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The Impact of Nursing Hours and Hospital and Patient Characteristics on Medicare Hospital Acquired Conditions: A National Pooled Cross-Sectional Secondary Data Model and Analysis

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THE IMPACT OF NURSING HOURS AND HOSPITAL AND PATIENT CHARACTERISTICS ON MEDICARE HOSPITAL ACQUIRED CONDITIONS: A NATIONAL POOLED CROSS-SECTIONAL SECONDARY DATA MODEL AND ANALYSIS

A Dissertation Presented

by

TERRY KAHLERT ENG

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ABSTRACT

THE IMPACT OF NURSING HOURS AND HOSPITAL AND PATIENT CHARACTERISTICS ON MEDICARE HOSPITAL ACQUIRED CONDITIONS: A NATIONAL POOLED CROSS-SECTIONAL SECONDARY DATA MODEL AND ANALYSIS

June 2015

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Background: Previous research and quality improvement initiatives have underscored the prevalence of healthcare acquired conditions (HACs) and their associated costs in American hospitals. In response to these findings, in 2008, The Centers for Medicare and Medicaid Services identified 10 condition categories that they would no longer pay for if acquired during hospitalization. The conditions were selected based on high cost, high volume, or both, assigned to a higher paying medical severity diagnostic related group (MS-DRG), and were deemed preventable through application of evidence-based guidelines. The Health Quality Outcomes Model and a Path Model guided the study.

Objective: To quantify the association between patient and hospital characteristics, and nursing care intensity of HACs.

Data Sources: Medicare Provider Analysis and Review file, Provider of Service file, 2010 Medicare Occupational Mix Adjustment Survey for Acute Care Hospitals, Medicare Hospital and Hospital Health Care Complex Cost Report, and Magnet Hospital List.

Methods: Pooled cross-sectional secondary analysis of a random set of Medicare beneficiaries admitted to an inpatient prospective payment system hospital (2009 – 2011). Descriptive statistics, correlation analysis, and multivariate regression analyses were computed.

Results: The significant predictors of a reported HAC were length of stay (LOS) and severity of illness (SOI). Patients with a high SOI were 9-times more likely than patients with a lower SOI to incur an HAC. Controlling for LOS, the likelihood of a patient incurring an HAC declined almost 1/3 (OR= 8.9 vs. 12.8). High (>20.1) RN hours per patient day were significantly ($p=<.05$) associated with a higher likelihood of incurring an HAC *only* before controlling for SOI and LOS. Northeast hospitals were 12-21% less likely to report a HAC. Female patients were 43% more likely to incur a HAC. The length of time a hospital was designated a Magnet hospital had no significant effect on the probability of an HAC.

Conclusions: The hospital acquired condition program is a significant step in aligning pay-for-performance incentives for reducing hospital-acquired conditions and infections. This policy has important implications for health care quality and costs and research should be conducted to evaluate the long term consequences of this policy.

DEDICATION

In loving memory of my mother, Dorothy Jane Hefflefinger Kahlert (1924 – 1995) who aspired to be a registered nurse and was proud that I fulfilled her dream. To Wayne, my husband, best friend and love of my life for his unwavering support and encouragement as I stayed the course to becoming a researcher.

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CHAPTER 1.

INTRODUCTION

In 2006 the Centers for Medicare and Medicaid Services (CMS) circulated regulations in response to the Deficit Reduction Act of 2005 (The Act) which had authorized CMS to develop a plan for value based purchasing (VBP) for Medicare hospital services commencing in fiscal year (FY) 2009. The Deficit Reduction Act of 2005 modified payment policy for acute care hospitalizations of Medicare fee-for-service beneficiaries ---specifically in the case that a complicating condition occurred during the hospitalization that could have reasonably been prevented. Section 5001 c of The Act required the Secretary of Health and Human Services (HHS) to identify complications of care that meet the following three conditions: 1) high cost, high volume, or both; 2) were assigned to a higher paying medical severity diagnostic related group (MS-DRG) when present as a secondary diagnosis; and 3) could reasonably have been prevented through the application of evidence-based guidelines. In response to the Act, CMS developed the Hospital-Acquired Conditions-Present on Admission (HAC-POA) program, whereby inpatient prospective payment system cases could no longer be assigned to higher paying MS-DRGs on the basis of preventable complicating conditions that were acquired during the hospital stay (Federal Register, 2007, p. 47200), West, Eng, Lyda-McDonald & McCall, 2010).

To implement this quality and payment change, beginning in April 2008, CMS began requiring hospitals participating in the inpatient prospective payment system (IPPS) to code all *International Classification of Diseases, Ninth Revision* (ICD-9) diagnoses on the inpatient claim as either present on admission (POA) or acquired during the hospital stay. As of October 1, 2007, CMS required all IPPS hospitals to submit POA information on all primary and secondary diagnoses for inpatient discharges using specific indicators to determine if the condition was present on admission, not present on admission, or the medical information was insufficient to determine if the condition was present on admission. POA indicators are used at the time of the inpatient admission and comprise conditions that develop during an outpatient encounter, including those in the emergency department, observation, or ambulatory surgery (CMS, 2008).

In collaboration with the Centers for Disease Control and Prevention (CDC), the Agency for Healthcare Research and Quality (AHRQ) and the Office of Public Health and Science and with extensive input from the public, CMS identified 8 initial HACs as preventable under accepted guideline-consistent care and targeted these for application of the HAC-POA payment policy. In 2009 deep vein thrombosis (DVT)/ pulmonary embolism (PE) and hospital related falls and trauma were added to this list of conditions which CMS would not reimburse. The current HACs, which, in addition to DVT and PE, have expanded since the policy's inception, have in part evolved from the original

National Quality Forum (NQF) serious reportable events and the AHRQ Patient Safety Indicators (PSIs) (Federal Register, 2010). They are:

- Foreign Object Retained After Surgery
- Air Embolism
- Blood Incompatibility
- Pressure Ulcer Stages III and IV
- Hospital Related Falls and Trauma (fracture, dislocation, intracranial injury, crushing injury, burn, and electric shock)
- Catheter-Associated Urinary Tract Infection (CAUTI)
- Surgical Site Infection (SSI) - (mediastinitis after coronary artery bypass graft)
- Surgical Site Infection (SSI) - (following certain orthopedic procedures)
- Vascular Catheter-Associated Infections (CLABSI)
- Deep Vein Thrombosis (DVT)/Pulmonary Embolism (PE)
- Manifestations of Poor Glycemic Control

Prior to the implementation of the Deficit Reduction Act, acute care hospitals were reimbursed for Medicare beneficiaries based on an assigned diagnostic related group (DRG) and were paid for stays that varied in length and the services provided. In many instances complications acquired in the hospital generate higher payments than the hospital would otherwise receive for uncomplicated cases paid under the same DRG. Hospital acquired infections, for example, may generate a higher Medicare payment under this regime. This could occur through an outlier payment wherein the treatment of complications increased the cost of the length of stay through the 258 sets of MS-DRGs that were split into 2 or 3 subgroups based on the presence or absence of a contributing complication (CC) or a major contributing complication (MCC). Hospitals received a higher payment under the MS-DRGs prior to October 1, 2008 when the HAC payment provision was implemented if the condition acquired during the hospital stay was one of the conditions on the CC or MCC list (Federal Register, 2008). The Affordable Care Act of 2010 extended the Value-Based Purchasing provision of 2009 by linking payment to quality of care including penalties for readmission and rewarded providers for quality of care (CMS, 2013).

Study Purpose

The health care policy of interest in this study is the Hospital-Acquired Conditions-Present on Admission (HAC-POA) Centers for Medicare and Medicaid Services (CMS) regulations. The purpose of this study was to quantify the association between patient characteristics and hospital characteristics as well as nursing care intensity on the reported incidence of HACs. The specific study domains included: 1) patient outcomes and the reported incidence of HACs and 2) hospital characteristics and the reported incidence of HACs.

Significance

Patient safety events, defined as “any event or circumstance that could have resulted or did result in unnecessary harm to a patient or caregiver” (Oliver, Demiris, Wittenberg-Lyles, Gage, Dewsnap-Dreisinger, & Luetkemeyer, 2013) are pervasive and costly in American hospitals. Between 2007 and 2009, patient safety events cost Medicare nearly $7.3 billion and resulted in 79,670 potentially preventable deaths (Reed

& May, 2011). Reed and May (2011) used the Patient Safety Indicators (PSIs) software developed by AHRQ to study the national event rate, mortality and cost associated with thirteen patient safety indicators among Medicare beneficiaries from 2007 through 2009. They documented 708,642 total patient safety events affecting 667,828 Medicare beneficiaries (Reed & May, 2011). Bahl, Thompson, Kau, Hu & Campbell (2008) conducted a study to assess the effect of the POA variable on unadjusted PSIs in measuring a hospital's performance. The results showed that when the POA variable was applied, the rates of unadjusted PSIs were lower than without the POA indicator. However, they concluded that PSIs should not be used to evaluate a hospital's quality of care nor used to determine reimbursement because of the likelihood of reporting false positives when POA PSIs are not identified and coded accurately. Another problem with PSIs is that they have not been tested for validity (Bahl et al, 2008).

A plethora of research, quality improvement initiatives and published literature have underscored the prevalence of medical errors and adverse medical outcomes and their associated costs in American hospitals. Sentinel studies of iatrogenic injuries from medication administration, conducted in the 1990s, ignited the whole movement on identifying and preventing adverse medical outcomes in United States hospitals- a movement, which continues today (Brennan, Leape, Laird, Hebert, Localio, Lawthers, Newhouse, Weiler, & Hiatt, H., 1991). Early examples of such work include the Adverse Drug Event Prevention Study, in which medical records were reviewed and pharmacists and nurses self- reported incidents on a sample of eleven medical-surgical units including intensive care (Bates et al, 1995). Over a six month period, 247 adverse drug events

(ADEs) were found of which 70 (28%) were preventable, and 83 (43%) were near misses. These findings translated into an estimated 11.5 ADEs per 1000 patient days and 6.1 per 100 admissions. When the data were extrapolated across all of the study hospitals, the ADE rate was 1900 per hospital per year.

In another arm of the Adverse Drug Event Prevention Study, Leape et al., (1995) identified seven system failures that contributed to errors causing ADEs and potential ADEs, the most common being dissemination of drug knowledge, particularly to physicians. Failures in the identified seven systems accounted for 78% of all of the errors that were detected.

In addition to the impact of medication errors on cost and quality, healthcare acquired infections (HAIs) have also been identified as an important safety problem. Klevens, Edwards, Richards, Horan, Gaynes, Pollock, & Cardo (2007) conducted a study to estimate the number of HAIs and deaths in United States hospitals. Using the National Nosocomial Infections Surveillance System (NNIS), the National Hospital Discharge Survey (NHDS), and the American Hospital Association (AHA) survey as data sources, they estimated the number of HAIs in U.S. hospitals in 2002 was approximately 1.7 million. Among these patients, there were 155,000 related deaths of which 99,000 were caused by or associated with the HAI (Klevens et al., 2007). The infection rate per 1,000 patient days (13%) was highest in intensive care units (ICU). Infections from surgical sites were estimated to be 274, 385 with 244,385 surgical site infections (SSIs) in adults and children outside of the ICU. The SSIs made up about 20% of all infections and in this study the authors estimated that there were 424,060 urinary tract infections, 129,519 pneumonias, 133, 368 blood stream infections, and 263,810 other infections. These numbers equated to 1,195,142 HAIs among adults and children outside of ICUs in the United States (Klevens et al., 2007). When all patient subpopulations were included (newborns [high–risk and infant nurseries] and adults and children in and outside of ICUs, the adjusted rate calculated to be 9.3 infections per 1,000 patient-days or 4.5 per 100 admissions in 2002 (Klevens et al, 2007).

The cost of HAIs is also significant. Kilgore, Ghosh, Beavers, Wong, Hymel, & Brossette (2008) estimated the incremental cost of nosocomial infections at $12,197 per patient in 2007 dollars. Hollenbeak (2007) reported that hospital inpatient margins were reduced by $286 million amounting to $5,018 per infected patient.

Patients also experience a number of other preventable harms while receiving care. For example, diagnostic errors contribute to an estimated 40,000 to 80,000 US hospital deaths annually (Newman-Toker & Pronovost, 2009). In 2008, the acting surgeon general estimated that at least 350,000, and as many as 600,000 Americans are affected each year by DVT/PE, and at least 100,000 deaths are thought to be related to these conditions (Galson, 2008). It is also estimated that 60,000 U.S. patient deaths per year are attributed to complications associated with hospital acquired pressure ulcers (Lyder, 2011), and miscommunication between medical providers contributes to an estimated 80% of serious medical errors worldwide (Mujumdar, 2014).

One of the premises of the HAC/POA legislation is that non-payment of HACs will slow or lower the costs of healthcare by way of reductions in hospital payments as HACs will not be paid at the higher DRG and because hospitals will be incentivized to improve care and thereby decrease the incidence of HACs. Table 1 is an illustration of the estimated net savings of current HACs for the period of October 2008 through September 2009 by categorizing individual HACs as a secondary diagnosis and calculating the number of discharges that changed the MS-DRG. The net savings for these 10 HACs was estimated at $16,442,185 which translates into an average savings of $5,456 per discharge. Table 2 reports discharge frequencies by HAC for October 2008 through September 2009. There were a total of 297,892 discharges that had one of the HACs as a secondary discharge diagnosis. Of those discharges, 15,232 were at risk for a HAC.

This dissertation research is significant from a number of different perspectives: It is an inaugural study that incorporated a composite adverse event measure comprised of the ten CMS identified HACs to study the impact of hospital, as well as patient and nursing characteristics on the incidence of reported HACs. Prior studies have investigated a variety of patient outcomes, some of which are broader in nature (hospital mortality) or focused on a few non-CMS specified HACs, like abdominal surgical wound infections (Aiken, Clarke, Sloane, Sochalski & Silber, 2002). This is the first study to use three years of national Medicare Claims Data that included secondary diagnosis codes that differentiated HACs from present on admission conditions (for a sample size of 2.9 million patient admissions). Prior to the implementation of this policy, researchers used present on admission codes to predict the probability of reported HACs.

This study builds on previous studies that have investigated the impact of nursing care hours on the incidence of individual nurse sensitive HACs. Findings across similar studies of HACs have been inconsistent particularly as they pertain to the impact of nursing care hours on nurse-sensitive measures like pressure ulcers. This study incorporated a variety of hospital, patient, and nursing characteristics that were stratified by length of stay, severity of illness, specific surgical procedures and Magnet status as a proxy for excellent nursing care to predict the incidence of reported HACs.

This study is also significant for advancing Nursing practice, particularly the impact of nurse staffing in preventing hospital acquired conditions in terms of quality, and; cost of care, and length of stay. Policy implications gleaned from this study also serve to inform health policy. Nurses, as administrators, clinicians, educators, policy analysts, and researchers, are on the forefront of implementing policy that will serve to reduce the incidence of HACs at the point of care. Findings from this study will inform health care providers and policy makers about characteristics that have the most impact on the potential for reducing HACs.

Table 1.

Estimated Net Savings of Current HACs- October 2008 through September 2009

	Selected HAC Category	Number of Discharges with This Condition as Secondary Diagnosis	Number of Discharges Identified as a HAC	Number of Discharges That Change MS-DRG Due to HAC	Net Savings (In Dollars)	Net Savings Per Discharge (In Dollars)
1.	Foreign Object Retained After Surgery CC	378	172	40	$142,681	$3,567
2.	Air Embolism – MCC	29	23	12	$148,394	$12,366
3.	Blood Incompatibility-CC	23	8	0	$0	$0
4.	Pressure Ulcer Stages III & IV-MCC	76,041	960	337	$1,869,956	$5,549
	a. Stage III			286	$1,552,057	$5,427
	b. Stage IV			57	$340,263	$5,970
5.	Falls and Trauma-MCC & CC	109,728	3,852	1,476	$7,580,774	$5,136
	a. Fracture			1,267	$6,523,144	$5,148
	b. Dislocation			3	$13,984	$4,661
	c. Intracranial Injury			213	$1,089,813	$5,166
	d. Crushing Injury			0	$0	$0
	e. Burn			6	$21,639	$3,607
	f. Shock			1	$12,749	$12,749
6.	Catheter-Associated Infection – CC	11,424	1,896	197	$567,933	$2,883
7.	Vascular Catheter Associated Infection – CC	5,470	2,107	23	$74,586	$3,243
8.	Poor Glycemic Control – MCC & CC	10,937	319	98	$489,733	$4,997
9A.	Surgical Site Infection, Mediastinitis, Following Coronary Artery Bypass Graft (CABG) – MCC	29	21	5	$54,276	$10,855
9B.	Surgical Site Infection Following Certain Orthopedic Procedures – CC	199	123	4	$39,363	$9,841
9C.	Surgical Site infection Following Bariatric Surgery for Obesity – CC	12	10	1	$2,381	$2,381
10	Pulmonary Embolism & DVT Orthopedic MCC & CC	2,494	1,892	845	$5,605,229	$6,633
Total[1]		216,764	11,383	3,038	$16,442,185	

[1]Discharges can appear in more than one row.

Source: RTI Analysis of 234 IPPS Claims, October 2008 through September 2009

Table 2.

Discharge Frequencies of Current CMS HACS October 2008 through September 2009

HAC Category	Frequency and percent as a secondary diagnosis		Qualifies as a HAC (Not Present on Admission)				Does not qualify as a HAC (Present on Admission)			
			POA = "N"		POA = "U"		POA = Y		POA = "W"	
	n	%[2]	n	%[3]	n	%	n	%	n	%
1. Foreign Object Retained after Surgery	441	0.00	189	42.9	0	0.0	252	57.1	0	0.0
2. Air Embolism	33	0.00	24	72.7	0	0.0	9	27.3	0	0.0
3. Blood Incompatibility	28	0.00	8	28.6	0	0.0	20	71.4	0	0.0
4. Pressure Ulcer Stage III and IV	105,092	1.07	1,311	1.2	65	0.1	103,686	98.7	30	0.0
5. Falls and Trauma	153,284	1.6	5,684	3.7	270	0.2	147,257	96.1	73	0.1
6. Catheter Associated Urinary Tract Infection	14,089	0.15	2,323	16.5	19	0.1	11,717	83.1	30	0.2
7. Central Line Associated Blood Stream Infections	6,933	0.07	2,555	36.9	22	0.3	4,342	62.6	14	0.2
8. Manifestations of Poor Glycemic Control	14,135	0.15	435	3.0	10	0.1	13,851	96.8	7	0.0
Surgical Site Infections:										
9. Mediastinitis following CABG	35	0.04	26	74.3	1	0.0	9	25.7	0	0.0
10. Following Certain Orthopedic Procedures	260	0.26	157	60.4	1	0.4	101	38.8	1	0.4
11. Following Bariatric Surgery for Obesity	17	0.12	15	88.2	0	0	2	11.8	0	0.0
12. Deep Vein Thrombosis/Pulmonary Embolism	3,377	0.87	2,505	74.2	17	0.5	832	24.6	23	0.7
Total	297,892	_	15,232	5.1	404	0.1	282,078	94.7	178	0.1

[1] Discharges can appear in more than one row.

[2] Percent computed relative to total discharges "at risk". For HACS 1-8, this is 9,298,503. For HAC 9 this is 94,346. For HAC 10, this is 101,309. For HAC 11, this is 14,068. For HAC 12, this is 386,501.

[3] Percent computed relative to discharges with condition as a secondary diagnosis.

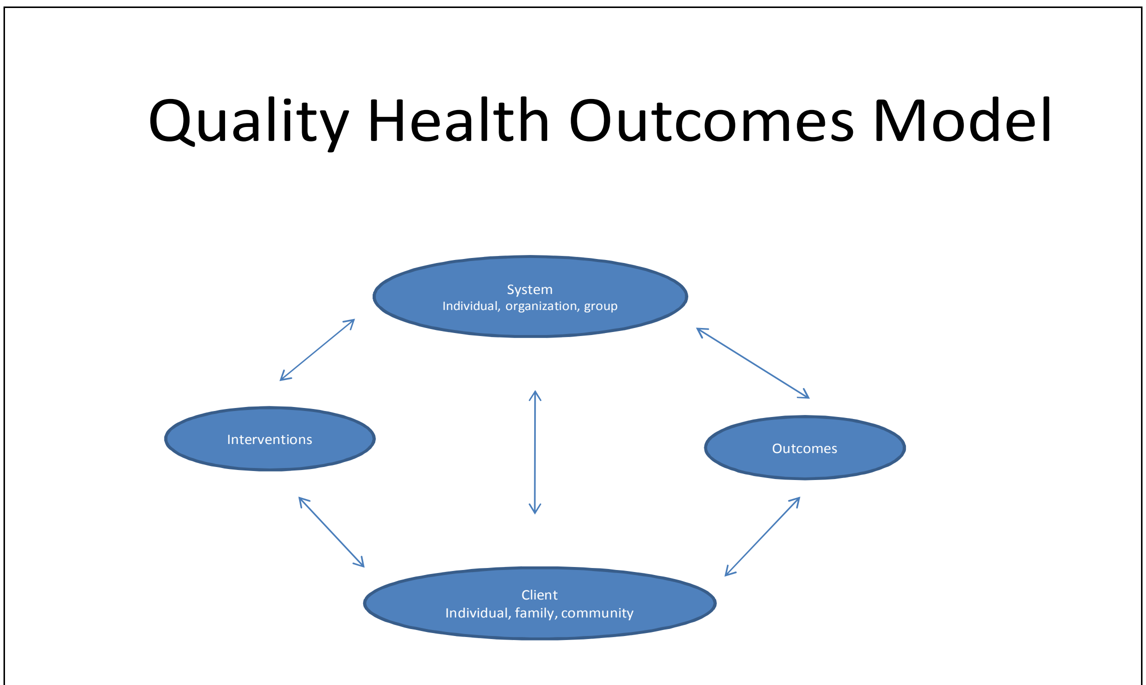
Table adapted from Dalton, K. & Kandilov, A. (2010) Estimating the Incremental Costs of Hospital-Acquired Conditions (HAC). RTI International, Chart C.

Conceptual Framework

This study was guided by the Quality Health Outcomes Model (QHOM) which was developed by the American Academy of Nursing Expert Panel on Quality of Health Care (Mitchell, Ferketich, & Jennings, 1998). The diagram of the QHOM is shown in Figure 1. The QHOM was selected because it is applicable to studying health policy and quality improvement from a hospital system perspective (acute care hospitals). The conceptual-theoretical-empirical structure for this study is depicted in Figure 2.

Figure 1.

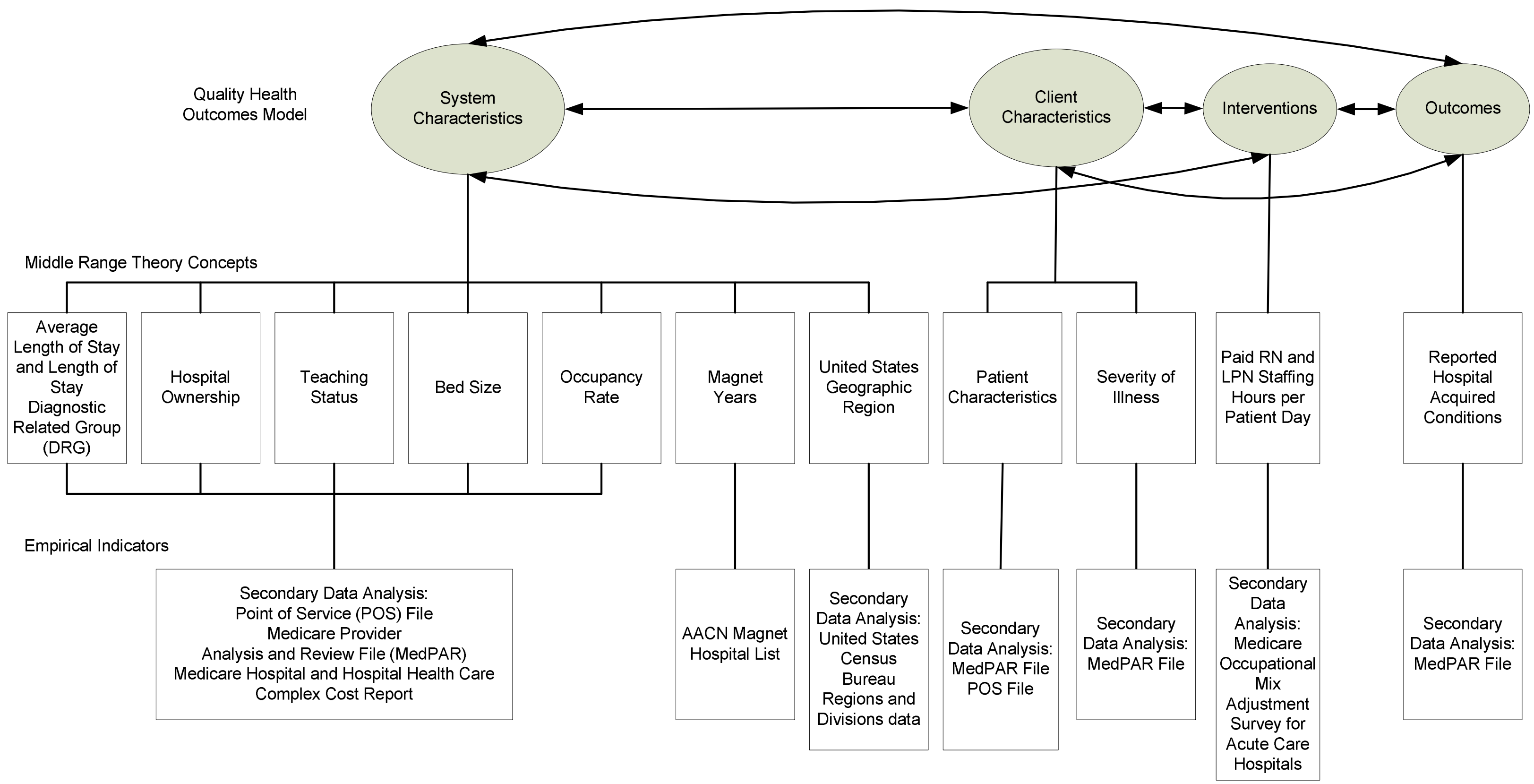
Quality Health Outcomes Model



Redrawn from Mitchell,P., Ferketich, S., and Jennings, B. (1998) Quality health outcomes model. Image: Journal of Nursing Scholarship, 30, 43-46

Figure 2.

