quality 21(6 Suppl.):17S-28S. Published: November/December 2006.	State-mandated data base, PA (2004). All-payer discharges age 18+	Days and charges for initial hospitalization	HAIs as identified by MediQual (Atlas) electronic surveillance system	Average outcome differences by type of procedure, after propensity score matching on p(death) w/ additional balancing on hospital characteristics.	Average HAI stays 13 days longer (16 vs. 3). Average HAI charges $129k higher ($173k vs. $44k. Uncontrolled confounding thought to be still present because non-HAI observations were younger and less severely ill than HAI observations.

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Appendix Table A-2 (continued)
Selected Empirical Studies Addressing Resource Utilization Attributable to Hospital-Acquired or Preventable Events
Population-based

Author/Title/Journal	Population Studied	Outcome Utilization Measure	Adverse Event Measure	Study Design and Estimation Methods	Cost Findings
15. Fuller, R. L., McCullough, E. C., Bao, M. Z., Averill, R. F. Estimating the Costs of Potentially Preventable Hospital-Acquired Complications. Health Care Financing Review 30(4):17-32. Published: Summer 2009.	State all-payer discharges: CA (FY08) MD (FY06)	Charges for initial hospitalization; discounted Charges (CA); billed charges (MD)	64 mutually exclusive "Potentially Preventable Complications" (PPCs), as developed by Hughes et al (2006) based on ICD-9 coding.	OLS with dummy variables by PPC and by APRDRG	California: PPCs associated with average 9.2% increase. Maryland: PPCs associated with average 9.6% increase
16. de Lissovoy, G., Fraeman, K., Hutchins, V., Murphy, D., Song, D., Vaughn, B. Surgical Site Infection: Incidence and Impact on Hospital Utilization and Treatment Costs. American Journal of Infection Control 37(5):387-397. Published: June 2009.	HCUP NIS (2005)	Days and discounted charges for initial hospitalization	SSIs as identified by ICD9 code 998.59	Average outcome differences after propensity score matching on p(SSI), by type of surgery procedure	Average increase of 9.7 days and $20,842 cost per case, w/ largest impact in cardiovascular surgeries (13.7 days and $37,513).