Conceptual – Theoretical – Empirical Structure



Quality Health Outcomes Model

The QHOM (Mitchell, et al., 1998; Mayberry & Gennaro, 2001; Radwin & Fawcett, 2002) (Figure 1) is a conceptual model of nursing that incorporates the Donabedian (2003) Structure-Process-Outcome Quality Assurance Model (DSPOQA) and elements of Holzemer's (1994) extension of Donabedian's 1966 work. Previous research (Mitchell & Shortell, 1997) has suggested that neither structure nor process variables show consistent relationships to patient outcomes such as mortality nor adverse events when either structure or process is examined alone.

The QHOM is a dynamic interactive model that is composed of four elements: *System, Client, Outcomes and Interventions. System i*ncorporates traditional structure and process elements and refers to a system as an organized agency such as a hospital (Mitchell et al., 1998). *Interventions* are those clinical processes that are direct and indirect interventions. *Client* includes the individual, family and community and addresses how patient outcomes are affected by patient characteristics (Mitchell et al., 1998). As for *Outcomes*, Mitchell et al., (1998) suggest that outcome measures should be results of care structures and processes and integrate functional, social, psychological, physical, and physiologic aspects of people's experiences in health and illness into the model. To that end the developers of the model operationalized these outcome measures into five categories: "achievement of appropriate self-care; demonstration of health-promoting behaviors; health-related quality of life; perception of being well cared for; and symptom management" (Mitchell et al., 1998, p.45). The model also links more traditional outcomes of mortality, morbidity, adverse events, and costs with organizational factors. The QHOM has mainly been used to guide nursing discipline specific research. In this study it was be applied to the investigation of the HAC/POA health policy. All of the components of the model are applicable to this policy. However, the main emphasis of this study was the analysis of client and hospital characteristics and outcomes.

The model takes into account the feedback and reciprocal influences that occur among patients, the system, and interventions (Mitchell et al., 1998). Contrary to the traditional view that interventions directly produce expected outcomes, as adjusted for client characteristics (Wilson & Cleary, 1995), the original QHOM had no single direct connection linking interventions and outcomes. Instead the model suggested that interventions affect and are affected by both system and client characteristics in producing desired outcomes and no single intervention acts directly through either the system or client alone (Mitchell et al., 1998). In a study of second-stage labor patients, Mayberry & Gennaro (2001), expanded on the QHOM to demonstrate the reciprocal nature of interventions and outcomes by suggesting that interventions such as cesarean delivery and epidural analgesia may result in several significant quality of health outcomes for women (Mayberry & Gennaro, 2001). Mark & Harless (2009) adapted the QHOM to study the linkage between interventions and outcomes using a California data set that included the present on admission indicator. They found no statistically significant relationship between nurse staffing (intervention) and six post-surgical complications (outcome). They concluded that further research is needed to incorporate other aspects of the model that expands the limited definition of outcomes as complications. They also suggested the need for a micro-level theory to understand how nurses create quality of care (Mark & Harless, 2009).

In this study the relationship of nurse staffing (intervention) was linked to the outcomes of reported number of HACs. In addition to the QHOM system characteristics that Mark & Harless (2009) used in their study--teaching status, hospital ownership, and urban area, this study included bed size, average length of stay, and occupancy rate as they were hypothesized to have an association with the incidence of reported HACs.

The QHOM was developed in order to address a gap in the research—specifically, to capture the contributions of nursing interventions to achieving optimal health outcomes and link them to outcomes of nursing care and other care system factors (Mitchell, Heinrich, Moritz, & Hinshaw, 1997). Aiken, Sochalski, & Lake (1996) also called for research that focuses attention on the relation between organizational attributes and patient outcomes.

The QHOM suggests that outcome measures should be results of care structures and processes that integrate functional, social, psychological, physical, and physiologic aspects of people's experience in health and illness. In this study the conceptual – theoretical – empirical structure (Figure 2) depicts the reciprocal nature of the interaction of the four QHOM model components; *Interventions, Client, System, and Outcomes* as they affect the implementation of the HAC/POA policy. As can be seen in Figure 2, system characteristics are composed of hospital ownership type, teaching status, United States geographic region, occupancy rate, Magnet years, and hospital average length of stay.

Client characteristics include the patient's severity of illness and registered nurse staffing intensity. Outcomes include the reduction of reported HACs. The QHOM is linked to the theory of not-for-profit and for-profit hospitals and provides guidance for further linkages between study variables as the HAC/POA regulations are an economic as well as quality improvement policy.

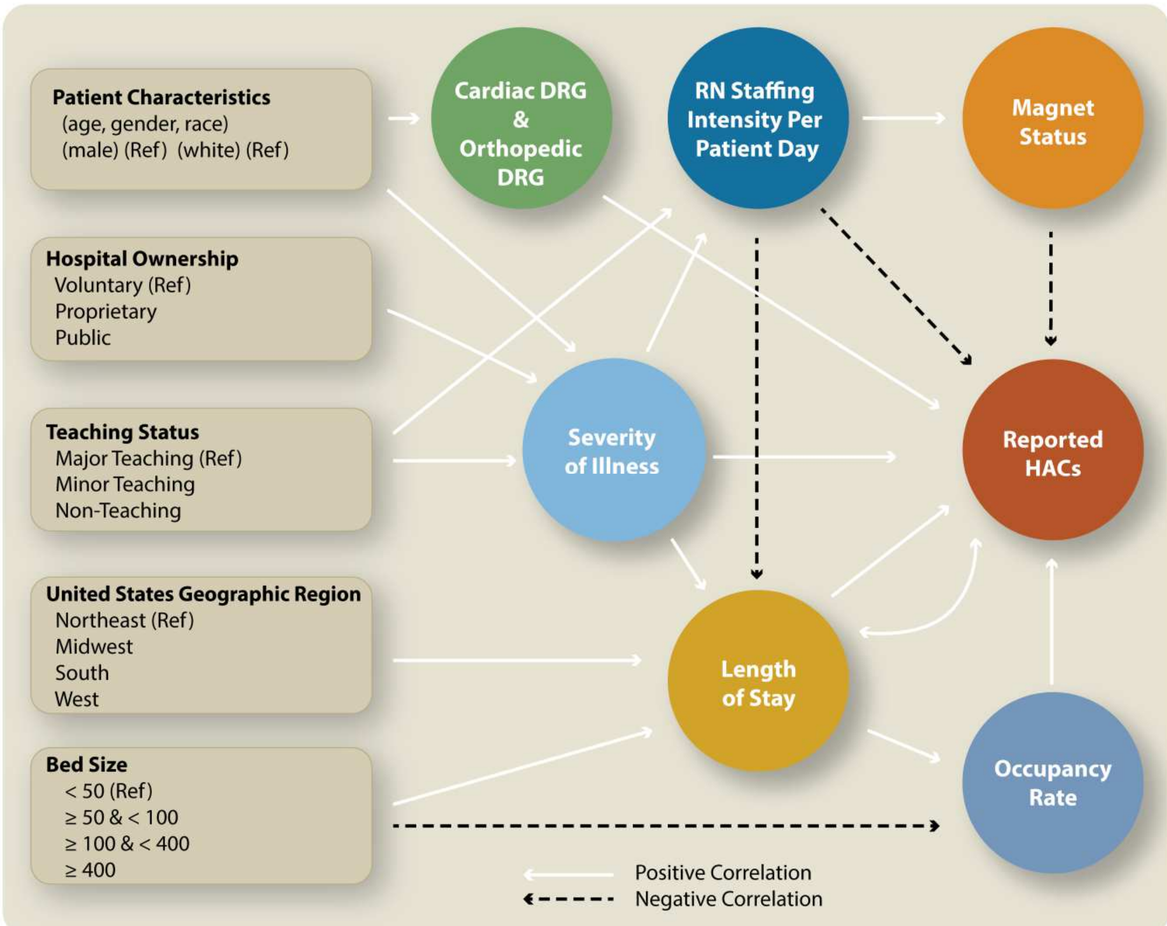
The Path Model (Figure 3) depicts the middle-range theory concepts that were tested in this study. The outcomes of the path model form the feedback loop and depict the reciprocal nature of the QHOM. The Path Model was tested empirically through a secondary data analysis of an analytic file that linked the CMS Medicare Provider Analysis and Review (Med PAR) file, CMS Provider of Services (POS) file, the United States Census Bureau Regions and Divisions file, 2010 Medicare Occupational Mix Adjustment Survey for Acute Care Hospitals, Medicare Hospital and Hospital Health Care Complex Cost Report, and List of Magnet Hospital facilities.

Path Model

The Path Model represented in Figure 3 guided the selection of variables and the specification of the relationship between them. It was hypothesized that the variables in this model all had an impact on the incidence of reported HACs. The exogenous variables in this model are hospital ownership (proprietary, non-profit), government, teaching status (academic medical center, [major teaching hospital], minor teaching hospital, and non-teaching hospital), United States geographic region (Northeast, Midwest, South, and West), and patient characteristics (age, gender, race), and bed size. The endogenous variables were average length of stay (ALOS), severity of illness, RN staffing LPN staffing intensity per patient day, Magnet Hospital years, and occupancy rate. The outcome variable tested was the incidence of reported HACs.

Figure 3.

Hospital Acquired Condition Path Model



Reported HACs

Reported HACs refers to the number of International Classification of Diseases (ICD-9) secondary diagnosis codes for any of the 10 Medicare designated HACs that were submitted as Medicare claims. It was hypothesized that HACs are under-reported because these adverse events may not be evident at the time the patient is discharged from the hospital. An HAI, such as mediastinitis after coronary artery bypass graft surgery, is an example of a potentially under-reported infection. Five factors were hypothesized to have a direct impact on the incidence of reported HACs:

- RN and LPN staffing intensity per patient day
- Severity of Illness
- Length of Stay
- Magnet Hospital Years, and
- Occupancy rate.

The sections below describe the hypothesized causal relationships of these five factors as well as the exogenous variables. Each variable with a direct effect on the outcome variables is explained as well as how each of the variables is influenced by the others.

Paid Registered Nurse and Licensed Practical Nurse Hours per Patient Day

Registered nurse and licensed practical nurse staffing was defined as the total number of paid hours per patient day of care each patient received. It was hypothesized that registered nurse staffing is inversely correlated with the incidence of reported HACs (the higher the nurse staffing the lower the incidence of HACs) because the nurse has more time to provide direct care, theoretically mitigating the potential for an HAC when assigned to patients according to their acuity and specific care needs.

Indeed, there is evidence to support the association between nurse staffing, quality of patient care, and patient outcomes (Blegen, Goode, Spetz, Vaughn, & Park, 2011;

Needleman, Beurhaus, Pankratz, Leibson, Stevens, & Harris, 2011; Aiken, Smith & Lake, 1994; Aiken, Clarke, & Sloane, 2002; Needleman, Beurhaus, Mattke, Stewart, & Zelevinsky, 2002; Cho, Ketefian, Barkauskas, & Smith, 2003). However, there are inconsistencies among the relevant studies with respect to how nurse staffing was measured, where the staffing data were obtained, and what types of patient care units were included (Blegen et al., 2011; Blegen, 2006; Kane, Shamliyan, Mueller, Duval, & Wilty, 2007; Staton & Rutherford, 2004; Unruh, 2008). One study suggested that higher registered nurse (RN) and licensed practical nurse hours (LPN) per equivalent patient day and increasing the percentage of registered nurses in the skill mix predicted a lower number of adverse events, controlling for patient age and complications (Frith, Anderson, Caspers, Tseng, Sanford, Hoyt, & Moore, 2010).

Five variables in the model were hypothesized to influence nurse staffing. RN staffing intensity was in turn hypothesized to be determined, in part, by hospital ownership and teaching status. Private non-profit hospital ownership would presumably be positively correlated with RN staffing intensity per patient day as these hospitals should provide more nursing resources based on their stated mission and economic status. Private hospitals are either nonprofit or proprietary (for profit). Public hospitals can be federal, state, county, or local (Folland, 2007). Proprietary hospitals, in contrast, are in business to make a profit and it was hypothesized that staffing intensity would be lower than private non-profit hospitals if the former were indeed more cost conscious. Finally, public hospitals were generally presumed to have fewer economic and human resources than private and proprietary hospitals as they are heavily subsidized by government agencies which have challenging fiscal constraints and are therefore not in a position to provide the same level of staffing intensity.

Teaching, nonprofit private, Academic Medical Centers (AMCs) were hypothesized to have an especially high staffing intensity as they usually treat patients with higher severity that require intensive nursing care. (See discussion of case mix below.) AMCs, through generous bequests and favorable insurer and indirect and direct medical education (IME/DME) payments, are also able to afford more intensive nursing care. Likewise, hospitals that have a higher case mix of patients will adjust staffing to accommodate acuity and provide a safe patient care environment.

Severity of Illness

It was hypothesized that severity of illness (SOI) is positively correlated with the incidence of reported HACs, holding all other variables constant. Patients with more severe illnesses usually undergo more diagnostic tests and treatments than less acute patients, which places them at higher risk for an adverse medical event and renders them more vulnerable to infections as well.

Larger hospitals, and AMCs, in particular, were presumed to exhibit a higher SOI because they are better able to diagnose and treat a wide range of illnesses. Larger, non-AMC hospitals were also hypothesized to have a higher SOI due to the breadth of their service mix. The AMC was also hypothesized to positively correlate with a higher SOI, because patients with complex illnesses, trauma, and rare diseases come to the AMC for diagnosis and treatment that cannot or is not usually provided in a non-academic setting.

Average length of stay (ALOS) was also hypothesized to be positively correlated with the incidence of reported HACs.

Average Length of Stay (ALOS)

Longer stays are related to the likelihood of HACs via two factors: 1) exposure time defined as the amount of time the patient spends in the hospital, and 2) extended treatment time required for care after an adverse event has occurred. Only in (1) is ALOS a causal factor. Patients who sustain a HAC were expected to have a longer ALOS because their hospitalization would be extended to treat the HAC.

United States Geographic Region

It was hypothesized that ALOS and geographic region would influence case mix. It was also hypothesized that hospitals in the Western United States region would negatively correlate with ALOS and therefore exhibit lower HAC rates, because of their shorter average length of stays relative to other regions. Case mix was expected to relate positively to ALOS for the reasons discussed above. It was also hypothesized, although not tested in this study, that different medical provider practice patterns and treatments may have an impact on the association of the incidence of reported HACs. ALOS was also hypothesized to positively correlate with occupancy rate.

Occupancy Rate

Occupancy rate is defined as the number of hospital admissions per year times the ALOS divided by the number of beds times 365. It was hypothesized that occupancy rate is positively correlated with the incidence of reported HACs via the reasoning that high occupancy increases staff workload which in turn places patients at higher risk for experiencing an adverse medical event. Weissman et al., (2007) studied daily workload in four hospitals characterized by their volume, throughput (admissions and discharges) intensity, aggregate DRG case mix, and staffing. Although their sample size was small, they found that at one urban teaching hospital with a high occupancy rate, admissions and patients per nurse were significantly related in a positive way to the likelihood of an adverse event and that holding annual admissions constant, bed size reduced occupancy rate and ALOS increased it. An exogenous variable, bed size, was hypothesized to directly impact LOS and indirectly occupancy rate.

Bed- Size

Bed- size refers to the number of staffed licensed beds available to admit patients. While bed size was hypothesized to have no direct effect on HAC rates; it was hypothesized to be negatively correlated with occupancy rate holding ALOS and severity of illness constant. Bed size was included in the model as it was hypothesized that hospitals with larger bed-size would have a higher incidence of reported HACs.

Hypotheses

H1: Patients with a longer LOS will be more likely to experience a reported HAC due to a longer "exposure" time.

H2: As patients age they will have a higher likelihood of experiencing a HAC.

H3: Medicare patients with a high severity of illness score will have a higher incidence of reported HACs.

H4: Hospitals with greater RN-intensive staffing per inpatient day will exhibit lower hospital acquired condition (HAC) rates.

H5: Years of Magnet Hospital status will be associated with a lower incidence of HACs.

H6: There will be geographic differences in the incidence of HACs because of variation in care practices to prevent HACs.

H7: Public hospitals will have a higher incidence of HACs because of greater financial constraints.

H8: Teaching hospitals will have a higher incidence of reported HACs because they have a more severe longer length of stay (LOS) case mix acuity.

H9: Acute care hospitals with a high occupancy rate will have a higher incidence of HACs because they will have higher case mix acuity.

H10: Hospitals with a large bed-size will have a higher incidence of HACs because they will have higher case mix acuity.

CHAPTER 2.

REVIEW OF THE LITERATURE

Introduction

The purpose of this study was to quantify the association between patient characteristics, hospital characteristics and nursing care intensity on the reported incidence of HACs. This chapter presents the review of relevant literature conducted within the following health policy contexts: historical, sociological, economic, and political. The historical section includes pertinent literature on quality, cost, and adverse patient care events. The sociological literature includes serious reportable events, patient safety indicators, and patient safety organizations. The economic section describes the literature surrounding the costs of hospital acquired conditions. Finally, the political context is examined by summarizing the relevant policies that lead to the HAC/POA program.

Also included in this chapter is a review of the literature concerning evidence-based practice, safety culture, and state tracking of hospital acquired conditions. The application of evidence-based practice that could reasonably prevent HACs is one of the three conditions used to select the CMS designated HACs. A hospital organization's safety culture is also viewed as an important component in the prevention of HACs and is included in the literature review but was not studied. The final section of the literature review presents a summary of the current status of United States tracking of HACs.

Historical Context

Quality

Concerns about the poor quality of American medicine and the perceived deplorable state of the nation's medical schools and major hospitals was documented as early as the 19^{th} century (Luce, Bindman, & Lee, 1994). Several organizations were established to rectify these conditions. The American Medical Association (AMA) was established in 1847, and the American College of Surgeons established its Hospital Standardization Program in 1917 drafting minimum standards for care in hospitals. These minimum standards included organizing hospital medical staffs, assuring that staff was well-educated, competent, and licensed; keeping medical records; and establishing clinical laboratories and radiology departments for diagnosis and treatment (Luce et al., 1994). Governmental regulatory programs played a role in establishing standards as early as 1906 when the development of national regulation of medication under the Food and Drug Administration was assumed. Health care fell under federal supervision in 1935 with the implementation of the Social Security Act and the Hill-Burton Act of 1946 established minimum codes for new hospital structures (Luce et al., 1994). In 1952 the Joint Commission on Accreditation of Hospitals was established to survey the conditions of health care organizations and in 1966 developed more rigorous standards (Luce et al., 1994). The passage of Title XVIII (1965) of the Social Security Act established Medicare and Congress established the Conditions of Participation standards for operating a hospital.

Cost

In the 1970's, concerns over rising health care costs and the percentage of gross national product (GNP) devoted to health care became a pivotal point in health care reform efforts. In 1979 President Carter made hospital cost containment his highest legislative priority and proposed legislation that would have placed limits on the annual percent increase in each hospital's expenditures (Feldstein, 2001). This measure was seen as too threatening to hospital's goals and revenues and was defeated through the efforts of the AMA and hospital associations.

In the 1980s and early 1990s healthcare reform focused on controlling costs, increasing access and coverage, and improving healthcare performance (Aday et al., 2004). President Clinton in the 1990s proposed a healthcare plan that attempted to achieve increased access to care through universal coverage and to decrease the rising growth in medical expenditures. Many reasons have been cited for its eventual defeat in Congress (Antos, 2008; Feldstein, 2001; McMahon, 1995) but the major contributors to its defeat were the lack of public confidence in a major reform proposal and bipartisan congressional support at the time.

Since then several incremental changes have been implemented in an attempt to extend coverage to the uninsured and vulnerable and to slow increased cost growth of health care. Between 1993 and 1997, the expansion of managed care slowed the average annual growth in private spending below the growth in gross domestic product (GDP), while public spending continued to increase. The controls put in place through the Balanced Budget Act of 1997 served to also quell the growth in Medicare expense growth (Zuckerman & McFeeters, 2006). However overall health expenditure growth accelerated between 1993 and 2003, increasing from 5.3 percent between 1993 and 1997 to 6.2 percent between 1997 and 2000 to 8.6 percent during the most recent period (2000-2003) (Zuckerman & McFeeters, 2006).

Adverse Patient Care Events

Beecher & Todd (1954) in an early study of adverse patient events of patient deaths associated with anesthesia noted that a significant portion of them were attributed to medication errors. A seminal study on medication errors conducted in 1962 indicated an error rate of 16 errors per 100 doses of medication (Barker & McConnell, 1962). Medication error research throughout the 1970s and 1980s focused on non-acute care settings, monitoring and dispensing systems to reduce errors, and the interdisciplinary nature of medication errors and increased policy attention on the problem of adverse medication events.

In 1991 the seminal Harvard Medical Practice Study I and II brought attention to the incidence of adverse events and negligence in hospitalized patients (Brennan, Leape, Laird, Hebert, Localio, Lawthers, Newhouse, Weiler, & Hiatt, 1991; Leape, Brennan, Laird, Lawthers, Localio, Barnes, Hebert, Newhouse, Weiler, & Hiatt, 1991). In a sample of over 30,000 randomly selected non-psychiatric New York State 1984 hospital records the researchers found that adverse events occurred in 3.7 percent of the hospitalizations and that 27.6 percent of the adverse events were due to negligence. Almost seventy one percent of adverse events accounted for a disability lasting less than six months, while 2.6 percent resulted in permanent disability and 13.6 resulted in death. Complications from medications were the most common type of adverse event followed by wound infections. These studies suggest that there is a substantial amount of injury to patients attributed to medical management as a result of substandard care (Brennan et al., 1991; Leape, et al., 1991).

Sociological Context

The landmark Institute of Medicine (IOM) publication To *Err is Human Building a Safer Health System* (Kohn, Corrigan, & Donaldson, 2000) catapulted the significant problem of adverse medical events in American hospitals into both professional and public awareness. The IOM report estimated that at least 44,000 and possibly as high as 98,000 Americans died each year as a result of medical errors and that those preventable adverse events were a leading cause of death in the United States (Kohn et al 2000; Brennan et al 1991). Of those 98,000 deaths, nearly 7,000 occurred each year from medication errors in or out of the hospital (Kohn et al, 2000). The 2006 IOM report, estimated that errors in the way medications were prescribed, delivered and taken harmed 1.5 million people every year and in the hospital setting alone, cost more than $3.5 billion per year to treat (IOM 2006). These historical studies formed the impetus for the current quality improvement movement in the United States to reduce preventable events by identifying their causes and developing methods to reduce their effects.

Serious Reportable Events

The initial IOM report (Kohn et al, 2000) recommended that a nationwide public mandatory reporting system be established to identify and learn from medical errors and other adverse events. Under the reporting system, state governments would be required to collect standardized information about adverse medical events that result in death and serious harm. In response to this recommendation, the National Quality Forum (NQF) created and endorsed *Serious Reportable Events in Healthcare* in 2002, a core set of reporting standards, to increase public accountability and consumer access to critical information about healthcare performance (NQF, 2007). This groundbreaking document reflected consensus on a list of 28 serious, preventable adverse events that could form the basis for a national reporting system and lead to substantial improvements in patient safety. Each of the twenty eight events is classified under 1 of 6 categories: surgical, product or device, patient protection, care management, environment or criminal (NQF, 2007).

Patient Safety Indicators and Patient Safety Organizations

In response to the 1999 IOM report, researchers at the Agency for Health Care Research and Quality (AHRQ) developed patient safety indicators (PSIs) for identifying potential instances of compromised patient safety in the inpatient setting (Miller, Elixhauser, Zhan, & Meyer, 2001). PSIs are measures used to screen for adverse events and potential complications following surgeries, procedures, and childbirth. There are 20 indicators (e.g. foreign body left in during procedure, postoperative sepsis, transfusion reaction) for complications that may occur in the inpatient hospital setting that may indicate a patient safety event (AHRQ, 2006).

It has been argued that as the public's awareness of medical errors deepens, plaintiffs' attorneys will grow more empowered and aggressive, which will in turn increase the pressure of the current tort (medical malpractice) crisis and the defensiveness of the medical profession (Mello, Kelly, & Brennan, 2005). This conflict between tort liability and patient safety laws was raised at the Federal level in the early 2000s, which subsequently led to the creation of the Patient Safety and Quality Improvement Act of 2005 (the Patient Safety Act). The legislation directed HHS to create a list of public or private organizations known as patient safety organizations (PSOs), and it prohibits unauthorized disclosure of certain types of data regarding patient safety events that providers send to PSOs (Government Accountability Office [GAO], 2010). PSOs analyze data regarding patient safety events, provide feedback to providers, and develop and disseminate information on ways providers can improve patient safety. To support PSOs and providers in their efforts to develop and adopt improvements in patient safety, AHRQ has created a network of patient safety databases (NPSDs). These databases collect and aggregate nonidentifiable data on patient safety events voluntarily submitted by the PSOs and providers. Patient safety data are aggregated and analyzed nationally (West, Eng, Lyda-McDonald, & McCall, 2011).

Economic Context

In addition to providing incentives for improving quality of care and fewer unintended outcomes, achieving Medicare cost savings is one of the driving forces of the HAC-POA regulations. In 2006 IPPS allocated $104 billion in payments for inpatient services – about 20 percent of overall hospital revenues and 32 percent of Medicare spending nationwide. It is estimated that fifteen percent of inpatient costs are attributed to complications of care and half of these are considered preventable (McNair, Luft, & Bindman, 2009). Under the HAC-POA regulations, CMS estimated that 490,000 claims could be paid at a lower rate (Kurtzman & Beurhaus, 2008), saving Medicare over $21 million out of the total $105 billion that was paid in 2008 for inpatient hospital operating payments within the IPPS for short term acute care hospitals (Fuller et al., 2009).

Fuller et al., (2009) studied the financial impact of sixty four potentially preventable hospital acquired complications (PPCs) in Maryland and California by estimating the incremental cost of different types of HACs to determine the incremental cost burden of HACs on the health care system. Their analysis revealed that the incremental costs of claims for Maryland were $6,504,557,501, of which $626,416,710 (9.63%) was associated with PPCs. California's claims constituted a similar percentage of total costs associated with PPCs (9.39%). For example urinary tract infections (UTIs) in Maryland accounted for 0.67% of total inpatient hospital costs and on average patient level costs increased by 19.6%. In California UTIs accounted for 0.66% of total inpatient costs and on average increased the patient level cost by 21.48%, (Fuller et al., 2009). A limitation of this study was that the analysis did not include incremental costs associated with treating a PPC. Another limitation is that claims based data may contain inaccuracies and variation in coding completeness, which could contribute to both biases in the total as well as incremental estimated costs for individual PPCs.

McNair et al., (2009) modeled the financial impact of six of the HACs using discharges from the 2006 California Patient Discharge Dataset from the California Office of State Health Planning and Development. They simulated the impact of the policy by deleting the secondary diagnosis codes of the six examined HACs to determine if it changed the DRG classification for the hospitalization. If the DRG changed, they estimated the effect on hospital payments by calculating the difference between the original DRG and the reallocated DRG. Their study revealed that HACs were present in 0.11 percent of acute care hospital discharges and only three percent of discharges were affected by the change in DRG classification. They estimated the reduced hospital payments from this HAC rate in California would be $92,000 – $227,000 which would translate into nation-wide reductions of $1.1 – $2.7 million (McNair et al., 2009). The limitations of this study include using only data from California which represented only 8 percent of total Medicare acute inpatient PPS payments; however, the distribution among California Medicare patients was similar to other states. In addition, modeling of the financial impact of the policy was conducted prior to the implementation of the policy. As the financial implications are affected by coding, it is possible that coding changes made after the policy was implemented could have diminished the policy's financial impact. Another limitation is that the financial implications of preventing avoidable complications may be underestimated as the study only modeled Medicare policy. The analysis also did not include payment to additional nonacute care required as a result of the complication. McNair and colleagues concluded that the new policy may have implications for improving quality of care but that the financial gains in reduced hospital payments may not be as significant as projected by CMS.

In contrast to the conclusions of McNair et al. (2009), McNutt et al. (2009) suggest that the amount of change in payment for HACs could be sizeable. Their study estimated the proportion of cases that change MS-DRG assignment when HACs are removed from the calculation. Using AMC data from the University Health System Consortium they identified all cases with 1 of 7 HACs coded through the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis codes and calculated the MS-DRG with and without the HAC. Their results revealed that 27.6% of cases with at least one HAC would experience a change in MS-DRG assignment without the HAC factored into the assignment. When they estimated the possible impact of POA status on each HAC and subsequent reassignment of MS-DRG, the estimated reduction in reimbursement per case ranged from $1548 for a CAUTI to $7310 for a SSI. These reductions translated into a total estimated reimbursement loss of $50,261,692 (Range: $38,330,747 – $62,344,360) for the 86 AMCs in the study. Studying only AMCs and the lack of actual POA coding (study was prior to POA regulation) were limitations of this study as was the lack of including central line associated blood stream infections (CLABSI) as no corresponding ICD-9-CM code existed at the time.

The difference in estimated savings from these two studies may be related to the method used to calculate the range in the proportion of cases changing assignment to account for the POA status as the POA status was not reported by the 86 study hospitals.

The McNair study had 828 Medicare discharges where the codes met the definition of at least one of the six HACs, whereas the McNutt study had 184,932 discharges that had at least 1 of the 7 HACs.

Political Context

The Patient Safety and Quality Improvement Act of 2005 authorized the formation of Patient Safety Organizations (PSOs) to address the reporting and analysis of data on safety events to improve quality and reduce harm to patients which was a serious need articulated in the 1999 IOM report (AHRQ, 2010). The Department of Health and Human Services (HHS) implemented The Act by issuing the Patient Safety and Quality Improvement Final Rule (Patient Safety Rule). AHRQ oversees the provisions of the Patient Safety Act and the Patient Safety Rule as it applies to PSOs (AHRQ, 2010). PSOs act as repositories of confidential safety event data for analysis and aggregation from healthcare organizations that voluntarily join them. PSOs also act as patient safety experts collaborating with healthcare organizations to develop strategies for improving quality. HHS delegated to AHRQ the creation of a network of patient safety databases (NPSD) to collect the data gathered by PSOs into a central location (West, Eng, & McDonald, 2010). There are currently 85 PSOs representing twenty nine states and the District of Columbia that have at least one PSO with several states having more than one (AHRQ, 2010).

The American Recovery and Reinvestment Act of 2009(The Recovery Act)

More recently, The American Recovery and Reinvestment Act of 2009 authorized $50 million to support states in the prevention and reduction of HAIs. The CDC was the responsible agency for distributing the Recovery Act funds to State health departments through cooperative agreements. HAI Recovery Act funds were invested in efforts that support surveillance and prevention of HAIs, encourage collaboration, train the workforce in HAI prevention and measure outcomes. States' primary means of collecting data from health care facilities through the Recovery Act agreements is through the National Healthcare Safety Network (NHSN). NHSN is a voluntary, secure, internet – based surveillance system operated by the CDC that is open to all types of health care facilities in the United States. The CDC currently supports more than 2,000 hospitals using the NHSN, and 21 states require hospitals to report HAIs using NHSN (West et al., 2010).

Patient Protection and Affordable Care Act (Affordable Care Act) Expands DRG-HAC Legislation

Section 3008 of Title III Improving the quality and efficiency of health care in the Patient Protection and Affordable care Act (Affordable Care Act) expanded the current payment system for HACs by making adjustments to hospital payments during fiscal year 2015, paying ninety nine percent of the amount of payment that would otherwise apply to discharges falling into the designated HACs. In addition the Secretary for Health and Human Services (SHHS) was directed to identify states that currently withhold payment for HACs to Medicaid beneficiaries and apply appropriate applications to the Federal Medicaid regulations. Another significant step was charging the Secretary with making available to the public reports of applicable Hospital's HACs (Patient Protection and Affordable Care Act, 2010). The Secretary was also directed to report no later than January 1, 2012 a study of the impact of quality of care, patient safety, and Medicare spending on expanding the HAC program to inpatient rehabilitation hospitals, long-term care hospitals, hospital outpatient departments, skilled nursing facilities, ambulatory surgical centers, and health clinics (Patient Protection and Affordable Care Act, 2010).

Present on Admission Conditions

On each patient's Medicare discharge abstract, eight diagnostic codes are used to identify HACs. Because many seeming HACs (e.g., infections) were really present on admission, it is critical to a fair and efficient payment that Medicare be able to distinguish true HACs from POAs. Hospitals, therefore, are required to submit present on admission information on all primary and secondary diagnoses for inpatient discharges using specific indicators at the time of inpatient admission. The challenge of identifying POA conditions is in the accuracy of coding. In a study of California and New York Medicare discharge abstracts from 2003, Zhan et al, (2007) identified inconsistencies in coding. Moreover, it was found that New York coded secondary diagnoses in the medical record as POA four times as often as California. Hospitals reporting missing POA information or who coded all secondary diagnoses as non-POA were also higher in New York than California. The study also revealed that large teaching hospitals coded more secondary diagnosis codes as not present on admission (Zhan et al, 2007). This study raised the issue of establishing coding standards and rules and assuring they are applied correctly and uniformly.

Houchens, Elixhauser, & Romano (2008) also used New York and California data to evaluate the relationship between patient safety indicators (PSIs) and POA information and to examine the extent that PSIs without POA information are valid measures of hospital-level quality of care. Their results were similar to Zhan (2007) in that 17% of cases from New York revealed suspect coding compared with 1% - 2% in California. When records with questionable POA coding were removed from the data, 92%-93% of secondary diagnoses in both California and New York were POA. The authors concluded that ten of 13 PSIs appeared to be valid measures of in-hospital patient safety events even in the absence of POA codes (Houchens et al. 2008).

In yet another study, Hughes & colleagues (2006) used the POA indicator to identify in-hospital complications among secondary diagnoses that arose after admission. These authors also concluded that the POA indicator was valuable for identifying complications but added that adequate risk-adjustment methods were needed for comparing hospital complication rates (Hughes et al. 2006).

The conclusion from this brief review of the research is that while there may be issues in differentiating a condition as POA or HAC, the POA indicator provides critical information about true HAC conditions when they are present.

Nurse Staffing

The relationship between nurse staffing and patient outcomes has been investigated in numerous research reports that resulted in divergent conclusions (Lake &

Cheung, 2006). However, prior research generally supports the association between higher proportions of RNs and greater total number of hours of care by RNs and LPNs per day is associated with better care.

Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky (2002), used administrative data from 1997 for 799 hospitals in 11 states covering both medical and surgical patient discharges to examine the relationship between the amount of care provided by hospital nurses and patients' outcomes. Several hospital acquired complications were studied including urinary tract infections, pressure ulcers, deep venous thrombosis, and wound infections. Controlling for differences in nursing case mix and the patients' level of risk the authors reported an association between the proportion of total hours of nursing care (registered-nurse-hours plus licensed practical-nurse hours plus nursing assistant hours and the total hours per day provided by licensed nurses) provided by registered nurses and six outcomes among medical patients. Specifically, more registered nurse hours per day were associated with a shorter length of stay (incidence-rate-ratio -1.12; 95 percent confidence interval [CI]), and a lower rate of urinary tract infections, (incidence-rate-ratio 0.48; 95percent CI), upper gastrointestinal bleeding, (incidence-rate-ratio 0.66; 95percent CI), hospital acquired pneumonia, (incidence-rate-ratio 0.59; 95 CI), shock or cardiac arrest, (incidence-rate-ratio 0.46; 95percent CI),failure to rescue(incidence-rate-ratio 0.81; 95percent CI), (Needleman et al., 2002).

For surgical patients, the proportion of total hours of nursing care was positively associated with urinary tract infections, (incidence-rate-ratio 0.67; 95 percent CI) failure to rescue (incidence-rate-ratio 0.73; 95 percent CI) and in-hospital death (incidence-rate-ratio 0.99; 95 percent CI). There were no significant associations observed between hours of care provided by licensed practical nurses or nursing assistants for these six outcomes.

Needleman et al, (2002), concluded that a higher proportion of total hours of nursing care provided by registered nurses was more frequently associated with lower rates of adverse outcomes than a greater number of registered nurse hours per patient day. The authors raised the concern that some of the associations found in the study may be false positives as they tested 25 outcomes in both medical and surgical patients and found a positive association for 8 of them. One limitation of the study was the difficulty in standardizing the nursing data from multiple states and determining what proportion of nursing hours were attributed to inpatient care. The absence of secondary coding of adverse outcomes at the time of the study was also cited as a limitation of the study as these outcomes were likely to be underreported.

Esparza, Zoller, Weatherby, White, & Highfield, (2004) also reported that a higher RN staffing skill mix was associated with a decline in hospital acquired urinary tract infections (OR=4.25, p=<0.001) and length of stay (R^2 =.01, p=<0.001) when controlling for location (urban/rural), ownership, bed size, and case mix. A limitation of this study was that nurse staffing data were reported at the hospital level versus at the adult medical-surgical unit level which was the intent of the study. Another limitation was using only staffing numbers and not accounting for the cognitive and technical skills that make up the complex process of caring for patients (Esparza et al., 2004).

Stone, Mooney–Kane, Larson, Horan, Glance, Zwanziger, & Dick (2007) studied nurse working conditions, specifically staffing, with the incidence of pressure ulcers and

CLABSI and catheter associated urinary tract infections (CAUTI) using data from National Nosocomial Infection Surveillance system protocols and Medicare files. Nursing case mix and type of intensive care unit (ICU), medical or surgical, were the ICU level variables in the study. Nursing case mix was estimated using unit-specific nurse intensity weights which were also used in the Needleman et al., 2002 study. Patients admitted to an ICU with more nursing hours had a statistically lower incidence of CLABSI (OR=.32 $p=\leq$, 0.05) ventilator acquired pneumonia (VAP) (OR=.21, $p=\leq$, 0.05), 30 day mortality (OR=.81 $P=\leq$, 0.05) and pressure ulcers (OR=.69, $p=\leq 0.01$) for either the third and fourth staffing quartiles as compared to the first quartile. The authors concluded that intensive care units with higher staffing, defined as RN hours per patient day, had a lower incidence of CLABSI, VAP, 30 day mortality, and pressure ulcers (Stone et al., 2007). A limitation of the study, identified by the authors, was the absence of variables not measured such a presence of an intensivist, working conditions for non-nursing personnel, team stability and the use of evidence-based protocols (Stone et al., 2007).

Evidence-Based Practice

A statutory requirement for Medicare's non-payment policy of HACs was that they be reasonably preventable by using evidence-based-guidelines (EBG) for clinical care. EBGs are integral to the implementation of evidence-based practice (EBP). A 2007 Leapfrog Group survey of 1,256 hospitals found that 87% of those hospitals did not consistently follow recommendations to prevent many of the most common HACs (Leapfrog Group, 2007). Evidence-based clinical practice guidelines are systematically developed statements derived from a systematic review of the best evidence available and expert consensus to help practitioners, administrators, and patients make decisions about treating specific diseases (Boyd et al., 2005 - Lim et al., 2008). The United States Preventive Services Task Force (USPSTF) is one example of an evidence-based medicine organization that conducts scientific evidence reviews on a broad range of clinical preventive health care services. The USPSTF evaluates clinical research in order to assess the merits of preventive measures such as screening tests and preventive medications. Prevention of falls in community dwelling older adults is an example of one of its recommendations. Research, administrative, technical, and dissemination support for the USPSTF is provided by AHRQ's Prevention and Care Management Portfolio (USPSTF, 2014). EBGs are developed by conducting a comprehensive literature search, critically appraising and grading the quality of evidence, and generating recommendations for care while also considering the patients' preferences and values (Lim et al, 2008). EBGs provide a standard of care for improving quality and are increasingly used to guide reimbursement decisions (Boyd et al., 2005 - Lim et al., 2008).

An important component of guideline development is the use of a hierarchy of evidence to critically appraise the quality of relevant evidence. The grading system, which includes the level of evidence (study design), assists practitioners in determining when recommendations are beneficial or harmful, or where the risks and benefits are uncertain (Lim et al., 2008). A limitation of the grading system is the absence of a uniform method to rank each of the guideline statements. For example, the developers of the CLABSI EBG used a three level scale (I-III) characterizing evidence ≥ 1 properly randomized trials (I) to evidence from opinions of respected authorities (III). The developers of the CAUTI guideline used a range of 1-4, (high to very low) where 1 indicated that further research was very unlikely to change confidence in the estimate of effect (high) and 4 indicated that any estimate of effect was very uncertain (very low) (AHRQ, 2009). This lack of a uniform grading method makes it difficult for practitioners to determine appropriate use of the guidelines based on the strength of the evidence. The *National Guideline Clearing House* is a public resource sponsored by AHRQ that contains all currently available EBGs; by whom and how they were developed, and the quality of supporting evidence.

EBP is a term that has become prominent in both nursing and medicine since the mid-1990s. Several variations of the definition have been suggested by theorists with the common thread being that theory is central to the definition. EBP is defined as the conscientious and explicit and judicious or intentful use of theory-derived research in making decisions about patient care delivery (Ingersoll, 2000 - Macnee, 2004 - Driever 2002). Driever (2002) adds that decision making about health care delivery for patients be based on consensus of the most relevant and supported evidence. Straus, Richardson, Rosenberg, & Hayes (2000) in DiCenso, Guyatt, & Ciliska (2005) include a dimension of patient values to facilitate clinical decision making to their definition of EBP. Fawcett & Garrity (2009, p. 8), state that "Evidence-based nursing practice is the deliberate and critical use of theories about human beings' health-related experiences to guide actions associated with each step of the nursing process". Similar to EBP, Sackett et al., (1996, p. 71) in Colyer & Kamath (1999) define evidence-based medicine as "the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients…evidence-based medicine means integrating individual clinical expertise with the best available external clinical evidence from systematic research."

Integral to the HAC/POA program and the use of EBGs is the question of the effectiveness of the EBG in preventing HACs. There is minimal research, documenting the reductions in HACs following implementation of EBGs. Guideline-development processes have been evolving from expert panel recommendations supported by a selective literature search or based on a consensus of the panel members, to the more recent adoption of systematic processes. These processes employ an explicit evidence-grading and strength-of-evidence designation. A full systematic review also includes a literature search framed by critical questions and defined inclusion and exclusion criteria. Nevertheless, there remains an important clinical area for which no definitive clinical trial or other relevant evidence base exists. This issue is typically addressed by either making no recommendation when there is clinical uncertainty, or by making recommendations, clearly specified as expert opinion, typically based on clinical experience and reasoning from underlying scientific principles (Labresh, Lux & Eng, 2010).

Both the CDC CAUTI 2009 guidelines for urinary catheter-related infection and the Institute for Clinical Systems Improvement (ICSI) Health Care Protocol: Perioperative Protocol (2012) provide estimates of the effectiveness of the recommended actions in preventing the condition- the former for CAUTI, and the latter for surgical site infections following select procedures. The guideline for CAUTI notes that an estimated 17% to 69% may be preventable by applying recommended infection control measures (Jarrett, Holt & Labresh, 2013). The ICSI Perioperative Protocol contains extensive recommendations for general SSI prevention and notes that “by focusing on adherence to recognized techniques and protocols, the National Surgical Infection Prevention Collaborative was able to reduce surgical site infections by 27%” (Card et al, 2014).

Lipitz-Snyderman & colleagues (2011) conducted a study of CLABSIs in 80 teaching and non-teaching hospital intensive care units (ICUs) as part of the Michigan Keystone ICU Project. In that study, the investigators used the *Comprehensive Unit-based Safety Program* (CUSP) CLABSI evidence-based guidelines to determine the length of time ICUs were able to sustain zero CLABSIs. Their findings revealed that sixty percent of ICUs sustained zero CLABSIs for 12 months or more, and 26% for 24 months or more. Seventy eight percent of non-teaching hospital ICUs had 12 consecutive months with zero infections compared to 51% of teaching hospitals. At twenty four months the percentage of ICUs with zero infections decreased, however non-teaching ICUs performed better than teaching hospitals (48% vs15%). For teaching hospitals with greater than 399 beds the percent of ICUs with zero infections at 12 months decreased to 32% compared to nonteaching hospital ICUs which had no infections (Lipitz-Snyderman et al., 2011). Although this study only included Michigan hospitals, it demonstrated that CLABSIs are preventable. A prior study by Pronovost et al., (2006) utilized an evidence-based intervention to reduce the incidence of CLABSIs in a sample of 108 Michigan Hospital ICUs. The incidence of CLABSI decreased from 2.7 infections per catheter days to 0 at 3 months after implementation of the study intervention ($p \leq 0.002$).

Goode, Tanaka, Krugman & O’Connor (2000) view EBGs as aiming to improve the outcomes of patient care and reduce health care costs. They conducted a project to develop an EBG for women with acute cystitis, determine the use of a guideline by providers, and measure the quality and cost of outcomes of its use. Using pre- and post - guideline comparison groups and a retrospective chart review prior to guideline implementation, their findings revealed that using an outpatient guideline resulted in a statistically significant decrease in variation of practice patterns between nurse practitioners and physicians in the use of the recommended antibiotic, and a statistically significant reduction (25.7%) in the total direct cost of treating an episode of cystitis. A limitation of this study was the use of a retrospective chart review, which may not have captured all of the care provided or the rationale regarding treatment choices. In addition, retrospective chart reviews may have data integrity and quality issues. Underreporting of adverse events in the medical record, for example, may result in a potentially biased sample from which to draw conclusions (Weinger, Slagle, Jain & Ordonez, 2003).

Aarons, Sommerfield & Walrath-Greene (2009) studied the relationships among organizational and provider characteristics in adopting evidence-based practice in a group of mental health providers. They specifically examined the differences between hospital ownership (public versus private), organizational support for EBPs, clinician attitudes toward adopting EBP, and EBP use. Their findings supported their hypotheses that hospital ownership type matters in regard to both organizational support for EBP and provider attitudes toward adopting EBP. Private organizations provided more support for EBP and providers working in private organizations had more positive attitudes towards adopting EBP. This was a rigorous study using causal path analysis and a measurement of provider attitude towards adopting EBP that replicated findings from a previous study.

A limitation of the study was that it was a cross-sectional study, and as such causal inferences could not be made. In addition, there were organizational dimensions such as case mix, which could not be accounted for in their analyses.

Barriers to Implementing Evidence-Based Nursing and Medicine

DiCenso et al., (2005) report previous research on barriers to implementing evidence-based nursing (EBN) at both the individual as well as organizational level. Individual level barriers included nurses' lack of skill in evaluating the quality of research, access to colleagues to discuss research findings, and confidence in implementing change. Previous studies also identified organizational characteristics as a significant barrier to research use among nurses. Nurses identified insufficient time on the job to go to the library to read research or to implement new ideas due to excessive workload (in DiCenso et al. 2005: Upton, 1999; Nilsson et al., 1998; Rodgers, 1994; Retsas, 1999; and Retsas et al., 2000). Organizational support for EBN, lack of leadership, and direction among managers were also identified by nurses as barriers to EBN (Paraboo, 2000 in DiCenso et al., 2005).

Shortell et al., (2001) studied the role of market pressures, compensation incentives and culture in physician organizations in implementing evidence-based medicine. The authors constructed several stepwise linear regression models to test the association between the variables and the implementation of evidence-based medicine. Model 1 included average age of physicians in the practice and percent of male physicians. Practice size, multispecialty type, and the average number of years of practice in which physicians had been associated with the system were entered in the second model. The third model included compensation incentives, culture, and percent of health maintenance organization / preferred provider organization (HMO/PPO) patients seen by the practice. A positive association (R^2 0.26, p=<0.01) was found between compensation incentives among a survey of 56 medical groups with the implementation of care management practices (e.g., clinical guidelines, protocols, critical pathways). Likewise, for the study physician organizations, there was a positive association (R^2 0.26, p=<.01[group and hierarchical culture on care management deployment]; R^2 0.30, p=<0.01 [direct effect of managed care market pressure, compensation incentives, and group culture on care management comprehensiveness]; R^2 0.29, p=<0.01 [direct effect of managed care market pressure, compensation incentives, and hierarchical culture on care management comprehensiveness]) between the percentage of the group's patients coming from managed care organizations and the implementation of care management practices. There was no significant relationship to support their hypothesis that a more hierarchically oriented culture would be negatively associated with the implementation of care management practices. The authors concluded that a variety of compensation elements (cost control, productivity, quality criteria) are levers that can be used by physician leaders to influence desired patient care practices. Although not as strong of an association, they also concluded that groups who saw more managed care patients were further along in their use of evidence-based medicine.

Safety Culture

Determining the association of safety culture to the incidence of reported HACs if any, is an important relationship to examine. The safety culture of an organization as defined by The Agency for Healthcare Research and Quality (AHRQ) and adopted from the Health and Safety Commission of Great Britain is the product of individual and group values, attitudes, perceptions, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, an organization's health and safety management. Organizations with a positive safety culture are characterized by communications founded on mutual trust, by shared perceptions of the importance of safety, and by confidence in the efficacy of preventive measures (Cooper, 2000), and is a product of psychological, behavioral, and organizational factors.

In *Keeping Patients Safe Transforming the Work Environment of Nurses* (2004), the interplay of three organizational elements are thought to be essential in an effective culture of safety: 1) organizational processes and structures, 2) workers' attitudes and perceptions, and 3) individuals' safety behaviors. Relevant organizational processes and structures include a commitment by leadership to safety; communication, such that all employees are empowered and engaged in identifying and resolving safety concerns; nonhierarchical decision-making; constrained improvisation; training; rewards and incentives; confidential error reporting; fair and just responses to reported errors; reporting near misses as well as errors; and data analysis and feedback (IOM, 2004).

Measuring safety culture and understanding variations in safety climate can be helpful in targeting efforts to improve patient safety (Vogus & Sutcliffe, 2007) in Singer et al., 2009). There is a significant amount of literature devoted to quantitatively measuring hospital safety climate, organizational comparisons; specific clinical settings; and healthcare workers' perceptions of safety; using safety climate surveys such as the

AHRQ Hospital Survey on Patient Safety Culture (HSOPS) (Allen et al., 2010; Singer et al., 2009; Modak, et al., 2004; Pronovost et al., 2003; Weingart et al., 2004). Armstrong & Laschinger (2006), for example, tested a theoretical model, linking Magnet hospital characteristics, structural empowerment, and safety culture. Their results revealed that total empowerment was significantly positively related to perceptions of patient safety culture ($r=0.50$, $p=<.01$) and that the combination of structural empowerment and Magnet hospital characteristics was a significant predictor of staff nurses' perceptions of patient safety in their organization ($p=0.001$). However, analyses of the link between hospital safety climate and patient safety outcomes at the organizational level of analysis have not been conducted (Singer et al., 2009).

Mardon et al., (2010) examined data from the 2007 Hospital Survey on Patient Safety (HSOPS) and used a composite score of 8 PSIs in a statistical analysis (e.g.; iatrogenic pneumothorax, postoperative sepsis) to screen for potentially preventable adverse events. Their results showed that hospitals with a more positive patient safety culture score had lower rates of adverse events as measured by the PSIs, adjusting for hospital bed size, teaching status, and ownership. In their model, this suggested that, all factors being equal, a hospital 1 standard deviation above the mean on the HSOPS composite average would experience 0.64 fewer cases per 1000 patients for the PSI average than a hospital at the HSOPS mean. While this study controlled for hospital characteristics that tend to be associated with both HSOPS and PSI scores, it was limited by the possibility of unmeasured confounding variables (e.g. differences in case mix and other patient characteristics).

Singer et al., (2009) found similar results in a study designed to examine the relationship between measures of hospital safety climate and hospital performance on twelve PSIs. Their results revealed that higher levels of safety climate were associated with higher safety performance as measured by a lower relative incidence of PSIs. A 1 standard deviation improvement in their aggregate measure of safety climate was associated with a ten percent lower risk of a hospital experiencing a PSI. Of note is the finding that there was a strong and relatively consistent relationship between the measures of better safety climate and lower risk of pressure ulcer (19%) one of the CMS HACs. The study results also suggest a relationship between the risk of a PSI and two interpersonal safety climate dimensions—specifically, that hospitals with a higher percent of responses indicating the presence of fear of blame and shame had a higher risk of experiencing a PSI (Singer et al, 2009). The authors identified four study limitations: 1) potential sample bias as a representative sample of community hospitals was used; 2) results may have been confounded by omitted variables, 3) possible measurement error, and 4) the validity of the PSIs as a "true" measure of safety (Singer et al., 2009). Moreover, it is worth noting that this study used data from a safety climate survey. There are limitations associated with using survey data namely: 1) when used in explanatory research, the criteria for inferring cause-and-effect relationships cannot be established as easily in surveys as experiments; 2) surveys are highly standardized and therefore it is difficult to change the course of the research after it has begun; 3) surveys can introduce systematic measurement error, as they are susceptible to reactivity; and 4) surveys do not lend themselves to providing a good understanding of the context within which behavior may be interpreted over an extended period of time (Singleton & Straits, 2005).

In another study, linking organizational climate (task and relational) to objective clinical outcomes Benzer et al. (2011) examined the effect of adherence to a clinical standard for patients with diabetes. Adherence to the diabetes guideline was measured by an independent chart review of randomly selected patients through the Veterans Administration‘s External Peer Review Program. Their results partially supported the relationship between organizational climate and primary care effectiveness. Relational climate, a management focus on mutual support and respect, was positively related to an increased likelihood of patients receiving annual foot inspections (OR=1.77, p=.05) and HbA1c tests (OR=2.22, p=.05). Relational climate was also observed to be a robust predictor of high-quality diabetes care across process measures (Benzer et al., 2011). There were no significant findings for task climate (management focus on achievement and improvement) on blood pressure control (OR=.82, p=>.10), HbA1c control (OR=.95, p=>.10), or LDL-C control (OR=1.1, p=>.10). The authors attribute this to several factors, one being that a management emphasis on assigned performance goals may not be very effective for improving care for chronic conditions such as diabetes. Limitations of this study include possible threats to internal validity such as accounting for endogeneity in an observational, cross -sectional study. The authors also state that achievement of goals could possibly influence safety climate perceptions and that facilities may systematically differ by patient or organizational factors. Another limitation was generalizability of the results, as the study examined only one primary care disease in one public health clinic (Benzer et al., 2011).

State Tracking of Hospital Acquired Conditions

In *To Err is Human,* the IOM called for a nationwide public mandatory reporting system to identify and learn from medical errors and other adverse events (IOM, 2000). Under this reporting system, State governments would be required to collect standardized information about adverse medical events that result in death and serious harm. As previously noted, the NQF *Serious Reportable Events* released in 2002, has become the foundation for a national reporting system and has led to substantial improvements in patient safety (West et al., 2010). Since, that time, state activity has focused on the development and improvement of systems that can help improve quality and outcomes by identifying system weaknesses, compliment other state functions, and help safeguard the health care consumer (Rosenthal & Takach, 2007). Numerous adverse-events reporting systems are in operation, and there is growing evidence that these efforts have been bringing positive change to the quality of care delivered. Despite these advances, high rates of adverse events in hospitalized patients persist (Classen et al., 2011).

In the absence of a nationally mandated reporting system for medical errors and patient safety events, state-based reporting systems serve a significant role collecting and reporting data for the Medicare HACs. Twenty–six states and the District of Columbia track at least one HAC through a State reporting system. Another 21 states track at least one infection from the Medicare list of HACs through NHSN. These systems appear to have great variability in terms of what events are tracked, what the reporting criteria are, and what other information accompanies the report, such as requirements for facilities to perform root cause analyses, corrective action plans, and report near misses. Despite these inconsistencies across states, there are common characteristics among state reporting systems. For example, the states use data in similar ways to improve patient safety and employ quality improvement programs within health care facilities. Most of the states also provide public reports; data are provided in aggregate to protect individual facilities from potential litigation or sanctions of medical professionals. Also, only one state with a state reporting system collects event data on a voluntary basis. All other states with a reporting system have mandates in place to collect data (West et al., 2010).

Current Federal initiatives have bolstered HAC reporting activities at the state level, yet there are still overriding concerns surrounding the variability and lack of standardization across state reporting systems. These differences make it unsuitable to identify national incidence and trends for HACs. Reporting formats vary substantially from state to state; underreporting of HAC data makes it problematic to make any significant inferences or to track improvement over time. The passage of health care reform did not mandate or provide national guidelines for reporting systems to collect more standardized information on HACs, but the law does call for stronger patient safety protections in health care settings, so more states will likely take action to implement patient safety event reporting systems (West et al., 2010).

Summary

As early as the nineteenth century, the American healthcare community identified serious issues regarding the quality of healthcare in the United States. Since that time, both professional organizations as well as government agencies have endeavored to improve care quality and manage the extraordinary cost growth of American healthcare through the development of standards of care, regulations, and laws. The 2000 IOM report brought national recognition to the significant problem of medical errors and deaths, as well as their staggering associated costs occurring in United States hospitals despite the emergence of contemporary medical knowledge and technology. Since that time, numerous federal and regulatory agencies, professional organizations, and special interest groups have attempted to address the problem. There have been significant contributions to the research on identifying adverse events, specifically medication errors, extrapolating their associated costs, and identifying hospital organizational factors that contribute to medical errors. There has also been a proliferation of issued standards of care in the form of evidence-based guidelines, as well as the development of patient safety indicators, serious reportable events, and never events in an effort to bring recognition and change to the problem. Likewise, there has been extensive empirical research on factors that contribute to adverse events, including organizational structures and processes, human factors, and systems.

Years of healthcare reform efforts have addressed medical errors through legislation, regulations and incentives. In response, many healthcare organizations have implemented extensive quality improvement programs and changed the way they do business in an effort to improve patient safety. Despite these efforts, American healthcare quality has not improved. The current CMS non-payment policy for hospital acquired conditions is another policy aimed at reducing medical errors and their associated costs while improving quality of care. The HAC-POA policy is a well-intended next step towards improving quality and reducing reimbursement costs associated with these 10 clinical conditions. However, there are multiple issues affecting the implementation and outcomes of the policy. These include: accurate identification of HACS and POAs through strict medical record documentation and coding, rigorous research-based EBGs, implementation of EBP, preventability, and research methods to analyze outcomes of the policy, to name a few. Several studies of varying methodologies have attempted to determine the impact on clinical outcomes using subsets of the PSIs (pressure ulcers) and nurse sensitive outcomes (falls). The results have been inconsistent and not generalizable due to variations in methods and study limitations. Organizational characteristics--such as safety culture, EBGs, case mix, and nurse staffing, to name a few-- have been measured in these studies to determine if any relationship exists to the incidence of HACs.

Currently, it appears that no comprehensive empirical study has been conducted using a composite of HACs to study the association of nursing hours, as well as hospital and patient characteristics on the reported incidence of HACs. The major purpose of this study, a secondary analysis of MEDPAR and POS admission claims data, was to quantify the association between patient characteristics, hospital characteristics and nursing care intensity on the reported incidence of HACs. The results will add to the growing body of research on the factors that affect the incidence of reported HACs, the problems with accurately identifying adverse medical events, and the role that patient severity of illness plays in the incidence of HACs. The results of this study will also enable identification of further HAC prevention strategies and potential modifications to the HAC-POA program, such as incorporating risk adjustment into the payment penalty component of the policy.

CHAPTER 3.

METHODS

Introduction

This study utilized a secondary analysis of Medicare Provider Analysis and Review File (Med PAR) and Provider of Service (POS) claims data. This pooled cross-sectional data model and analysis was used to investigate the incidence of reported hospital acquired conditions (HACs) among acute care hospitalized Medicare beneficiaries.

This chapter presents the methods used to test the study hypotheses. It includes descriptions of the study design, data source, study sample (including the inclusion and exclusion criteria), and dependent and explanatory variables, as well as a discussion of the problem of underreporting HACs (the dependent variable). A description of the estimation methods employed is also provided.

Study Design

This was a pooled cross-sectional study of a random set of Medicare beneficiaries who were admitted to an acute care inpatient prospective payment system (IPPS) hospital. This study was a secondary analysis of existing data from the CMS MedPAR and POS claims files. Secondary data analysis was used as the Med PAR file included data on the primary outcome variable, HACs.

Data Sources

Five data sources were used to construct the analytic file for this study: 1)Medicare Provider Analysis and Review File (Med PAR), 2) Provider of Service File (POS), 3) 2010 Medicare Occupational Mix Adjustment Survey for Acute Care Hospitals, 4) Medicare Hospital and Hospital Health Care Complex Cost Report, and 5) List of Magnet hospitals. The Med PAR file contains information on services provided to all Medicare beneficiaries admitted to Medicare-certified inpatient hospitals and skilled nursing facilities (SNF). Data was provided by state and then by DRG for all short stay and inpatient hospitals. The file contains patient demographic characteristics, diagnosis and surgery information, and use of hospital or SNF resources. Other information also furnished includes: total charges, covered charges, Medicare reimbursement, total days, number of discharges and average total days. The file is organized to reflect a hospital stay, which may represent one claim or multiple claims rather than a single patient encounter. The Med PAR file contains patient-identifiable data and therefore a request to use the data was developed and reviewed by the Research Data Assistance Center (ResDAC).

The POS file is a publicly obtained Medicare file that contains an individual record for each Medicare-approved provider and is updated quarterly. The file includes: provider number, provider demographics, facility size, and facility staffing.

The Medicare Wage Index Occupational Mix Survey for Acute Care Hospitals was used to create a paid registered nurse and a paid licensed practical nurse variable. This data base is a triennial survey mandated by the Social Security Act to collect data on occupational mix of employees for each short-term, acute care hospital participating in the Medicare program. The file contains the occupational categories of registered nurses, licensed practical nurses, nursing aides, orderlies and attendants, medical assistants, and other occupations which include non-nursing employees. Paid salaries and paid hours are included in the calculation. Paid wages and salaries include total paid wages for the specific category of hospital employee including overtime, vacation, holiday, sick, lunch and other paid-time off, severance and bonuses. Paid hours include total paid hours for the specified category of hospital employee. Paid hours include regular hours, overtime hours, paid holiday, vacation sick, and other paid-time off hours.

The Medicare Hospital and Hospital Health Care Complex Cost Report contains provider information such as facility characteristics, utilization data, cost and charges by cost center (in total and for Medicare), Medicare settlement data, and financial statement data. CMS maintains the cost report data in the Healthcare Provider Cost Reporting Information System (HCRIS), which includes subsystems for the Hospital Cost Report (CMS-2552-96 and CMS-25552-10. The data consist of every piece of information included in the HCRIS extract created by the CMS administrative contractor. Medicare-certified institutional providers are required to submit an annual cost report to a Medicare Administrative Contractor (MAC). Both CMS-2552-96 and CMS 2552-10 data were used for this study in order to link patient days to create a nursing staff variable (CMS, 2013). The American Nurses Credentialing Center's list of all Magnet–recognized organizations was merged into the analytic file and was used to identify Magnet hospitals and construct the Magnet hospital variable.

Human Subjects Review

Informed consent was obtained in accordance with the University of Massachusetts Boston Institutional Review Board policies. A Data Use Agreement was obtained from the Medicare Research Data Assistance Center (ResDAC) to use the MedPAR data.

Study Sample

A five percent pooled cross-sectional random sample (2,950,640) of Medicare fee-for-service patients was used for this study. Admission claims from the Medicare Provider Analysis and Review File (Med PAR) were used for patients who were admitted to an acute care inpatient prospective payment system (IPPS) hospital between government fiscal years 2009 through 2011.

Inclusion and Exclusion Criteria

The inclusion criteria consisted of all fee-for-service Part A Medicare beneficiaries including those patients on Medicare disability, who were hospitalized in an acute care hospital during October 2008 through September 2011. Patients who had an admission to a specialty hospital, SNF, nursing home, or rehabilitation hospital were excluded from the study.

The Medicare Provider Analysis and Review File (Med PAR) was used to analyze data on reported HACs. All admissions during the study period and within the sample were included in the analysis.

Variables

Several analytic variables included in the path model (Figure 3) were constructed for this study. The following sections discuss the variables that were included in this study in greater detail. The problem of underreporting the incidence of HACs is discussed in this section as it has an impact on the sample size for the dependent variables. There were four dichotomous dependent variables for this study.

Dependent Variables

HAC

The aggregate HAC variable, a dichotomous variable, was the primary dependent variable and was constructed to identify beneficiaries that had one or more of the ten HACs coded as hospital acquired in the MedPAR file. A code of “0” or “1” indicated that the patient had no or at least one HAC coded on the Medicare Claims file, respectively. A HAC variable was constructed for each of the selected sub-set of HACs to identify beneficiaries that had one of the sub-set of conditions coded as hospital acquired. A code of “1” indicated that the patient had the specific HAC, (i.e. pressure ulcers stage III or IV); while a “0” indicated that the patient did not have the sub-set HAC coded on the Medicare Claims file.

Catheter Associated Urinary Tract Infection

The catheter associated urinary tract infection (CAUTI) variable was obtained from the Med PAR file and was constructed from the designated ICD-9-CM codes (Table 5).

Vascular Catheter – Associated Infection

The vascular catheter –associated infection (CLABSI) variable was obtained from the Med PAR file and was constructed from the designated ICD-9-CM codes (Table 5).

Falls and Trauma

The falls and trauma variable was constructed by aggregating all of the falls and trauma ICD-9-CM codes that were designated as separate diagnoses in the Med PAR file (Table 5). This variable was constructed in order to secure a large enough sample to enter into the estimate in the models.

Hospital Acquired Conditions Underreporting

It is probable that HACs are underreported in the Medicare Claims file and therefore difficult to obtain an accurate count of the true incidence of HACs. There are several reasons HAC s are likely underreported. Firstly, accuracy of coding. At the time of this study, only the first eight secondary diagnoses were submitted to the Medicare program for purposes of assigning the case to a MS-DRG (McCall, Dalton, Bernard, Healy, & Jordan, 2010). Therefore, all of a patient's secondary diagnoses were not submitted on the Medicare claim. A limitation of using secondary diagnosis codes for identifying true HACs is that other secondary diagnoses that have a higher severity of illness ranking also have a higher rate of reimbursement. It is likely that secondary diagnoses with higher severity of illness and thus reimbursement are listed first on the Medicare claim. Accuracy of coding for HACs depends on the completeness of the medical history and physical examination at the time of admission, the degree of training and collaboration between medical record coders and physicians, and the guidelines or definitions being followed when assessing the presence of a co-morbid condition, (McCall et al., 2010).

Secondly, HACs may not be recorded during the hospital admission because they have not manifested prior to discharge. For example, a patient may experience a surgical site infection that occurs after leaving the hospital. The patient may not have been symptomatic while hospitalized and therefore a diagnostic work-up was not performed. However, the patient may subsequently become symptomatic after discharge and seeks care.

Another challenge in analyzing hospital acquired conditions is the lack of consistent definitions. Existing definitions include those on the CMS list of HACs, the NQF's list of Serious Reportable Events, and the list by the National Coordination Council for Medication Errors Reporting and Prevention (NCC MERP) (McCall et al., 2010).

Lastly, the condition may be coded as being present on admission when the patient is readmitted, when the condition was caused by a HAC on a previous admission. This scenario is problematic, as the adverse event was, in reality, hospital-acquired but not recorded as such. This would affect the incidence of actual reported HACs and the payment penalty associated with an individual HAC, and would primarily manifest as false negatives where the HAC was unreported.

Together, these limitations raise the possibility that the dependent variables in this study may not have been measured accurately. This measurement error could lead to an inaccurate estimate of the true causal relationship with the explanatory variables, leading to attenuation bias (i.e. regression odds ratios near zero).

Exogenous variables

Table 3 outlines the exogenous variables used in this study, including the corresponding logistic regression acronyms, definitions, unit of observations, measurements, types, and data source that were used to construct the individual variables. The exogenous variables for this study included patient characteristics, hospital ownership, teaching status, United States region, and bed size and were constructed from the Med PAR file.

Table 3.

Exogenous Variables

Acronym	Definition	Unit of Observation	Measurement	Type	Data Source
Patient Characteristics					Med PAR
age_admsn	Age	Patient		Continuous	
age_admsn2	Age2	Patient		Continuous	
female	Sex	Patient	0=Male 1=Female	Dichotomous	
race_category	Race	Patient	1=White 2=African American 3= Other	Categorical	
US_region	Northeast	Hospital	1 = Northeast	Categorical	United States Census Bureau
	Midwest		2 = Midwest	Categorical	
	South		3 = South	Categorical	
	West		4 = West	Categorical	
Hospital Ownership		Hospital	1= For Profit 0= Otherwise	Dichotomous	CMS Point of Service File (POS)
Voluntary	Not-for-Profit For Profit		1= Not for Profit 0 = Otherwise	Dichotomous	
Proprietary					
Public	Municipal		1= Public 0 = Otherwise	Dichotomous	
Federal	Government				

(continued)

Table 3. (continued)
Exogenous Variables

Acronym	Definition	Unit of Observation	Measurement	Type	Data Source
Teaching Status		Hospital	1= Academic Medical Center	Dichotomous	CMS POS File
Major	Academic Medical Center &- Major Teaching Hospital		0 = Otherwise		
Minor	Minor Teaching		1 = Minor Teaching 0 = Otherwise	Dichotomous	
Non	Non-teaching		1= Non Teaching 0 = Otherwise	Dichotomous	
_iurban_rur_2	Urban	Hospital	0= Rural 1=Urban	Categorical	CMS POS File
Bed Size	Bed Size	Hospital	1= <50 2= ≥ 50 & <100 3= ≥ 100&<400 4= ≥400	Categorical	CMS POS File

Age and Disabled

Age was obtained from the Med PAR file, and reflected the overall pool of beneficiaries in the file, which included patients both over the age of 65 as well as those who were disabled and may have been younger. A linear form and a quadratic form of age were constructed in order to test whether or not as patients age their likelihood of experiencing a HAC rose faster or slower. Using a set of discrete age groups to capture non-linear relationships can potentially fail to capture the key forms of non-linear relationships, as the age groups are somewhat arbitrarily defined.

The disabled variable was also constructed from the Med PAR file by including only those beneficiaries who were under age sixty five (0,1=<65). This variable was constructed in order to determine the reported incidence of HACs among disabled patients.

Gender

In this study, gender was reported as a dichotomous categorical variable, (male and female). Male served as the reference category in the multivariate analysis and was obtained from the Med PAR file, as the sample included a larger proportion of females.

Race

Race was obtained from the Med PAR file and was categorized as White, Black, Asian, Hispanic, North American Native, Other, and Unknown. Asian, Hispanic, North American Native, Unknown, and other were collapsed into the other race category for analysis purposes. In this study, race was coded as a categorical variable as White, Black or Other, 0, 1 indicators. White served as the reference category in multivariate analysis.

Hospital Ownership

Hospital Ownership refers to the way a hospital is financed, organized, and delivers care (Thomas, Orav, & Brennan, 2000). The hospital ownership variable was constructed from the Provider of Service File (POS) which categorizes hospitals as Not For Profit, For Profit, Federal, State, Local, Hospital District or Authority, Physician Ownership, Tribal, or Other. In this study, four explanatory variables were constructed to differentiate non-profit hospitals (Voluntary), for-profit (Proprietary), public, and federal hospitals. The Voluntary hospital variable was constructed by combining the Tribal, Private, Not for profit and Other categories. The Proprietary hospital variable combined the For-Profit and Physician Ownership categories. Hospital ownership involved dichotomous variables with Voluntary hospitals as the reference group.

Geographic Region

Patients from all four United States geographic regions--Northeast, Midwest, South, and West--were included to examine if there were any differences in HAC rates by geographic location. The region variables were constructed from the 2007 Economic Census Regions and Divisions information. The Northeast Region included the New England and Middle Atlantic Divisions. The Midwest Region consisted of the East North Central and West North Central Divisions. The South Region variable consisted of states in the South Atlantic, East South Central, and West South Central Divisions. The West region consisted of the states in the Mountain and Pacific Divisions. The reference category used in the multivariate analysis was the Northeast Region.

Bed Size

Bed size refers to the number of staffed licensed beds available to admit patients. Four bed size categories were stratified by quartiles (<50, ≥ 50 & <100, ≥ 100 & <400, and ≥ 400). Bed size was obtained from the POS file as a categorical variable. All hospital bed sizes were included as long as the hospital met the definition of an acute care hospital, accepted Medicare patients, and met the criteria for hospital ownership as above. The reference category for bed size was hospitals with less than 50 beds.

Teaching Status

Teaching status refers to the level of medical education provided within the hospital. Major teaching hospitals have residency programs and are affiliated with the Council of Teaching Hospitals (COTH), which represents over 400 academic medical centers (AMC) and health systems, and provides services that are related to the specific needs of AMCs. Minor teaching hospitals have residency programs but are not affiliated with the COTH, and non-teaching hospitals have no interns or residents and are not affiliated with the COTH (Thomas et al., 2000). The Teaching status variable was derived from the CMS POS file and was categorized as Major, Limited, Graduate, or No Affiliation. The Major teaching category was constructed by combining the Major and Graduate designations. Minor teaching was drawn from the Limited category and Non-teaching was derived from the No Affiliation category. The reference category was major teaching.

Urban- Rural

The variable was measured at the hospital level and indicated where the hospital was located—an urban or a rural area.

Endogenous Variables

Several endogenous variables (Table 4) were also constructed from the Med PAR file. The logistic regression acronym, variable definition, unit of observation, how it was measured, and variable type, and data source that was used to construct each variable are similarly provided in Table 4.

Table 4.

Endogenous Hospital Characteristics

Acronym	Definition	Measurement	Unit of Observation	Type	Data Source
ALOS	Average Length of Stay	0 = < 5 days 1 = ≥ 5 days	Patient	Categorical	Med PAR and CMS Provider of Service File (POS
LOS	Continuous Length of Stay	Number of Days	Patient	Continuous	Med PAR and CMS Provider of Service File (POS
losdrg	DRG Average Length of Stay (Instrumental Variable)	Number of Days	Patient	Continuous	Med PAR and CMS Provider of Service File (POS
Occrate category	Occupancy Rate	1 = <35% 2 = ≥35% & ≤ 54% 3 = > 54% & ≤ 71% 4 = >71%	Hospital	Categorical	Med PAR and CMS Provider of Service File (POS)
Rn_day_24_lmh	Paid Registered Nurse Hours per Patient Day	1 = ≥ 8 & ≤ 15.15 2 = >15.15 & ≤ 20.14 3 = > 20.14 & ≤ 24	Hospital	Continuous (with constraints)	CMS Occupational Mix Survey and Wage Index
lpnhripd	Staffing Intensity – Paid Licensed Practical Nurse Hours per Patient Day	Number of Paid Hours	Hospital	Continuous	CMS Occupational Mix Survey and Wage Index

(continued)

Table 4. (continued)

Endogenous Hospital Characteristics

Acronym	Definition	Measurement	Unit of Observation	Type	Data Source
Magnet len	Magnet Years	Number of years 1 = < 6 years 0 = ≥ 6 years	Hospital	Categorical Continuous	American Association of Colleges of Nursing (AACN) Magnet Status List and Med PAR
Severity_illness_eng_lomehi	Severity of Illness	Low ≤ .868 Medium > .868 & ≤ 2.236 High > 2.236	Hospital	Categorical	Med PAR
cardiacdrg	Cardiac Surgical Procedure DRG	0 = No Cardiac Surgical Procedure 1 = Cardiac Surgical Procedure	Patient	Categorical	Med PAR
orthodrg	Orthopedic Surgical Procedure DRG	0 = No Orthopedic Surgical Procedure 1 = Orthopedic Surgical Procedure	Patient	Categorical	Med PAR

Severity of Illness

A severity of illness variable was constructed for each patient using publicly available hierarchical condition category (HCC) software. The measure was a weighted sum of each patient's own set of diagnoses divided by the average weighted sum of all patients in the sample. Weights were based on regulations of annual Medicare cost on a set of roughly 150 diagnoses and patient demographics. The variable was constructed using the following data elements from the file: sex, date of birth, year, disabled, and the ten Med PAR diagnoses codes. These variables were linked by the beneficiaries health insurance claim (HIC) number. The severity of illness variable was stratified as low (≤ .868), medium (> .868 & ≤ 2.236), and high (> 2.236) using the 50% percentile for medium severity. The reference category was low severity of illness (≤.868).

Length of Stay

Average length of stay (ALOS) has two different effects in this study: 1) exposure time to HACs defined as the amount of time the patient spends in the hospital; and 2) HAC treatment time, defined as the amount of additional time required for the patient to receive care after the adverse event has occurred. In the Path Model (Figure 3), ALOS is represented as a feedback loop.

Three length of stay variables were constructed and tested in this study. The first stratified length of stay into intervals of equal or less than 5 days or greater than 5 days. The second, continuous length of stay variable, represented the patient's actual length of stay based on the differences between the patient's discharge and admission date in the Med PAR file. Finally, an instrumental variable, average length of stay by diagnosis related group (DRG), (losdrg), was constructed to address a unique attribute of HACs, the feedback effect.

Overall, the interest was in quantifying the exposure effect of longer stays, which raise the likelihood of an HAC. A patient who sustains an HAC early in their stay is, however, more likely to have a longer length of stay, as well; hence, the feedback effect. By using the instrumental variable, losdrg, the resulting odds ratio should be a more accurate measure of expected exposure to HACs by ignoring unexpectedly long stays that are due to an HAC.

Occupancy Rate

Hospital occupancy rate is defined as the number of admissions per year times average length of stay (ALOS) divided by the number of beds times 365. The Hospital occupancy rate variable was constructed from the POS file and calculated using inpatient days of care and bed days available by hospital. The occupancy rate was stratified by four categories (< 35%), (≥ 35% & < 54%), (≥ 54% & < 71%), and (≥ 71%). The reference category was hospitals with less than 35% occupancy. The mean occupancy rate in this sample was 46%, with a standard deviation of 27%. The average bed size in this sample was 417.

Paid Registered Nurse and Licensed Practical Nurse Hours per Patient Day

The 2011 Medicare Wage Index Occupational Mix Survey (CMS, 2011) was used to construct the paid registered nurse hours per patient day (rnhppd) and paid licensed practical nurse hours per patient day (lpnhppd) variables. Total paid hours by category of worker, registered nurse (RN) and licensed practical nurse (LPN) hours were linked to the analytic file by hospital provider number. Paid registered nurse hours per patient day were stratified by Low (≥ 8 & ≤ 15.15), Medium (> 15.15 & ≤ 20.14), and High (> 20.14 & ≤ 24).

The High paid registered nurse hours per patient day were adjusted not to exceed 24 hours per day. Using hospital level paid hours per patient day meant that in some cases the hours for some hospitals exceeded 24 hours.

Magnet Hospital Years

A categorical variable, Magnet years, was constructed to determine if there was a difference in the incidence of HACs among early adopters of Magnet status versus more recent adopters. Achieving Magnet status is an initiative designed to improve patient care. Magnet status hospitals are thought to provide excellence in nursing care and demonstrate a high level of patient satisfaction. Research exists to conclude that Magnet hospitals do provide improved patient outcomes (Rosenberg, 2008) and nurse work environments (Kramer, Maguire & Brewer, 2011). Smith (2013) conducted a study to test the claim that Magnet hospitals provide the "Best Quality of Patient Care" and to determine if significant relationships existed between the Magnet status of hospitals 30 day mortality and readmission rates for myocardial infarctions (MI), congestive heart failure CHF), and pneumonia, and patient- reported quality of care measures. Multivariate analysis suggested that 30- day mortality rates after MI, CHF, and pneumonia were not significantly different between Magnet and non-Magnet hospitals. Analysis of patient- reported satisfaction with care scores was significantly higher for hospitals preparing for Magnet status versus non-Magnet hospitals on six out of seven survey measures (Smith, 2013).

The Magnet Years variable measured the length of time that the hospital had been designated as a Magnet hospital, and was divided into two categories: hospitals that had been designated as Magnet less than 6 years (=1) and those designated as Magnet longer than 6 years (=0). The variable was constructed by linking the name of a designated Magnet hospital, obtained from the American Nurses Credentialing Center (a division of the American Nurses Association), to hospital names in the Med PAR file. A total of 288 out of 397 United Sates Magnet hospitals were identified in the study sample. It is hypothesized that the longer a hospital has held Magnet status, the more likely it is to provide better quality care and thus a lower incidence of reported HACs.

Two surgical procedure variables, Cardiac DRG and Orthopedic DRG, were constructed that corresponded to two of the HACs: 1) mediastinitis after coronary artery bypass surgery, and 2) surgical site infections following certain orthopedic surgical procedures. The cardiac surgical procedures variable was constructed using 2011 DRG codes for patients undergoing coronary artery bypass surgery, cardiac valve and other cardiothoracic procedures. The orthopedic surgery variable was constructed using DRG codes specific to hip and knee replacement and revision. These variables were constructed to test the effect of co-morbidities (post-surgical procedure status) as determinants of the likelihood of a reported HAC.

Estimation Methods

The unit of analysis in this study was Medicare patient admissions. Data analysis consisted of descriptive and correlation statistics, as well as multivariate regression. Descriptive statistics included the reported incidence of each of the ten individual HACs, patient severity of illness, hospital ownership, and teaching status, paid registered nurse hours per patient day, occupancy rate, bed size, age, race, and sex. Table 5 lists the ten HACs and their related secondary ICD-9-CM codes.

In this study, multivariate logistic step-wise regression by type of HAC was used to test the hypothesized causal effects of exogenous and endogenous variables on the likelihood of observing an inpatient HAC. This form of sequential regression analysis followed the chronological entry of predictor variables based on the Path Model as presented in Chapter 1. The four dependent variables in the model are: 1) the probability of incurring any reported HAC, 2) CLABSI, 3) CAUTI, and 4) falls and trauma.

Table 5.

Hospital acquired conditions as of October 2009

Hospital-acquired condition	ICD-9-CM codes used to identify HACs
Foreign object retained after surgery	998.4 (CC), 998.7 (CC)
Air embolism	999.1 (MCC).
Blood incompatibility	999.6 (CC).
Pressure Ulcer Stages III & IV	707.23 (MCC), 707.24 (MCC).
Fall and Trauma • Fracture • Dislocation • Intracranial Injury • Crushing Injury • Burn • Electric Shock	Codes within these ranges on the CC/MCC list: 800-829 830-839 850-854 925-929 940-949 991-994
Catheter-associated urinary tract infection	996.64 (CC). Also excludes the following from acting as a CC/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).
Vascular Catheter-Associated Infection	999.31 (CC).
Manifestations of Poor Glycemic Control	250.10-250.13 (MCC), 250.20-250.23 (MCC), 251.0 (CC), 249.10-249.11 (MCC), 249.20-249.21 (MCC).
Surgical Site Infection (SSI)-Mediastinitis Following Coronary Artery Bypass Graft Surgical Site infection Following Certain Orthopedic Procedures Surgical Site infection Following Bariatric Surgery for Obesity	519.2 (MCC) and one of the following procedure codes: 36.10-36.19. 996.67 (CC), 998.59 (CC). And one of the following procedure codes: 81.01-81.08, 81.23-81.24, 81.31-81.38, 81.83, and 81.85. Principal Diagnosis – 278.01, 998.59 (CC) And one of the following procedure codes: 44.38, 44.39, or 44.95.
Deep Vein Thrombosis (DVT)/Pulmonary Embolism (PE)	415.11 (MCC), 415.19 (MCC), 453.40-453.42 (CC) And one of the following procedure codes: 00.85-00.87, 81.51-81.52, or 81.54

Federal Register /Vol. 74, No. 165 /Thursday, August 27, 2009/ Rules and Regulations, p. 43783.

Five multivariate logistic step-wise regression models tested the probability of incurring any reported HAC. Model1 included all exogenous variables that were considered independent of severity and length of stay for a given admission: patient demographic characteristics, hospital ownership, teaching status, United States geographic region, and bed size. Endogenous variables included occupancy rate, and length of Magnet designation. Model 2 included all of the exogenous variables in Model 1 and stepped in two hypothetically endogenous variables: paid registered nurse hours per patient day and paid licensed practical nurse hours per patient day. Model 3 included all of the variables in the first two models and stepped in the variables SOI, and (0, 1) indicators of Cardiac and Orthopedic DRGs. Model 4 included all of the variables from model three and stepped in the continuous length of stay variable (loscon), the sample patient's actual length of stay. Model 5 replaced the patient's own continuous length of stay variable with the instrumental variable, DRG average LOS (losdrg).This variable was used as a proxy for the DRG exposure effect.

Six multivariate logistic step-wise regression models tested the probability of three specific HACs: CAUTI, CLABSI, and falls and trauma. This sub-set of HACs was selected in order to isolate nursing intensity effects on nursing-sensitive hospital acquired conditions. The criteria used to select a subset of HACs were: 1) most frequently occurring annual incidence; and 2) nurse-sensitive conditions. For each of the subset of HACs, multivariate regressions were performed for patients who had one of the subset of HACs, and for patients who were at risk for the HAC. This sub-set of HACs was selected because all of these conditions were identified as adverse outcomes that are sensitive to nursing care (NQF,2004), have “high” CMS reported number of cases, and run the risk of being missed when analyzed using Medicare Claims data (Zhan et al., 2009).

Infections of the urinary tract are the most common condition of these three conditions and account for approximately forty percent of all hospital-acquired conditions. Eighty percent of nosocomial urinary tract infections (UTIs) are attributable to the use of an indwelling catheter (Wilson et al., 2009; Zhan et al., 2009), with the risk of infection increasing by 5%- 7% per catheter day beyond the first 48 hours of hospitalization (Schaeffer, 1986).

According to 2007 CMS data, 29,536 cases of vascular catheter-associated infections (CLABSI) were identified from the Med PAR database that met the associated HAC diagnosis for a secondary diagnosis on the HAC list (Federal Register, 2008). According to a recently published report by the Centers for Disease Control and Prevention (CDC) (2011), healthcare associated infections affect 5% of hospitalized patient in the United States each year (CDC, 2011). The CDC compared estimates of CLABSI in intensive care units, inpatient units, and outpatient hemodialysis facilities and reported that in 2001, an estimated 43,000 CLABSIs occurred among patients hospitalized in intensive care units. By 2009, the estimated number of ICU CLABSIs had decreased to 18,000. CLABSIs in inpatient units in 2009 were estimated at 23,000, and CLABSIs in out-patient hemodialysis facilities were estimated at 37,000 in 2008 (CDC, 2011). In 2007, CMS reported 193,566 cases of falls and trauma (Federal Register, 2008).

In this study, the following equations were tested to quantify the hypothesized relationships among study explanatory variables using the aggregate dependent variable

HAC as previously described. The equations for the three sub sets of HACs are included in Chapter 4.

Model 1

$$Pb[HAC] - \beta_0 + \beta_1\, age + \beta_2\, age^2 + \beta_3 disabled + \beta_4 female + \beta_5 race + \sum \beta_6 region + \sum \beta_7 hospital\ ownership + \sum \beta_8 teaching\ status + \beta_9 urban + \sum \beta_{10} bedsize + \sum \beta_{11} occupancy\ rate + \beta_{12} magnet\ years + e$$

Model 2

$$Pb[HAC] - \beta_0 + \beta_1\, age + \beta_2\, age^2 + \beta_3 disabled + \beta_4 female + \beta_5 race + \sum \beta_6 region + \sum \beta_7 hospital\ ownership + \sum \beta_8 teaching\ status + \beta_9 urban + \sum \beta_{10} bedsize + \sum \beta_{11} occupancy\ rate + \beta_{12} magnet\ years + \beta_{13} prnhrs / day + \beta_{14} plpnhrs / day + e$$

Model 3

$$Pb[HAC] - \beta_0 + \beta_1\, age + \beta_2\, age^2 + \beta_3 disabled + \beta_4 female + \beta_5 race + \sum \beta_6 region + \sum \beta_7 hospital\ ownership + \sum \beta_8 teaching\ status + \beta_9 urban + \sum \beta_{10} bedsize + \sum \beta_{11} occupancy\ rate + \beta_{12} magnet\ years + \beta_{13} prnhrs / day + \beta_{14} plpnhrs / day + \beta_{15} severity + \beta_{16} orthodrg + \beta_{17} carddrg + e$$

Model 4

$$Pb[HAC] - \beta_0 + \beta_1\, age + \beta_2\, age^2 + \beta_3 disabled + \beta_4 female + \beta_5 race + \sum \beta_6 region + \sum \beta_7 hospital\ ownership + \sum \beta_8 teaching\ status + \beta_9 urban + \sum \beta_{10} bedsize + \sum \beta_{11} occupancy\ rate + \beta_{12} magnet\ years + \beta_{13} prnhrs / day + \beta_{14} plpnhrs / day + \beta_{15} severity + \beta_{16} orthodrg + \beta_{17} carddrg + \beta_{18} loscon + e$$

Model 5

$$Pb[HAC] - \beta_0 + \beta_1\, age + \beta_2\, age^2 + \beta_3 disabled + \beta_4 female + \beta_5 race + \sum \beta_6 region +$$
$$\sum \beta_7 hospital\ ownership + \sum \beta_8 teaching\ status + \beta_9 urban + \sum \beta_{10} bedsize +$$
$$\sum \beta_{11} occupancy\ rate + \beta_{12} magnet\ \ years + \beta_{13} prnhrs/day + \beta_{14} plpnhrs/day +$$
$$\beta_{15} severity + \beta_{16} orthodrg + \beta_{17} carddrg + \beta_{18} losdrg + e$$

CHAPTER 4.

RESULTS

This study was designed to quantify the effects of hospital and patient characteristics and nursing care hours on the incidence of hospital acquired conditions (HACs.) The findings of this study are presented in this chapter. The results include descriptive analytic statistics, correlation analysis, and multivariate regression modeling based on a Path Model of hospital and patient characteristics and paid nursing hours per patient day on the incidence of reported HACs.

Descriptive Statistics

Patient Characteristics

A five percent sample representing a total of 2,946,546 Medicare patient discharges and 5,537 HACs from government fiscal years 2009-2011 was used for this study. Table 6 presents patient demographics and hospital characteristics by type, frequency, and frequency percentage.

Table 6.

Patient and Hospital Characteristics

Characteristics	N	Frequency %
Age		
<65	578,887	19.62
≥65 & <75	865,846	29.35
≥75	1,505,731	51.03
	2,950,464	100.00
Gender		
Female	1,654,361	56.15
Male	1,292,180	48.35
	2,946,541	100.00
Race		
White	2,414,871	81.96
African American/Black	378,360	12.84
Other	153,313	5.20
	2,946,544	100.00
US Region		
Northeast	742,019	25.25
Midwest	596,451	20.29
South	1,183,382	40.26
West	417,323	14.20
	2,939,175	100.00
Hospital Ownership		
Voluntary	2,104,957	71.36
Proprietary	441,992	14.98
Public	380,817	12.91
Federal	21,988	0.75
	2,949,754	100.00
Teaching Status		
Major Teaching	157,740	5.35
Minor teaching	1,250,207	42.38
Non-Teaching	1,541,807	52.27
	2,949,754	100.00

(continued)

Table 6. (continued)

Patient and Hospital Characteristics

Characteristics	N	Frequency %
Urban- Rural		
Rural	409,770	13.89
Urban	2,539,415	86.11
	2,949,185	100.00
Bed Size		
< 50	60,990	2.07
≥ 50 & < 100	192,806	6.53
≥ 100 & < 400	1,511,192	51.22
≥ 400	1,185,476	40.18
	2,950,464	100.00
Occupancy Rate		
< 35%	737,027	24.98
≥ 35% & ≤ 54%	737,027	24.98
> 54% & ≤ 71%	1,327,401	44.99
> 71%	149,009	5.05
	2,950,464	100.00
Magnet Hospitals		
Non-Magnet	2,403,388	81.46
Magnet	547,076	18.54
	2,950,464	100.00
Magnet Years		
< 6 Years	2,778,329	94.17
≥ 6 Years	172,135	5.83
	2,950,464	100.00
Paid Registered Nurse Hours		
≥ 8 & ≤ 15.15	578,213	24.88
> 15.15 & ≤ 20.14	1,163,520	50.07
> 20.14 & ≤ 24	582,146	25.05
	2,323,879	100.00

(continued)

Table 6. (continued)

Patient and Hospital Characteristics

Characteristics	N	Frequency %
Severity of illness		
Low ≤ .868	738,794	25.04
Medium > .868 & ≤ 2.236	1,474,145	49.96
High > 2.236	737,525	25.00
	2,950,464	100.00
Average Length of Stay		
< 5 days	1,793,450	60.79
≥ 5 days	1,157,014	39.21
Total	2,950,464	100.00

Note: Differences in Total Admissions due to missing data.

Source: Med PAR 2009–2011.

The majority of patients (82%) were white, with African American patients representing 13% and other races 5%. More than half of the sample was female (56.15%) and were at least 75 years of age or older (51.03%). The majority of patients represented the South geographic region (40.26%) and was cared for in voluntary (71.36%) and non-teaching hospitals (52.27%). The majority of patients were cared for in urban hospitals (86.11%) with between 100 and 400 beds (51.22%) and an occupancy rate of between 54 and 71%. Hospitals with Magnet status represented 18.54% of the sample, with 94.17% holding this designation less than six years. Half of the patients (49.96%) were in the medium severity of illness category (>.868 & ≤ 2.236), with approximately sixty one percent (60.79%) in the hospital for less than five days. Half of all patients received between fifteen and twenty paid registered nurse hours per patient day (Table 6).

Overall Hospital Acquired Condition Frequency Distribution

Five thousand five hundred and thirty seven HACs were reported in this sample. Table 7 shows the HAC rate by type of HAC per 1 million admissions. The HAC rates were not evenly distributed across the 12 categories. The highest HAC rates were represented by four of the conditions: Falls/Trauma (531 per million), Deep Vein Thrombosis and Pulmonary Embolism (DVT/PE) (284 per million), Vascular Catheter Infections (CLABSI) (43.8 per million), and Urinary Catheter Infections (CAUTI) (36.9 per million). The HAC rate for foreign object retained after surgery was 27 per million admissions, infections after bariatric surgery was 23.4 per million admissions, and pressure ulcers accounted for 14.78 per million admissions. The HAC rate for the remaining HACs ranged from .68 (Blood Incompatibility) per million admissions to 3.72 (Mediastinitis).

As previously stated, one of the challenges in identifying HACs is the accuracy of coding. The number of reported HACs appears low given the large sample size. This may be attributed to the accuracy of coding and the fact that some HACs do not manifest themselves until after a patient has been discharged. This scenario appears to be true for the infection-related HACs, such as CAUTI, CLABSI, mediastinitis, and infections after orthopedic surgery.

Table 7.

Reported Hospital Acquired Conditions (HAC) rates by Type of HAC, 2009-2011

HAC	Frequency	HAC Rate	Per 1 Million
Foreign Object	79	.00267%	27.00
Air Embolism	7	.000237%	2.40
Blood Incompatibility	2	.0000679%	.68
Pressure Ulcer	436	.01478%	14.78
Catheter Infection(CAUTI)	1,091	.0369%	36.90
Vascular Catheter Infection(CLABSI)	1,293	.0438%	43.80
Glycemic Control	135	.004576%	4.60
Mediastinitis	11	.000372%	3.72
Infection after Orthopedic Surgery	7	.000237%	2.40
Infection after Bariatric Surgery	69	.00234%	23.40
Deep Vein Thrombosis/Pulmonary Embolism (DVT/PE)	841	.02847%	284.00
Falls/Trauma	1,566	.0531%	531.00
TOTAL	5,537	.188%	1,880.00

Note: N= 2,950,464

Source: Med PAR 2009–2011.

Overall Hospital Acquired Condition Rate by Patient and Hospital Characteristics

The overall 2009-2011 HAC rate was 0.19%, or nineteen HACs per 10,000 admissions (Table 8). A Chi-square test was used to assess whether or not the small differences in HAC rates within each of the beneficiary and hospital characteristics were meaningful. The results showed there was a statistically significant difference between the HAC rates within each of the beneficiary and hospital characteristics, except for occupancy rate and Magnet years.

The HAC rate was eight times higher for those patients with a length of stay (ALOS) of 5 days or more (0.41%) as compared to patients with a LOS less than 5 days (0.05%) (p=0.000). This difference was attributed either to exposure time or the length of time the patient spent in the hospital prior to the reporting of a HAC, or the length of time attributed to extra care the patient received after the adverse event had occurred.

The HAC rate for hospital ownership varied between 0.17% (Proprietary) and 0.20% (Public) (p=0.058). The HAC rate variation among teaching status was similar, 0.17% for non-teaching and 0.21% for minor teaching (p=0.000). The lowest HAC rate was in the Midwest (0.17%) and the highest in the Northeast (0.21%) (p=0.000).

There was variation in the HAC rate by hospital bed size (p=0.000) and patient severity of illness (p=0.000). Hospitals with greater than 400 beds unadjusted for case severity had an HAC rate that was almost two times higher than hospitals with less than fifty beds. This may be attributed to a propensity for smaller hospitals to care for less acutely ill patients. As expected, severity of illness was positively associated with higher HAC rates, with those patients with the highest severity of illness experiencing the highest HAC rate (0.36%). The high severity of illness HAC rate was approximately six times the HAC rate of the lowest severity of illness.

No statistically positive differences were observed among occupancy rates (p=.131) or between early adopters and later Magnet hospital adopters (p=.975).

Table 8.

Reported HAC Rates by Patient and Hospital Characteristics

Characteristic	HAC rate	χ2	P value
Gender		75.16	0.000***
Male	0.17%		
Female	0.20%		
Race		5.92	0.052*
White	0.19%		
Black	0.19%		
Other	0.17%		
Age			
< 65	0.17%		
≥65 & ≤ 75	0.19%		
> 75	0.19%		
ALOS		4.13+03	0.000***
< 5 Days	0.05%		
≥ 5 Days	0.41%		
Severity of Illness(low, medium, high)		1.3+03	0.000***
≤ .868 Low	0.05%		
> .868 & ≤ 2.236 Medium	0.17%		
> 2.236 High	0.29%		
Hospital ownership		7.47	0.058*
Proprietary	0.17%		
Public	0.20%		
Voluntary	0.19%		
Teaching status		44.85	0.000***
Major	0.19%		
Minor	0.21%		
Non	0.17%		
Rural		29.54	0.000***
Urban			

(continued)

Table 8. (continued)

Reported HAC rates by patient and hospital characteristics

Characteristic	HAC rate	χ2	P value
Paid Registered Nurse Hours- Low, Medium, High)		5.15	0.076*
≥ 8 & ≤ 15.15	0.16%		
> 15.15 & ≤ 20.14	0.16%		
> 20.14 & ≤ 24	0.18%		
Geographic region		21.97	0.000***
Midwest	0.17%		
Northeast	0.20%		
South	0.18%		
West	0.21%		
Bed size		76.90	0.000***
< 50	0.09%		
≥ 50 & < 100	0.09%		
≥ 100 & ≤ 400	0.13%		
> 400	0.17%		
Magnet Years		0.00	0.975
> 6 years	0.17%		
< 6 years	0.17%		
Occupancy rate		5.63	0.131
< 35%	0.18%		
35–44%	0.18%		
> 44–71%	0.20%		
> 71%	0.18%		

Notes:
HAC Rate = 0.19% (5537)
*p<.10
** P<.05
*** p<.01
N= 2,950,464
Source: MedPAR 2009-2011.

Hospital Acquired Condition Rate by Patient Characteristic

Tables 9, 10, and 11 present the frequency and HAC rate of individual HACs (5,531) stratified by gender, race, and age, respectively.

Gender

The HAC rate for females (0.20%) was slightly higher than for males (0.17%) (Table 9). Females experienced a slightly different mix of HACs as compared to males. Female patients experienced a fall or trauma (6.12% vs. 4.26%), DVT/PE (3.38% vs. 2.17%), or CAUTI (4.26% vs. 2.98%) at a higher rate than did male patients. In comparison, male patients had higher HAC rates for vascular infections (4.59% vs. 4.23%) and pressure ulcers (1.62% vs. 1.37%). Men and women showed roughly equivalent rates of the less frequent HACs, air embolism and blood incompatibility.

Table 9.

Frequency of hospital acquired conditions (HACs) by gender, 2009-2011

HAC	**Male N**	**% of HAC by total HAC male**	**HAC rate male**	**Female N**	**% of HAC by total HAC female**	**HAC rate female**
Foreign object	35	1.63%	0.27%	44	1.30%	0.27%
Air Embolism	3	0.14%	0.02%	4	0.12%	0.02%
Blood Incompatibility	0	0.00%	0.00%	0	0.00%	0.00%
Pressure Ulcer	209	9.72%	1.62%	227	6.71%	1.37%
Catheter Infection	385	17.91%	2.98%	705	20.85%	4.26%
Vascular Infection	593	27.58%	4.59%	699	20.67%	4.23%
Glycemic Control	60	2.79%	0.46%	75	2.22%	0.45%
Mediastinitis	10	0.47%	0.08%	1	0.03%	0.01%
Infection after Ortho	22	1.02%	0.17%	47	1.39%	0.28%
Infection after Bari	1	0.05%	0.01%	6	0.18%	0.04%
Thrombosis	281	13.07%	2.17%	560	16.56%	3.38%
Falls/Trauma	551	25.63%	4.26%	1,013	29.96%	6.12%
Total	2,150	100.00%		3,381	100.00%	
Total Admissions by Gender	1,292,180			1,654,361		
HAC rate		0.17%			0.20%	

Notes: hac_3year file

N=2,946,541

3 unknown gender 2010 for all HACs.

2 unknown gender 2011 for all HACs.

Source. Med PAR 2009 – 2011.

Race

Table 10 shows the frequencies and HAC rates of individual HACs by race. White patients (5.76%) and patients in the Other race category (5.09%) experienced falls and trauma HACs almost two and a half times more often than black patients (2.51%). The HAC rate for white patients incurring a DVT/PE HAC (3.10%) was more than one and a half times greater than black patients (1.88%) and two times (1.43%) greater than patients in the Other race category. Blacks and African Americans experienced a vascular catheter-related infection rate that was two times higher (7.74%) than whites (3.85%) and 1.7 times than other races (4.5%). The HAC rates for CAUTIs were almost identical between white patients (3.64%) and patients of the Other race category (3.65%).

Table 10.

Frequency of hospital acquired conditions (HACs) by Race, 2009-2011,

HAC	White	% of HAC by race	HAC Rate White	Black	% of HAC by race	HAC Rate Black	Other	% of HAC by race	HAC Rate Other
Foreign object	70	1.54%	0.29%	6	0.82%	0.16%	2	0.77%	0.13%
Air Embolism	6	0.13%	0.02%	1	0.14%	0.03%	0	0.00%	0.00%
Blood Incompatibility	2	0.04%	0.01%	0	0.00%	0.00%	0	0.00%	0.00%
Pressure Ulcer	340	7.48%	1.41%	79	10.85%	2.09%	17	6.51%	1.11%
Catheter Infection	878	19.33%	3.64%	156	21.43%	4.12%	56	21.46%	3.65%
Vascular Infection	930	20.47%	3.85%	293	40.25%	7.74%	69	26.44%	4.50%
Glycemic Control	105	2.31%	0.43%	19	2.61%	0.50%	11	4.21%	0.72%
Mediastinitis	9	0.20%	0.04%	1	0.14%	0.03%	1	0.38%	0.07%
Infection after Ortho	60	1.32%	0.25%	5	0.69%	0.13%	4	1.53%	0.26%
Infection after Bari	4	0.09%	0.02%	2	0.27%	0.05%	1	0.38%	0.07%
Thrombosis	748	16.46%	3.10%	71	9.75%	1.88%	22	8.43%	1.43%
Falls/Trauma	1391	30.62%	5.76%	95	13.05%	2.51%	78	29.89%	5.09%
Total	4543	100.00%		728	100.00%		261	100.00%	
HAC Rate		0.19%			0.19%			0.17%	
Total Admissions	2,414,871			378,360			153,313		
N Black = 378,360									
N Other = 153,313									

Notes: hac_3year file
N=2,946,546
2009 Falls/Trauma = 1 unknown
2010 CAUTI = 1 unknown
2011 CLABSI= 1 unknown
2011 Falls/Trauma = 1 unknown
Total HACs = 5,532
Total HAC Rate= 0.19%
Source Med PAR 2009-2011

Age

Table 11 shows the frequencies and HAC rate of individual HACs stratified by age. The overall age-stratified HAC was 0.18%. Those patients in the less than 65 years old age group had an HAC rate of 0.17% as compared to 0.19% in the other two age groups. There were some differences in the mix of HACs by age group. For instance, the CLABSI HAC rate in the youngest Medicare disabled age group (<65) was 7.32%. Those patients in the 65 to 75 age group experienced a CLABSI HAC rate (4.72 %). that was one and a half times less compared with those in the disabled age group. Patients in the older than 75 age group had a CLABSI HAC rate that was almost two and a half times lower (3.06%) than the youngest age group (7.32%), an interesting finding, as it was hypothesized those older patients would be more susceptible to an HAC. In contrast, the CAUTI HAC rate increased with age. The HAC rate for patients in the older than 75 age group (4.56%) was twice as high as the HAC rate for patients in the youngest age group (2.09%) and almost one a half times higher than the 65 to 75 age group (3.28%). Urinary tract infections were the most common hospital-acquired infection.

Table 11.

Frequency of hospital acquired conditions (HACs) by age, 2009-2011

HAC	Age < 65	% of Total HAC Age Group	HAC Rate Age < 65	Age ≥ 65 & < 75	% of Total HAC Age Group	HAC Rate Age ≥ 65 & <7 5	Age ≥ 75	% of Total HAC Age Group	HAC Rate Age ≥ 75
Foreign object	21	2.14%	0.36%	32	1.95%	0.37%	26	0.89%	0.17%
Air Embolism	1	0.10%	0.02%	3	0.18%	0.03%	3	0.10%	0.02%
Blood Incompatibility	0	0.00%	0.00%	2	0.12%	0.02%	0	0.00%	0.00%
Pressure Ulcer	85	8.66%	1.47%	88	5.37%	1.02%	263	9.03%	1.75%
Catheter Infection	121	12.33%	2.09%	284	17.32%	3.28%	685	23.52%	4.56%
Vascular Infection	424	43.22%	7.32%	409	24.94%	4.72%	459	15.76%	3.06%
Glycemic Control	65	6.63%	1.12%	33	2.01%	0.38%	37	1.27%	0.25%
Mediastinitis	3	0.31%	0.05%	4	0.24%	0.05%	4	0.14%	0.03%
Infection after Ortho	26	2.65%	0.45%	24	1.46%	0.28%	19	0.65%	0.13%
Infection after Bari	7	0.71%	0.12%	0	0.00%	0.00%	0	0.00%	0.00%
Thrombosis	64	6.52%	1.11%	368	22.44%	6.36%	409	14.05%	2.72%
Falls/Trauma	164	16.72%	2.83%	393	23.96%	6.79%	1,007	34.58%	6.71%
Total	981	100.00%		1,640	100.00%		2,912	100.00%	
HAC Rate		0.17%			0.19%			0.19%	
Total Admissions	578,887			865,846			1,501,813		

Notes:
N age <65 = 578,887
N age >65 & <75 =865,846
N age >75 = 1,501813
N = 2,946,546
HAC_3year file.
Total HACs = 5,533
Total HAC Rate= 0.19%
Source: Med PAR 2009-2011.

As expected, the falls and trauma HAC rate increased with age. The HAC rates for patients in the oldest age group (6.71%) and patients 65 to 75 years of age (6.79%) were almost two and a half times higher than that of the youngest age group (2.83%). This was expected, as older patients often have more chronic illnesses, co-morbidities, and immobility issues that place them at higher risk for falls and trauma. The DVT/PE HAC rate was more than five and a half times higher for patients in the 65 to 75 age group (6.36%) compared to the youngest age group (1.11%) and more than two times higher in the eldest group (2.72%).

Hospital Acquired Condition Rate by Hospital Characteristics

Tables 12 through 18 present frequency distributions and HAC rates stratified by key hospital characteristics.

Hospital Ownership

The variation in HAC rates by hospital characteristic can be expressed as a multiplicative function of the probability of a patient incurring a HAC for a given type of admission times the probability of being admitted to different hospitals for treatment of certain cases. As an example, consider the ratio of probabilities of reporting the j-th HAC (e.g., mediastinitis) in private voluntary (v) versus proprietary (p) hospitals:

$$\frac{\text{Pb}\,[\text{HACj}, \text{v}] \;=\; \sum \text{k}\;\text{Pb}[\text{ADMk}, \text{v}] \;*\; \text{Pb}[\text{HACj}, \text{k}, \text{v}\;|\text{ADMk}, \text{v}\,]}{\text{Pb}\,[\text{HACj}, \text{p}] \;=\; \sum \text{k}\;\text{Pb}[\text{ADMk}, \text{p}] \;*\; \text{Pb}[\text{HACj}, \text{k}, \text{p}\;|\text{ADMk}, \text{p}\,]}$$

where Pb[$HAC_{j,v}$], Pb [$HAC_{j,p}$] = the probabilities (HAC rates) of reporting a HAC of type j in either voluntary or proprietary hospitals, Pb[$ADM_{k,v}$], Pb[$ADM_{k,p}$] = the probabilities of an admission of the k-th type (e.g., cardiac surgery) in the two types of hospitals, and Pb[HACj,k,v |$ADM_{k,v}$], Pb[HACj,k,v |$ADM_{k,v}$] = the probabilities of reporting the j-th HAC for cardiac surgery patients in either type of hospital. The relative difference in HAC rates by hospital type is the difference in HAC rates for specific types of admissions weighted by each hospital group's case mix of admissions subject to a HAC.

In general, HAC rates were expected to vary considerably less across hospital types than across patients because of (a) the narrower range of HAC rates when averaged by hospital type across patients of varying degrees of illness severity, and (b) a potential inverse relationship between hospital case mix and HAC rates for particular reasons for admission. For example, HAC rates may be much greater (as is evident in the present data) for very ill versus "healthier" patients undergoing cardiac surgery—a variation that may be masked by a more similar mix of healthier and very ill patients at the hospital level. Alternatively, it may be that proprietary hospitals perform less cardiac surgery on average than voluntary hospitals but experience a higher HAC rate for the surgery. These offsetting effects could narrow the HAC rate for mediastinitis at the voluntary-proprietary level of comparison.

HAC rates were similar across all four ownership types. Public hospitals had the highest HAC rate (0.20%), followed by voluntary (0.19%) and proprietary hospitals (0.17%) (Table12). Falls and trauma, CLABSI, CAUTI, and DVT/PE were the most frequently occurring HACs across all beneficiary and hospital characteristics. Falls and trauma had the highest HAC rate when stratified by hospital ownership. Public hospitals showed the highest falls and trauma HAC rate (5.91%) compared to proprietary (5.11%) and voluntary hospitals (5.25%). The CLABSI HAC rate was similar among all ownership types (proprietary: 4.57%; public: 4.54%; voluntary: 4.30%). The CAUTI HAC rate was highest in public hospitals (4.04%) and lowest in proprietary hospitals (2.99%). The CAUTI HAC rate for voluntary hospitals (3.80%) was slightly lower than the public hospital HAC rate (4.04%). It was anticipated that voluntary hospitals, which represent not-for-profit and academic medical centers, would have higher HAC rates of the most commonly occurring HACs, as more acutely ill patients who are at risk for these conditions are often cared for in these types of hospitals.

The pressure ulcer HAC rate was slightly higher in public hospitals (1.58%) as compared to voluntary (1.52%) and proprietary hospitals (1.24%). The HAC rate for DVT/PE was highest in voluntary hospitals (3.07%) as compared to the next highest, public hospitals (2.42%) and the lowest, proprietary hospitals (2.24%). The difference between the proprietary hospital HAC rate and the voluntary hospital HAC rate may be explained by the traditional patient mix at voluntary hospitals. Hospitals with a more heterogeneous case mix may perform procedures and care for patients with co-morbidities that place them at high risk for a DVT/PE HAC.

Table 12.

Frequency of Hospital Acquired Conditions (HACs) by Hospital Characteristics by Hospital Ownership, 2009-2011

HAC	Proprietary			Public			Voluntary		
	N	%	HAC Rate	N	%	HAC Rate	N	%	HAC Rate
Foreign Object	13	1.70%	0.29%	18	2.38%	0.47%	46	1.15%	0.22%
Air Embolism	1	0.13%	0.02%	3	0.40%	0.08%	3	0.08%	0.01%
Blood Incompatibility	0	0.00%	0.00%	0	0.00%	0.00%	2	0.05%	0.01%
Pressure Ulcer	55	7.19%	1.24%	60	7.95%	1.58%	320	8.03%	1.52%
Catheter Infection(CAUTI)	132	17.25%	2.99%	154	20.40%	4.04%	799	20.06%	3.80%
Vascular Catheter Infection (CLABSI)	202	26.41%	4.57%	173	22.91%	4.54%	906	22.75%	4.30%
Glycemic Control	21	2.75%	0.48%	19	2.52%	0.50%	94	2.36%	0.45%
Mediastinitis	0	0.00%	0.00%	3	0.40%	0.08%	8	0.20%	0.04%
Infection after Orthopedic Surgery	15	1.96%	0.34%	7	0.93%	0.18%	47	1.18%	0.22%
Infection after Bariatric Surgery	1	0.13%	0.02%	1	0.13%	0.03%	5	0.13%	0.02%
Thrombosis and Pulmonary Embolism (DVT/PE)	99	12.94%	2.24%	92	12.19%	2.42%	647	16.24%	3.07%
Falls/Trauma	226	29.54%	5.11%	225	29.80%	5.91%	1,106	27.77%	5.25%
Total	765	100.00%		755	100.00%		3,983	100.00%	
Total Admissions	441,992			380,817			2,104,957		
HAC Rate			0.17			0.20			0.19

Notes:
N=2,949,754.
N Federal = 21,988
N Proprietary = 441,992
N Public = 380,817
N Voluntary = 2,104,957
Total HAC Rate = 0.19%
Source: Med PAR 2009-2011.

Teaching Status

There was a statistically significant difference between minor teaching hospitals, which had the highest HAC rate (0.21%), and non-teaching (0.20%) and major teaching (0.19%) hospitals. The four highest HAC rates stratified by teaching status were the same as hospital ownership (falls and trauma, CLABSI, CAUTI, and DVT/PE). The finding that non- teaching hospitals had the lowest HAC rate (0.17%) was expected, as non-teaching hospitals tend to care for patients who are healthier.

The falls and trauma HAC rate was fairly consistent across teaching (major: 5.07%; minor: 5.42%) and non-teaching (5.25%) hospitals. This finding was expected, as all patients are at risk for falls and trauma when they are hospitalized, regardless of their SOI.

In contrast, the HAC rate for CAUTI stratified by non-teaching status (3.22%) was 22% less than the HAC rate for minor teaching (4.24%). The CLABSI HAC rate was 31% lower for non-teaching hospitals (3.63%) as compared to minor teaching hospitals (5.26%).

The DVT/PE HAC rate for non-teaching (2.63%) hospitals was 17% lower than for minor teaching (3.18%) hospitals. These findings were expected as teaching hospitals are more likely to care for patients with a higher severity of illness, which CLABSI and DVT/PE (and CAUTI to a lesser extent) represent. The lower HAC rates observed in major teaching hospitals for these same conditions, in comparison to minor teaching hospitals, may potentially be explained by two possibilities. First, major teaching hospitals most likely have a higher volume and thus more experience caring for these patients. Secondly, major teaching hospitals are more likely to be early adopters of new technology and care improvement strategies to prevent these complications.

Table 13.

Frequency of Hospital Acquired Conditions (HACs) by Hospital Characteristics by Teaching Status, 2009-2011

	Major Teaching			**Minor Teaching**			**Non-Teaching**		
HAC	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**
Foreign Object	5	1.65%	0.32%	33	1.24%	0.26%	41	1.59%	0.27%
Air Embolism	0	0.00%	0.00%	5	0.19%	0.04%	2	0.08%	0.01%
Blood Incompatibility	0	0.00%	0.00%	2	0.08%	0.02%	0	0.00%	0.00%
Pressure Ulcer	27	8.91%	1.71%	226	8.53%	1.81%	183	7.08%	1.19%
Catheter Infection (CAUTI)	65	21.45%	4.12%	530	19.99%	4.24%	496	19.20%	3.22%
Vascular Catheter Infection(CLABSI)	76	25.08%	4.82%	657	24.78%	5.26%	560	21.68%	3.63%
Glycemic Control	10	3.30%	0.63%	65	2.45%	0.52%	60	2.32%	0.39%
Mediastinitis	1	0.33%	0.06%	9	0.34%	0.07%	1	0.04%	0.01%
Infection after Orthopedic Surgery	1	0.33%	0.06%	45	1.70%	0.36%	23	0.89%	0.15%
Infection after Bariatric Surgery	0	0.00%	0.00%	4	0.15%	0.03%	3	0.12%	0.02%
Thrombosis	38	12.54%	2.41%	398	15.01%	3.18%	405	15.68%	2.63%
Falls/Trauma	80	26.40%	5.07%	677	25.54%	5.42%	809	31.32%	5.25%
Total	303	100.00%		2,651	100.00%		2,583	100.00%	
Total Admissions	157,740			1,250,207			1,541,807		
HAC Rate		0.19%			0.21%			0.17%	

Notes: HAC_3year N=2,949,754.
Total HAC Rate = 0.19%
Missing 710
N Major Teaching= 157,740
N Minor Teaching = 1,250,207
N Non-Teaching = 1,541,807
Source: Med PAR 2009-2011.

Geographic Region

When HACs were stratified by geographic region (Table 14), the Midwest had the lowest HAC rate (0.17%) and the West had the highest (0.21%). The Midwest region had a CLABSI (3.22%) HAC rate that was 37.8% lower than the West (5.18%), 37.4% lower than the Northeast (5.15%), and 27.6% lower than the South region. This finding may be attributed to early adoption and spillover effects of the transformative national Comprehensive Unit-based Safety Program (CUSP), which is focused on the reduction of central line-associated bloodstream infections in Michigan intensive care units. Pronovost et al. (2006) demonstrated that an evidence-based intervention to reduce CLABSIs resulted in a sustained reduction of CLABSIs; the median CLABSI rate per 1,000 catheter-days was observed to decrease from 7.7 at baseline to 1.4 at 16 to 18 months of follow-up ($P<0.002$).

In contrast to CLABSI, the Midwest shows a 43.3% higher rate of DVT/PE (3.53%) as compared to the South (2.43%), which had the lowest HAC rate for this condition. The HAC rate for falls and trauma was comparable across all regions; the Midwest region (5.07%) had the lowest rate and the South region had the highest (5.58%). The HAC rate for CAUTI was similar in the Midwest (3.42%), Northeast (3.34%), and South (3.63%) regions. In comparison, the West region had the highest CAUTI HAC rate (5.18%), which was over a third higher than the lowest Northeast's region HAC rate (3.34%).

Table 14.

Frequency of Hospital Acquired Conditions (HACs) by Hospital Characteristics by Geographic Region, 2009-2011

	Midwest			Northeast			South			West		
HAC	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**
Foreign Object	12	0.94%	0.16%	18	1.51%	0.30%	28	1.29%	0.24%	21	2.39%	0.50%
Air Embolism	1	0.08%	0.01%	1	0.08%	0.02%	4	0.18%	0.03%	1	0.11%	0.02%
Blood Incompatibility	1	0.08%	0.01%	1	0.08%	0.02%	0	0.00%	0.00%	0	0.00%	0.00%
Pressure Ulcer	88	6.90%	1.19%	134	11.21%	2.25%	149	6.85%	1.26%	64	7.28%	1.53%
Catheter Infection	254	19.92%	3.42%	199	16.65%	3.34%	430	19.77%	3.63%	205	23.32%	4.91%
Vascular Infection	239	18.75%	3.22%	307	25.69%	5.15%	527	24.23%	4.45%	216	24.57%	5.18%
Glycemic Control	25	1.96%	0.34%	37	3.10%	0.62%	57	2.62%	0.48%	14	1.59%	0.34%
Mediastinitis	3	0.24%	0.04%	1	0.08%	0.02%	5	0.23%	0.04%	2	0.23%	0.05%
Infection after Ortho	12	0.94%	0.16%	14	1.17%	0.23%	25	1.15%	0.21%	18	2.05%	0.43%
Infection after Bari	2	0.16%	0.03%	2	0.17%	0.03%	3	0.14%	0.03%	0	0.00%	0.00%
Thrombosis	262	20.55%	3.53%	169	14.14%	2.83%	287	13.20%	2.43%	122	13.88%	2.92%
Falls/Trauma	376	29.49%	5.07%	312	26.11%	5.23%	660	30.34%	5.58%	216	24.57%	5.18%
Total	1,275	100.00%		1,195	100.00%		2,175	100.00%		879	100.00%	
Total Admissions	742,019			596,451			1,183,382			417,323		
HAC Rate		0.17%			0.20%			0.18%			0.21%	

Notes: HAC_3year N=2,949,754.
Total HACs = 5,524
Total HAC Rate= 0.19%
Midwest N= 742,019
Northeast N= 596,451
South N= 1,183,382
West N= 417,323
Source: Med PAR 2009-2011.

Bed Size

The overall HAC rate when stratified by hospital bed size was 0.19% (Table 15). The HAC rate increased as the number of hospital beds increased. Hospitals with more than 400 beds had the highest HAC rate (0.22%) and hospitals with more than 50 but less than 100 beds (0.13%) had the lowest HAC rate. Hospitals with less than 50 beds also showed a low HAC rate (0.14%). This finding was expected, as hospitals with more bed capacity traditionally care for patients with a higher SOI, are located in urban areas, and are generally teaching hospitals.

The HAC rates for CAUTI, CLABSI, and DVT/PE all increased as bed size increased. Hospitals with more than 400 beds had a CLABSI HAC rate (5.86%) that was five times higher than hospitals with less than fifty beds (1.15%), and three times higher than hospitals with fifty to one hundred beds (1.61%). The CAUTI HAC rate was almost three times higher in hospitals with more than 400 beds (4.44%) as compared to hospitals with less than fifty beds (1.48%).

The HAC rate for DVT/PE, however, varied less with increasing bed size. Hospitals with more than 400 beds had the highest DVT/PE HAC rate (3.21%), and hospitals with fifty to one hundred beds had the lowest HAC rate (2.44%).

The falls and trauma HAC rate for hospitals with between fifty and one hundred beds (4.98%), hospitals with 100 to 400 beds (5.12%), and hospitals with more than 400 beds (5.47%) were comparable. However, hospitals with less than 50 beds had the highest HAC rate for falls and trauma (7.71%), the highest HAC rate across all HACs stratified by bed size. This elevated rate suggests a potential upward due to the low number of admissions (60,990).

Table 15.

Frequency of Hospital Acquired Conditions (HACs) by Hospital Characteristics by Bed Size, 2009-2011

HAC	Bed Size < 50 Frequency	% of Total HAC by Bed Size	HAC Rate	Bed Size ≥50 & <100 Frequency	% of Total HAC by Bed Size	HAC Rate	Bed Size ≥100 & <400 Frequency	% of Total HAC by Bed Size	HAC Rate	Bed Size ≥400 Frequency	% of Total HAC by Bed Size	HAC Rate
Foreign object	2	2.27%	0.33%	2	0.80%	0.10%	37	1.43%	0.24%	38	1.43%	0.32%
Air Embolism	0	0.00%	0.00%	1	0.46%	0.05%	1	0.04%	0.01%	5	0.13%	0.04%
Blood Incompatibility	0	0.00%	0.00%	0	0.00%	0.00%	0	0.00%	0.00%	2	0.04%	0.02%
Pressure Ulcer	5	5.68%	0.82%	15	5.98%	0.78%	208	8.06%	1.38%	208	7.87%	1.75%
Catheter Infection	9	10.23%	1.48%	53	21.12%	2.75%	503	19.48%	3.33%	526	19.70%	4.44%
Vascular Infection	7	7.95%	1.15%	31	12.35%	1.61%	560	21.69%	3.71%	695	23.35%	5.86%
Glycemic Control	0	0.00%	0.00%	4	1.59%	0.21%	73	2.83%	0.48%	58	2.44%	0.49%
Mediastinitis	0	0.00%	0.00%	0	0.00%	0.00%	4	0.15%	0.03%	7	0.20%	0.06%
Infection after Ortho	0	0.00%	0.00%	2	0.80%	0.10%	26	1.01%	0.17%	41	1.25%	0.35%
Infection after Bari	0	0.00%	0.00%	0	0.00%	0.00%	1	0.04%	0.01%	6	0.13%	0.05%
Thrombosis	18	20.45%	2.95%	47	18.73%	2.44%	395	15.30%	2.61%	381	15.19%	3.21%
Falls/Trauma	47	53.41%	7.71%	96	38.25%	4.98%	774	29.98%	5.12%	649	28.28%	5.47%
Total	88	100.00%		251	100.00%		2,582	100.00%		2,616	100.00%	
Total Admissions	60,990			192,806			1,511,192			1,185,476		
HAC Rate		0.14%			0.13%			0.17%			0.22%	

Notes:
HAC_3year
Total HACs = 5537
HAC Rate = 0.19%
N= 2,950,464
Source: Med PAR 2009-2011

Hospital Occupancy

The overall HAC rate stratified by occupancy was 0.19% (Table 16). There was no significant difference in HAC rates between hospitals with the lowest occupancy (0.18%) as compared to hospitals with the highest occupancy rate (0.18%). Hospitals with the highest occupancy rate (>71%) had the lowest HAC rate for falls and trauma (4.23%). Hospitals with the lowest occupancy rate had the highest HAC rate (5.45%) for the same condition. In contrast, the DVT/PE HAC rate (4.16%) was 35.3% higher in hospitals with greater than 71% occupancy as compared to the lowest HAC rate (2.69%) in hospitals with between 35 and 54% occupancy.

The lowest CLABSI HAC rate (3.68%) occurred in hospitals with the lowest occupancy, and the highest HAC rate (4.75%) occurred in hospitals with occupancy rates between 54 and 71%. Hospitals with an occupancy rate of between 54 and 71% had the highest HAC rate for CAUTI (3.41%), and hospitals with occupancy rates between 35 and 54% had the lowest rate (3.41%). These findings are potentially attributed to hospital case mix, with higher occupancy hospitals likely treating patients who are at higher risk for these conditions.

Table 16.

Frequency of Hospital Acquired Conditions (HACs) by Hospital Characteristics by Occupancy Rate, 2009-2011

	Occupancy ≤35% Frequency			Occupancy >35-≤54% Frequency			Occupancy >54-≤ 71% Frequency			Occupancy >71% Frequency		
HAC	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**
Foreign Object	20	1.52%	0.27%	19	1.41%	0.26%	38	1.46%	0.29%	2	0.74%	0.13%
Air Embolism	1	0.08%	0.01%	3	0.22%	0.04%	3	0.12%	0.02%	0	0.00%	0.00%
Blood Incompatibility	0	0.00%	0.00%	1	0.07%	0.01%	1	0.04%	0.01%	0	0.00%	0.00%
Pressure Ulcer	98	7.45%	1.33%	102	7.57%	1.38%	214	8.22%	1.61%	22	8.12%	1.48%
Catheter Infection	271	20.61%	3.68%	251	18.63%	3.41%	523	20.08%	3.94%	46	16.97%	3.09%
Vascular Infection	271	20.61%	3.68%	326	24.20%	4.42%	630	24.19%	4.75%	66	24.35%	4.43%
Glycemic Control	30	2.28%	0.41%	28	2.08%	0.38%	73	2.80%	0.55%	4	1.48%	0.27%
Mediastinitis	2	0.15%	0.03%	4	0.30%	0.05%	5	0.19%	0.04%	0	0.00%	0.00%
Infection after Ortho	11	0.84%	0.15%	19	1.41%	0.26%	35	1.34%	0.26%	4	1.48%	0.27%
Infection after Bari	2	0.15%	0.03%	2	0.15%	0.03%	1	0.04%	0.01%	2	0.74%	0.13%
Thrombosis	207	15.74%	2.81%	198	14.70%	2.69%	374	14.36%	2.82%	62	22.88%	4.16%
Falls/Trauma	402	30.57%	5.45%	394	29.25%	5.35%	707	27.15%	5.33%	63	23.25%	4.23%
Total	1,315	100.00%		1,347	100.00%		2,604	100.00%		271	100.00%	
Total Admissions	737,027			737,027			1,327,401			149,009		
HAC Rate												
≤35% 737,027		0.18%			0.18%			0.20%			0.18%	
>35-≤54% 737,027												
>54- ≤71% 1,327,401												
>71% 149,009												

Notes: HAC_3year N=2.9M.
Total HACs = 5,537
Total HAC Rate = 0.19%
Source: Med PAR 2009-2011.

Length of Stay

Table 17 shows the frequency and HAC rate stratified by ALOS. Length of stay (LOS) was categorized as less than 5 days and greater than or equal to 5 days by the median length of stay (50^{Th} percentile). There was a significant difference in the HAC rate between patients who had an ALOS equal or greater than five days (0 .41%) as compared to patients who had an ALOS of less than five days (0.05%). The highest HAC rate (10.87%) occurred in longer stay patients with a CLABSI HAC. Patients whose length of stay was greater than five days had a CLABSI HAC rate that was 54.35 times higher than patients who were hospitalized for less than five days (0.20%). This finding is potentially attributed to the fact that patients with a central line have a higher SOI, other co-morbidities which place them at high risk for a CLABSI, and are generally cared for in an intensive care unit.

The HAC rate for CAUTI also showed a similar significant difference between shorter and longer hospital stays. Patients with a longer length of stay had a CAUTI HAC rate (8.60%) that was 16 times higher than patients with an ALOS of less than five days (0.54%).

The falls and trauma HAC rate was five times higher for longer stay patients (10.04%) as compared to patients with shorter stays (2.25%). Clinically, one would expect that patients experiencing some sort of fall or injury in the hospital would have a longer LOS for treatment.

Table 17.

Frequency of Hospital Acquired Conditions (HACs) by Hospital Characteristics by Length of Stay, 2009-2011

	ALOS < 5			ALOS ³ 5		
HAC	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**
Foreign Object	29	3.49%	0.16%	50	1.06%	0.43%
Air Embolism	2	0.24%	0.01%	5	0.11%	0.04%
Blood Incompatibility	0	0.00%	0.00%	2	0.04%	0.02%
Pressure Ulcer	26	3.13%	0.14%	410	8.71%	3.54%
Catheter Infection	96	11.54%	0.54%	995	21.15%	8.60%
Vascular Infection	35	4.21%	0.20%	1,258	26.74%	10.87%
Glycemic Control	25	3.00%	0.14%	110	2.34%	0.95%
Mediastinitis	0	0.00%	0.00%	11	0.23%	0.10%
Infection after Ortho	2	0.24%	0.01%	67	1.42%	0.58%
Infection after Bari	0	0.00%	0.00%	7	0.15%	0.06%
Thrombosis	213	25.60%	1.19%	628	13.35%	5.43%
Falls/Trauma	404	48.56%	2.25%	1,162	24.70%	10.04%
Total	832	100.00%		4,705	100.00%	
Total Admissions	1,793,450			1,157,014		
HAC Rate		0.05%			0.41%	

Notes: N ALOS<5 days= 1,793,450
N ALSO ≥ 5 days = 1,157,014
HAC_3year N=2,950,464
Total HACs = 5,537
Total HAC Rate = 0.19%
Source: Med PAR 2009-2011.

Severity of Illness

The most noteworthy HAC rates of all of the hospital characteristics were SOI scores. Patients' HAC rates increased exponentially as their SOI score increased (Table 18). Patients with a high SOI score (>2.236) had an HAC rate (0.36%) that was more than seven times higher than patients with a low (≤ .868) SOI score (0.05%) and more than two times higher (0.17%) than patients with a medium (>.868 & ≤ 2.236) SOI score. This finding was expected, as it was hypothesized that patients with an HAC were more likely to have other medical conditions and co-morbidities that place them at risk for an HAC.

Remarkable differences were observed between the type of HAC and corresponding SOI scores. The HAC rate for CAUTI, CLABSI, DVT/PE, and pressure ulcers dramatically increased as SOI increased (Table 18). For example, The CLABSI HAC rate (11.77%) was almost six times more for patients with a high SOI as compared to patients with a moderate SOI (2.66%) and 26 times more for patients with a low SOI (.45%).

The CAUTI HAC rate for patients with the highest SOI (6.92%) was almost two times higher than patients with a moderate SOI (3.73%) and sixteen times higher than patients in the lowest SOI (0.42%) category. The HAC rate for falls and trauma also increased as SOI increased, but not as dramatically as the rates for CLABSI, CAUTI, and pressure ulcers. Patients in the highest SOI category had an HAC rate (7.36%) that was 67% higher than patients with a low SOI (2.41%). While all hospitalized patients were at risk for falling, these data show that patients with a high SOI experienced a higher rate of hospital-acquired falls. The HAC rate for pressure ulcers at low (0.0%) and medium (0.25%) SOI was extremely low as compared to the HAC rate of patients with the highest SOI (5.50%). This

Table 18.

Frequency of Hospital Acquired Conditions (HACs) by Hospital Characteristics by Severity of Illness, 2009-2011

	Low ≤ .868			Medium > .868 & ≤ 2.236			High > 2.236		
HAC	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**	**N**	**%**	**HAC Rate**
Foreign Object	16	4.32%	0.22%	40	1.58%	0.27%	23	0.88%	0.31%
Air Embolism	1	0.27%	0.01%	4	0.16%	0.03%	2	0.08%	0.03%
Blood Incompatibility	0	0.00%	0.00%	0	0.00%	0.00%	2	0.08%	0.03%
Pressure Ulcer	0	0.00%	0.00%	30	1.18%	0.20%	406	15.45%	5.50%
Catheter Infection	31	8.38%	0.42%	550	21.66%	3.73%	510	19.41%	6.92%
Vascular Infection	33	8.92%	0.45%	392	15.44%	2.66%	868	33.03%	11.77%
Glycemic Control	5	1.35%	0.07%	57	2.24%	0.39%	73	2.78%	0.99%
Mediastinitis	0	0.00%	0.00%	5	0.20%	0.03%	6	0.23%	0.08%
Infection after Ortho	23	6.22%	0.31%	31	1.22%	0.21%	15	0.57%	0.20%
Infection after Bari	0	0.00%	0.00%	3	0.12%	0.02%	4	0.15%	0.05%
Thrombosis	83	22.43%	1.12%	582	22.92%	3.95%	176	6.70%	2.39%
Falls/Trauma	178	48.11%	2.41%	845	33.28%	5.73%	543	20.66%	7.36%
Total	370	100.00%		2539	100.00%		2628	100.00%	
Total Admissions	738,794			1,474,145			737,525		
HAC Rate		0.05%			0.17%			0.36%	

Notes: HAC_3year N=2,950,464
Total HACs 5,537
Total HCA Rate = 0.19%
Source Med PAR 2009-2011.

finding was expected, because patients with co-morbidities have a higher SOI, placing them at a higher risk for incurring a pressure ulcer.

Table 19 presents a summary of hospital characteristics by mean LOS and SOI. There was a consistent association across all hospital characteristics between mean LOS and mean SOI. The highest LOS was also the highest SOI, suggesting a strong association between LOS and SOI. For example, the Midwest had the highest LOS (5.53) and mean SOI score (1.69) as compared to the other geographic regions. Voluntary (5.14 & 1.68) and minor teaching (5.41 & 2.01) hospitals had the highest LOS and SOI.

As expected, hospitals with at least or more than 400 beds had the highest LOS and SOI, presumably because these hospitals are often associated with caring for patients with a broader range of tertiary care conditions and surgeries. In comparison, hospitals with occupancy rates in the >54% & ≤ 71% range had the highest LOS (5.32) and SOI (1.68), and, as expected, urban area hospitals had the highest LOS (5.21) and SOI (1.68) as compared to rural hospitals. This finding may be associated with the bed size finding because larger hospitals are often located in urban areas. Later adopting Magnet hospitals (<6 years) had higher SOI and LOS as compared to earlier adopters.

Table 19.

Hospital Characteristics Stratified by Length of Stay and Severity of Illness, 2009-2011

Hospital Characteristics	Length of Stay Mean	Severity of Illness Mean
United States Region		
Northeast	4.82	1.68
Midwest	5.53	1.69
South	5.11	1.64
West	4.91	1.67
Hospital Ownership		
Voluntary	5.14	1.68
Proprietary	4.95	1.61
Public	5.09	1.66
Teaching Status		
Major	5.26	2.00
Minor	5.41	2.01
Non-Teaching	4.84	1.98
Bed Size		
< 50	3.81	1.36
≥ 50 & < 100	4.16	1.55
≥ 100 & < 400	4.95	1.65
≥ 400	5.52	1.71
Occupancy Rate		
< 35%	4.68	1.63
≥35% & ≤ 54%	5.08	1.67
>54% & ≤ 71%	5.32	1.68
>71%	5.29	1.65
Urban		
0= Rural	4.44	1.59
1= Urban	5.21	1.68
Magnet Years		
≥ 6 years	5.09	1.67
< 6 years	5.21	1.69

Source: Med PAR 2009-2011

Table 20 stratifies HAC rate by the length of time in years a hospital has been designated as a Magnet Hospital. Magnet years were included in this study because hospitals that are designated as Magnet are recognized for providing high quality care. It was hypothesized that the HAC rate for Magnet hospitals would be less than in those hospitals not designated as Magnet. Likewise, the HAC rate for a Magnet Hospital was expected to be lower the longer the hospital held this designation. Two hundred eighty eight hospitals out of a possible 397 Magnet designated hospitals were included in the sample.

A fifth (1,185) of the total HACs (5,537) in this study occurred in Magnet Hospitals. The HAC rate for Magnet hospital years six or longer was 2.5 HACs per one thousand admissions. This HAC rate was higher than both the non-Magnet HAC rate (0.18%) and for hospitals that were later adopters of Magnet designation (< 6 years) (0.16%). This finding was contrary to the hypothesis that the longer a hospital held Magnet status, the lower the HAC rate would be.

The HAC rates for the most commonly observed HACs in this study were lowest in hospitals that held Magnet status less than 6 years (falls and trauma: 3.97%; CLABSI: 3.68%; CAUTI: 3.68%; and DVT/PE: 2.95%). Hospitals that held Magnet status longer than 6 years had DVT/PE and CLABSI HAC rates that were more than one and a half times higher than hospitals with less than six years. For non-Magnet hospitals the falls and trauma rate (5.39%) was similar to the HAC rate for the greater than six Magnet years hospitals (5.52%). The CLABSI HAC rate (6.41%) was 1.74 times higher and the

DVT/PE HAC rate (4.55%) was one and a half times higher in early adopting Magnet hospitals as compared to non-Magnet hospitals (4.16% and 2.6%, respectively).

Table 20.

Frequency of Hospital Acquired Conditions (HACs) by Hospital Characteristics by Magnet Years, 2009-2011

		Non Magnet				Magnet					
HAC	N	% of HAC	HAC Rate non-Magnet	Magnet Years <6	% of HAC by Magnet Year	HAC Rate Magnet Years <6	Magnet Years ≥6	% of HAC by Magnet Year	HAC Rate Magnet Years ≥6	Total Magnet	% of Total HAC by Magnet Years
Foreign object	60	1.38	0.25%	5	1.47	0.24%	14	1.66	0.41%	19	1.60
Air Embolism	5	0.11	0.02%	0	0.00	0.00%	2	0.24	0.06%	2	0.17
Blood Incompatibility	0	0.00	0.00%	0	0.00	0.00%	2	0.24	0.06%	2	0.17
Pressure Ulcer	349	8.02	1.45%	25	7.33	1.21%	62	7.35	1.82%	87	7.34
Catheter Infection	848	19.49	3.53%	76	22.29	3.68%	167	19.79	4.91%	243	20.51
Vascular Infection	999	22.95	4.16%	76	22.29	3.68%	218	25.83	6.41%	294	24.81
Glycemic Control	109	2.50	0.45%	8	2.35	0.39%	18	2.13	0.53%	26	2.19
Mediastinitis	6	0.14	0.02%	2	0.59	0.10%	3	0.36	0.09%	5	0.42
Infection after Ortho	51	1.17	0.21%	6	1.76	0.29%	12	1.42	0.35%	18	1.52
Infection after Bari	4	0.09	0.02%	0	0.00	0.00%	3	0.36	0.09%	3	0.25
Thrombosis	625	14.36	2.60%	61	17.89	2.95%	155	18.36	4.55%	216	18.23
Falls/Trauma	1296	29.78	5.39%	82	24.05	3.97%	188	22.27	5.52%	270	22.78
Total	4352	100.00		341	100.00		844	100.00		1185	
Total Admissions	2,403,388			206,734			340,342				
HAC Rate	0.18			0.16			0.25				

Notes: Total HAC rate .22%

Total Magnet Hospital Admissions = 547,076

Source: Med PAR 2009-2011

Hospital Acquired Conditions by Length of Stay and Paid Registered Nurse Hours

Table 21 displays the mean HAC rate stratified by low, medium, and high paid registered nurse hours per patient day and by patent length of stay less than or greater than 5 days. There was very little variation in mean HAC rate within LOS category by low, medium, and high paid registered nurse hours per patient day. However, the mean HAC rate for a LOS greater than 5 days (0.35) was almost 9 times greater than the HAC rate for LOSs fewer than 5 days (.04). This may be explained by the fact that the longer patients are in the hospital, the more likely they are to acquire a HAC.

Table 21.

Hospital Acquired Condition Rate Stratified by Length of Stay Category and Paid Registered Nurse Hours per Patient Day, 2009-2011

Paid Registered Nurse Hours per Patient Day	**Average Length of Stay(ALOS) <5 days**	**Average Length of Stay(ALOS) ≥5 days**
	%	**%**
Low Hours >8 & <15.15	0.03	0.33
Medium Hours ≥15.15 & <20.14	0.04	0.35
High Hours ≥20.14 & < 24	0.05	0.35
Mean HAC Rate	0.04	0.35

Note: Low = bottom 25% of hospital based paid Registered Nurse hours per patient day (RNHPPD), Medium = middle 50% RNHPPD, High = top 25% RNHPPD.
Source: Med PAR 2009-2011

In summary, the overall HAC rate when stratified by both patient and hospital characteristics was the same across all categories (0.19%), except for Magnet status (0.22%). Patients with an LOS of greater than or equal to five days have a 0.41% chance of incurring an HAC as compared to those patients with an LOS less than five days. The most common HACs for patients with an LOS of greater than or equal to five days and the highest SOI were CLABSI, pressure ulcers, and CAUTI. Patients with a LOS greater than or equal to five days experienced an HAC rate of 33-35 per 10,000 admissions regardless of the number of hours of nursing care as compared to those patients with a length of stay less than five day.

Correlation Analysis

Spearman correlation analysis was conducted to examine bivariate associations between study variables. Table 22 shows correlations with the main outcome variable and the explanatory variables. The strongest relationship in the matrix was a fairly strong negative correlation between disabled and the quadratic age: the older the patient, the less likely they were to be disabled. There were moderately strong negative correlations between bed size and teaching status, paid LPN hours per patient day, and urban location and occupancy rate. Teaching status was not necessarily an indicator of bed size. Urban hospitals and hospitals with higher occupancy rates were less likely to provide care using LPNs.

The strongest positive correlation in the matrix was between severity of illness and length of stay DRG: the higher the severity of illness, the longer the length of stay. Continuous LOS was also moderately and positively correlated. These findings were expected as patients with a high severity of illness and longer LOS have a higher incidence of reported HACs, as previously described (Table 8). Bed size and urban location were also moderately and positively correlated: hospitals with large bed sizes were located in urban areas. The United Sates geographic region was positively correlated with the type of hospital ownership as were urban hospitals and occupancy rate. The latter finding was expected, as hospitals located in urban areas usually have higher occupancy rates.

Table 22.

Correlation Between Study Variables

	hac_3m	age_ad~n	age_ad~2	disable	Female	race_c~y	us_reg~n	ownert~e	teachi~s	_iurba~2	bedsize	occrat~y	magne~en	rn_da~mh	lpnhripd	severi~i	orthodrg	cardia~g	los	losdrg
hac_3m	1																			
age_admsn	0.0023	1																		
age_admsn2	0.0023	1	1																	
disable	-0.0026	-0.6822	-0.6822	1																
female	0.0054	0.1117	0.1117	-0.0572	1															
race_categ~y	-0.0014	-0.1581	-0.1581	0.1787	0.0022	1														
us_region	0.0009	-0.0297	-0.0297	0.0115	-0.0074	0.0715	1													
ownertype	-0.0005	-0.033	-0.033	0.0247	-0.0005	0.0478	0.2626	1												
teaching_s~s	-0.0029	0.0362	0.0362	-0.0323	0.0113	-0.0658	0.1935	0.1693	1											
_iurban_ru~2	0.003	0.0025	0.0025	-0.0026	-0.0085	0.0568	-0.0553	-0.0843	-0.1651	1										
bedsize	0.0045	-0.0405	-0.0405	0.0287	-0.0191	0.076	-0.0851	-0.1481	-0.3967	0.3388	1									
occrate_ca~y	0.0012	0.0069	0.0069	-0.0168	-0.0073	0.0059	0.0094	-0.1321	-0.0743	0.2371	0.0617	1								
Magnet_len	0	0.0063	0.0063	-0.0059	-0.001	0.0003	-0.0795	-0.0895	-0.0877	0.079	0.0712	0.0785	1							
rn_day_24h~h	0.0014	-0.0251	-0.0251	0.0038	-0.009	-0.0487	-0.0106	-0.0021	-0.0577	0.0163	0.0302	-0.102	0.0374	1						
lpnhripd	-0.0016	-0.043	-0.043	0.0302	0.0033	-0.0528	0.1717	0.1797	0.1325	-0.3377	-0.2043	-0.2702	-0.1276	0.1057	1					
severity_i~i	0.0207	0.1466	0.1466	-0.0323	-0.084	0.0473	-0.0123	-0.0139	-0.0129	0.0203	0.0256	0.0079	0.0031	0.0028	-0.0241	1				
orthodrg	0.0349	-0.0135	-0.0135	-0.05	0.0389	-0.0464	0.002	-0.0084	-0.0013	0.0093	-0.0102	-0.0014	0.0055	0.0273	0.0149	-0.1692	1			
cardiacdrg	0.0025	-0.023	-0.023	-0.026	-0.0672	-0.0228	-0.0006	-0.0127	-0.0328	0.0325	0.0509	0.0252	0.0045	0.0259	-0.0162	0.0053	-0.0319	1		
los	0.0442	0.0649	0.0649	-0.0208	0.0123	0.0363	-0.0038	-0.0079	-0.0215	0.0331	0.0446	0.0237	-0.0018	-0.0402	-0.0242	0.3336	-0.023	0.0884	1	
losdrg	0.0249	0.0017	0.0017	0.0417	-0.0493	0.0495	0.0049	-0.0131	-0.0184	0.0338	0.0385	0.0052	0.0052	0.015	-0.015	0.4695	-0.0891	0.1273	0.517	1

Source: Med PAR 2009-2011

Multivariate Regressions

The results of five stepwise logistic models, using the outcome variable of any reported HAC, are reported below (Table 23). Four additional multivariate regression models, using a subset of HACs as outcome variables—CLABSI, CAUTI, falls and trauma, and pressure ulcers stage III and IV—are also presented (Tables 25-27).

Model 1

Model 1 included all exogenous variables that were considered independent of severity and LOS for a given admission (patient demographic characteristics, hospital ownership, teaching status, United States geographic region, and bed size). Endogenous variables included occupancy rate and length of Magnet designation. The R^2 for model 1 was .0034, indicating that only 0.34% of the likelihood of incurring any HAC on a particular admission was explained by these variables. The low R^2 was due to (a) the rate of reported HACs is less than 2%, (b) patient severity and LOS were not controlled for, and (c) some HACs go unreported during the inpatient stay.

Despite the model's low explanatory power, several patient characteristics were statistically significant in predicting the likelihood of an HAC before controlling for severity and length of stay. The likelihood of incurring a reported HAC rose with age, but at a slower rate with increasing age at time of admission. From the logit odds ratio, it appears that the likelihood of an HAC rose through age 52 and then declined. However, it must be remembered that this inverted u-shape effect was observed when holding disabled and all other patient and hospital characteristics constant. Female patients

(OR=1.29), (p <.01) were more likely to experience a reported HAC than males. Other minority races (OR=.836), (p<.05) were about 16% less likely to experience a HAC than white patients.

Several hospital characteristics had statistically significant associations with the incidence of a reported HAC when holding other exogenous variables constant. Patients in the Midwestern region (OR=1.10, p<.05), Southern (OR=1.08, p<.10), and Western (OR=1.29, p<.01) regions were all more likely to incur an HAC than patients who were treated in the Northeast. Patients admitted to a public versus private/voluntary hospital (OR=1.08, p<.10) or in an urban hospital (OR=1.12, p=<.05) were more likely to experience an HAC. Patients cared for in hospitals with 400 or more beds were 26% more likely to experience an HAC (OR=1.26, p<.05). As shown in other models, large bed size is likely a proxy for case mix. Hospitals above 400 beds are more likely to have medical programs and specialties that treat patients with a higher SOI and/or have longer stays. Patients who were cared for in hospitals with very low occupancy rates (<35%) appear to have higher HAC rates, but the relationship was not very strong. There were no statistically significant associations related to teaching status and the number of years with Magnet designation.

Model 2

Model 2 included all of the exogenous variables in Model 1, and stepped in two hypothetically endogenous variables: paid registered nurse hours and paid licensed practical nurse hours. A high level (>20.14 & ≤ 24) of paid registered nurse hours per patient day, holding all other exogenous variables constant, was positively correlated with the likelihood of any reported HAC (OR=1.11, p=<.05).

This result is inconsistent with the hypothesis that more nursing intensity per patient day would lower the incidence of reported HACs. The odds ratio for paid licensed practical nurse hours suggests that patients were less likely to experience an HAC, holding RN hours per day constant; however, this finding was not statistically significant. Absent any theoretical explanation as to why greater RN intensity per patient day should increase the reported HAC rate, it is likely that the odds ratio reflects the positive correlation of RN hours per day and case-mix severity. If patient age, disabled status, or gender, are also case-mix proxies that result in HACs, it is surprising how little their odds ratios change between models 1 and 2. Over 400 bed size became statistically insignificant in Model 2, suggesting that some of the case mix effects of bed size had shifted to registered nurse hours as a proxy for SOI.

As in Model 1, patients residing in the Midwest (OR=1.15, p=0.01), South (OR=1.11, p=.05), and West (OR=1.19, p=.01) were all more likely to incur a HAC as compared to the Northeast. The odds ratios for Midwestern and Southern regions increased somewhat after controlling for nursing intensity, implying that hospitals in these regions used less intensive nursing per day, on average, than did hospitals in the Northeast. The opposite must be true for the Western region, given the decline in its odds ratio after controlling for nursing intensity.

Also similar to Model 1, patients treated in an urban hospital were more likely to encounter an HAC (OR=1.12, p=.01). Hospital ownership, teaching status, occupancy rate, and Magnet years were not statistically significant in this model. The R^2 (.0032) for this model was similar to Model 1, suggesting that .32% of the variance in the incidence of any HAC was explained by these variables (holding all exogenous variables constant).

Model 3

Model 3 included all of the variables in the first two models and stepped in the variables SOI and (0, 1) indicators of Cardiac and Orthopedic DRG. Severity of illness had a highly statistically significant impact on any reported HAC. Patients with a high SOI (>2.23) were 12.8 times more likely (OR=12.78, p=.01) to incur an HAC as patients with a low status SOI, *ceteris paribus*. Patients with a medium SOI score (>.868 & ≤ 2.23) were 5.8 times more likely (OR=5.80, p=.01) as patients with a low SOI score (≤.868) to incur an HAC.

Orthopedic and cardiac DRG indicators were also strong predictors of any HAC, in part because 2-12 HACs were partially identified by having a cardiac or orthopedic procedure. Patients who underwent total hip or total knee replacement procedures were 12.3 times more likely to incur an HAC as compared to patients who did not have one of these procedures (OR=12.78), (p=.01). Patients who underwent a cardiac surgical procedure that placed them at risk for mediastinitis were also more likely (OR=1.78, p=.01) of incurring any HAC relative to patients who did not undergo a cardiac procedure.

Controlling for the patients' SOI resulted in important changes in some of the exogenous variables. For one, the odds ratios for the two age variables became less significant (p=<.10). Secondly, disabled patients were less likely to incur an HAC (OR=.81, p=.01).

Further notable changes observed when controlling for SOI included an increased propensity (41%) for female patients to experience an HAC as compared to males when controlling for SOI (OR=1.41, p=.01). Increasing from the three Models, females were more likely as compared to males to develop a HAC. Odds ratios also increased for both the Midwestern (OR=1.21, p=.01) and Southern (OR=1.21, p=.05) regions once SOI and the two surgical DRGs were stepped into the model. The likelihood of any HAC rose in these regions relative to the Northeast once controlling for these regions' relatively less severe case mix.

Patients who were cared for in public versus private and voluntary hospitals were about 10% more likely to experience an HAC, when controlling for all other variables (OR=1.095, p=.10). The odds ratio was somewhat higher than before controlling for patient severity, which suggests a somewhat simpler case mix in public hospitals.

Importantly, the positive odds ratio for hospitals with high RN hours per patient day was no longer significant (OR=1.044). This suggests that nursing intensity was generally a proxy for unmeasured case mix severity in Model 1 and not a "cause" of HACs. No statistically significant results were observed for race, teaching status, urban, bed size, or occupancy rate.

The R^2 in this model (.0644) shows that 6.4% of the variance in the likelihood of any HAC was explained by the explanatory variables. This increase in R^2 was due almost entirely to the patient's specific level of severity and procedure mix, and not basic age-gender-race or hospital level characteristics.

Model 4

Model 4 included all of the variables from Model 3 and stepped in the continuous length of stay variable (LOS-CON), the sample patient's actual length of stay. Length of stay was a strong predictor of any reported HAC (OR=1.042, p=.01), ceteris paribus. LOS reflected both the exposure effect and HAC effect of incurring any reported HAC.

To understand the significance of this odds ratio, the following example is provided showing the effect of the difference of two DRG lengths of stay. DRG 179 Respiratory Infections and Inflammations without co-morbid complications or major co-morbid complications have an arithmetic mean LOS of 5.0 days. A DRG 656 Kidney and Ureter procedure for neoplasm with major co-morbid conditions has an arithmetic LOS of 10 days. The difference between these DRGs is 5 days and the calculated OR for the difference is 1.228. (e.04114 (10-5) =5)=e.2057=OR 1.228).

The R^2 in this model (0.090) increased by one third with only one variable added to the model and showed that 9% of the variance in the likelihood of any HAC was explained by the explanatory variables. This increase in R^2 is extremely powerful and was due to the patient's actual LOS.

There was very little difference in the odds ratios for paid registered nurse hours (OR=1.048) and paid licensed practical nurse hours (OR=0.989) in Model 3, and both remained statistically insignificant. Adding LOS had very little effect on nursing care hours and the likelihood of an HAC. This was an interesting finding, as patients with a longer LOS usually have a higher SOI and are more likely to receive more nursing care hours.

The SOI score also remained strong and highly significant (OR=9.461, p=.01) in Model 4, but the odds ratio decreased by a third from the odds ratio in Model 3 (OR=12.786, p=.01). The odds ratio for a medium SOI score (OR=5.368, p=.01) also declined from Model 3, but the change was not as dramatic as for the high SOI score. This suggests that SOI leads to a higher LOS, which increases the likelihood of a patient incurring an HAC.

The odds ratio for Orthopedic DRG (OR=12.650, p=.01) increased almost 3% from Model 3 (OR=12.310, p=.01). Patients who underwent total hip or total knee replacement procedures were 12.6 times more likely to incur an HAC as compared to patients who did not have one of these procedures, suggesting a longer exposure effect. This is most likely due to the increased risks for specific HACs associated with these procedures, such as infections and DVT/PE. Controlling for LOS-CON, the cardiac DRG OR declined by 20%. The odds ratio for cardiac DRG remained highly statistically significant but decreased from Model 3 (OR=1.438, p=.01). This decline in positive correlation of cardiac DRG with LOS-CON was .0848.

Odds ratios declined for the Midwestern (OR=1.115, p=.05), Southern (OR=1.092, p=.10), and Western (OR=1.135, p=.05) regions once LOS-CON was stepped into the model. These changes reflect the average LOS between the regions as compared to the Northeast.

Model 5

Model 5 replaced the patient's own continuous length of stay variable with the instrumental variable, DRG average LOS (LOS-DRG). This variable served as a proxy for the DRG exposure effect. LOS -DRG was a strong predictor of any HAC (OR=1.098, p=.01), controlling for all other variables. This is most likely due to a combination of the residual DRG effect not picked up with SOI, cardiac, and orthopedic DRG. Substituting LOS-DRG for LOS-CON reduced the model R^2 by 31%, from 0.09 to 0.0789. This was expected because LOS-DRG does not reflect any significant HAC "feedback" on longer stays. Approximately 13% of the effect of longer stays on an HAC was due to the HAC lengthening stays; the remainder of the effect appears to be due to longer exposure to inpatient care.

In Model 5, a high SOI score remained highly significant (OR=8.910, p=.01) but the odds ratio decreased 69% from the odds ratio in Model 3 (OR=12.786, p=.01) and by 5.82% in Model 4 (OR=9.461, p=.01). The odds ratio for a medium SOI score (OR=5.240, p=.01) also declined across Models 3 and 4, but the change was less dramatic. This was due to the effect of adding LOS-DRG to the model and controlling for all other variables. Odds ratios increased in the Midwestern (OR=1.211, p=.01), Southern (OR=1.115, p=.05), and Western (OR=1.179, p=.01) regions as compared to the Northeast.

The odds ratio for Orthopedic DRG (OR=13.644, p=.01) increased 1.08 times from Model 4. Patients who underwent total hip or total knee replacement procedures were 13.6 times more likely to incur an HAC as compared to patients who did not have one of these procedures. Similar to Model 4, the odds ratio for cardiac DRG was lower than Model 3 but remained highly statistically significant (OR=1.36, p=.05) controlling for LOS. A very small residual degree of feedback was reflected in LOS-DRG due to the small (1-2%) positive correlation of DRG average length of stay with the likelihood of incurring an HAC.

Across 3 models, disabled patients were statistically less likely to incur an HAC. Female patients were 42% more likely to experience an HAC as compared to males when controlling for LOS (OR=1.428, p=.01). Across all 5 models, females were more likely to incur an HAC than males. The odds ratios increased across all 5 models even when controlling for SOI and LOS, two very strong predictors for HACs. This finding suggests that even adjusting for the effects of SOI and LOS-DRG, those females were highly likely to experience an HAC.

Patients who were cared for in public versus private and voluntary hospitals were about 3% more likely to experience an HAC, when controlling for all other variables, (OR=1.095, p=.10) than in Model 4. The odds ratio in Model 3 was the same as Model 5 before controlling for LOS. This finding suggests that when controlling for LOS-DRG, public hospitals have a longer LOS.

Table 23.

Multivariate Logistic Regression: Odds Ratio Likelihood of Any Reported HAC

	Model 1	Model 2	Model 3	Model 4	Model 5
Explanatory Variable	**Odds Ratio**	**Odds Ratio**	**Odds Ratio**	**Odds Ratio**	**Odds Ratio**
Age	1.028***	1.027**	1.006	1.002	0.999
Age²	.999***	.999**	.999*	0.999	0.999
Disabled	0.996	0.957	.817***	.813***	.832**
Female	1.293***	1.320***	1.410***	1.405***	1.428***
Race					
Black	0.938	0.941	0.920	.908*	.917*
Other	.836**	.831**	0.883	.858*	.862*
US Region					
Midwest	1.101**	1.155***	1.218***	1.115**	1.211***
South	1.079*	1.112**	1.215**	1.092*	1.115**
West	1.286***	1.194***	1.188***	1.135**	1.179***
Hospital Ownership					
Proprietary	0.979	0.992	1.025	1.004	1.019
Public	1.081*	1.076	1.095*	1.061	1.095*
Federal	0.925	0.830	0.847	0.752	0.805
Teaching Status					
Minor Teaching	1.042	1.047	1.051	1.025	1.043
Non-Teaching	0.922	0.961	0.978	0.991	0.992
Urban	1.116**	1.123*	1.069	1.07	1.039
Bed Size					
≥50 & <100	0.884	0.884	0.841	0.842	0.84
≥100 & <400	1.061	1.051	0.96	0.932	0.936
≥400	1.255**	1.225	1.112	1.028	1.049
Occupancy Rate					
>35% &≤54%	.932*	0.962	0.944	0.932	0.936
>54% & ≤71%	0.974	0.994	0.983	0.952	0.975
>71%	0.969	1.028	0.998	0.974	0.984

(continued)

Table 23. (continued)

Multivariate Logistic Regression: Odds Ratio Likelihood of Any Reported HAC

	Model 1	Model 2	Model 3	Model 4	Model 5
Explanatory Variable	**Odds Ratio**	**Odds Ratio**	**Odds Ratio**	**Odds Ratio**	**Odds Ratio**
Magnet Length	0.94	0.952	0.955	0.938	0.954
Paid Registered Nurse Hours					
Medium (>15.15 & ≤ 20.14)		1.010	0.976	0.991	0.975
High (>20.14 & ≤ 24)		1.110**	1.044	1.048	1.022
Paid Licensed Practical Nurse Hours		0.989	0.986	0.989	0.989
Severity of Illness					
Medium (> .868 & ≤ 2.236)			5.805***	5.368***	5.240***
High (> 2.236)			12.786***	9.461***	8.910***
Cardiac DRG			1.781***	1.438***	1.236**
Orthopedic DRG			12.310***	12.650***	13.644***
Length of Stay Continuous				1.042***	
Length of Stay DRG					1.098***
Constant	.000***	.000***	.000***	.000***	.000***
Number of Observations	2935258	2317639	2317639	2317639	2317639
Notes:					
Log Likelihood	-36518.066	-28453.7	-26706.6	-25975.25	-26294.347
R^2	0.0034	0.0032	0.0644	0.090	0.0789
Prob>chi²	0.000	0.000	0.000	0.000	0.000

*p<.10

** P<.05

*** p<.01

Source: Med PAR 2009-2011.

Multivariate Analysis of Three Hospital Acquired Conditions

Analytic models were developed based on a sub-set of HACs (CLABSI, CAUTI, and falls and trauma). This sub-set of HACs was selected in order to isolate nursing intensity effects on nursing-sensitive hospital acquired conditions. The criteria used to select the subset were that the HACs: 1) have a high annual incidence; and 2) be nurse-sensitive. For each individual HAC of the subset, multivariate regressions were performed for patients who had the HAC and for patients who were at risk for the HAC.

CAUTI

The probability of reporting a CAUTI HAC [pb [HAC_{CAUTI} |ADM] at the admission level can be decomposed as follows:

Equation 6: pb [HAC_{CAUTI} |ADM] =pb [HAC_{CAUTI} *pb $_{CAUTI}$ | UC] * pb [UC | ADM

pb[HAC_{CAUTI}|ADM] = pb[UC|ADM]*pb[CAUTI|UC]*pb[HAC_{CAUTI}|CAUTI]

where the probability of reporting a CAUTI-related HAC once admitted, pb [HAC_{CAUTI} |ADM], is decomposed into (a) the probability of having a urinary catheter (UC) inserted during an admission, pb [UC| ADM, times (b) the probability of experiencing a CAUTI given the insertion of a UC, pb [CAUTI | UC], times (c) the probability of a CAUTI actually being reported by the hospital as a HAC *during the admission* conditional on an infection actually occurring, pb [HAC_{CAUTI} |CAUTI] (many go undetected before discharge). The first right-hand-side term requires that a patient have a urinary catheter inserted during the stay (most do not) which varies by patient diagnosis and treatment regimen (i.e., case mix). Patients who are at risk for a urinary infection have a variety of confounding medical conditions and/ or procedures. Such conditions include diabetes, a poor general state of health, old age, fecal incontinence, malignancy, and dehydration. Female and hip fracture patients are also at greater risk for a urinary tract infection (Halleberg Nyman, Johansson, Persson & Gustafsson (2011).

The second right-hand term is the *true* rate of CAUTI once a catheter is inserted, but not all CAUTIs are actually reported as a HAC during the same admission; hence, the third right-hand term.

A hospital may exhibit a higher CAUTI HAC rate because (a) its case mix more often requires the insertion of a urinary catheter, (b) measures to prevent a urinary catheter infection failed, or (c) the infection is reported prior to discharge possibly due to a longer length of stay. The equation can be re-arranged to solve for the meaningful *true* CAUTI rate only among patients actually receiving a urinary catheter:

Equation 7

$pb\,[CAUTI \mid UC] = [CAUTI/HAC_{CAUTI}] * \{pb\,[HAC_{CAUTI} \mid ADM]/pb[UC \mid ADM]\}$.

The true rate of catheter associated infections conditional on receiving a urinary catheter requires multiplying the number of true CAUTIs per HAC-reported CAUTI times the ratio of HAC CAUTIs per admission to Urinary Catheters per admission. Both probabilities are less than 1, implying that the reported CAUTI HACs under represent the number of true CAUTIs.

Two multivariate logistic regressions were specified, one with respect to the hospital's overall CAUTI HAC rate, $pb\,[HAC_{CAUTI} \mid ADM]$, and a second, more focused model limited to at-risk patients actually receiving a urinary catheter, or the ratio of reported CAUTI HACs to Urinary Catheter patients. Odds ratios in the "admissions" model reflected patient and hospital differences in the likelihood of incurring a urinary catheter and being infected, while the "at-risk" model odds ratios narrowly focused on the CAUTI actually being reported.

From Table 24, last row N, the probability of inserting a urinary catheter was 0.0084 (=19.4 thousand/2.32 million), or slightly less than one percent of admissions. Thus, if all true CAUTIs incurred in hospitals were actually reported as HACs, i.e. $CAUTI/HAC_{CAUTI}$ = 1.0, the true CAUTI rate would be .00037/.0084 =.044 or 119-times the reported CAUTI HAC rate 0.00037. In other words, the true inpatient CAUTI rate would be 4.4 per 100 urinary catheter insertions and not the far less meaningful 3.7 per 10,000 admissions. If only 50% of true CAUTIs were reported as HACs, then the true CAUTI rate would be 0.088, or 8.8 per 100 UC insertions.

Table 24 presents results of the two logistic regressions. The first regression, column 1, is based on all admissions with available data (2.3 million admissions). Several variables were significant when controlling for all variables in the model. The model's explanatory power was low as expected (R^2 =0.047) because of the very small number of CAUTIs actually reported as HACs and the disparate nationally representative sample. Patients in hospitals reporting between 21 and 24 hours of paid registered nurse hours per patient day were 1.3 times more likely to report a CAUTI HAC (OR=1.319, p=<.05).

SOI was a strong predictor of CAUTI HACs. Relative to low severity, patients with a high SOI were 15.77 times more likely to incur a CAUTI HAC (OR=15.775, p=<.01) and patients with a medium SOI were 9 times more likely to incur a CAUTI

HAC (OR=9.302, p=<.01). The likelihood of incurring a CAUTI HAC was roughly 2-3 times more likely for patients who underwent an orthopedic (OR=2.663, p=<.01) or cardiac procedure (OR=2.322, p=<.01).

DRG "exposure" length of stay also was a powerful indicator of the likelihood of incurring a CAUTI HAC during hospitalization (OR=1.078, p=<.01). Each extra day raised the likelihood of a reported CAUTI by 7.8%. An extra week in the hospital raised the likelihood of a CAUTI HAC by 70 % (= exp {ln 1.078x 7 days} -1). These findings were consistent with the hypothesis that patients who are in the hospital longer, even when controlling for the higher severity of illness, are more likely to incur a CAUTI HAC.

Table 24.

Logistic Regression Catheter Associated Urinary Tract Infection (CAUTI) and Catheter Associated Urinary Tract Infection (CAUTI) at Risk

	HAC CAUTI/ADM Odds Ratio	HAC CAUTI/ UC Odds Ratio
Age	1.035	1.06
Age²	0.999	0.999
Disabled	0.824	1.329
Female	1.574***	0.91
Race		
Black	1.195*	1.392
Other	0.999	1.841
US Region		
Midwest	1.06	1.531
South	1.285**	1.446
West	1.455***	1.283
Hospital Ownership		
Proprietary	0.943	1.322
Public	1.107	0.912
Federal	0.867	5.314
Teaching Status		
Minor Teaching	0.876	0.466
Non-Teaching	0.798	0.633
Urban	0.982	6.386*
Bed Size		
≥ 50 & <100	1.946	0.84
≥ 100 & <400	2.123	0.769
≥400	2.322	1 (omitted)
Occupancy Rate		
>35% &≤54%	0.885	0.588
>54% & ≤71%	0.976	0.538
>71%	1.033	0.571
Magnet Length	1.105	1 (empty)
Paid Registered Nurse Hours		
Medium (>15.15 & ≤ 20.14)	1.187	3.114**
High (>20.14 & ≤24)	1.319**	3.945**

(continued)

Table 24. (continued)

Logistic Regression Catheter Associated Urinary Tract Infection (CAUTI) and Catheter Associated Urinary Tract Infection (CAUTI) at Risk

	HAC CAUTI/ADM Odds Ratio	**CAUTI/UC Odds Ratio**
Paid Licensed Practical Nurses	0.963	0.849
Severity of Illness		
Medium (> .868 & ≤ 2.236)	9.302***	6.059*
High (> 2.236)	15.776***	6.482**
Cardiac DRG	2.322***	1 (omitted)
Orthopedic DRG	2.663***	0.895
Length of Stay DRG	1.078***	1.014
_cons	1.30e-06***	.0000197**
R^2	0.0469	0.0573
Prob > chi^2	0	0.1987
N	2,317,639	19,385

Notes:
*p<.10
** P<.05
*** p<.01
Source: Med PAR 2009-2011.

Females were 1.57 times more likely than males to experience a CAUTI (OR=1.574, p=<.01)—unsurprising, as women in general are more susceptible to urinary infections (Halleberg Nyman et al., 2011; Johansson, Persson & Gustafsson (2011). African American patients were also more likely to incur a CAUTI (OR=1.19, p=<.10). Patients treated in the Southern (OR=1.285, p=<.05) and Western (OR=1.455, p=<.01) regions were more likely to incur a CAUTI HAC.

In the second CAUTI risk regression, there were slightly less than 20,000 reported urinary catheter insertions, or roughly 1% of the 2.3 million reported admissions. Such a small urinary catheter rate was expected to reduce the statistical significance of several odds ratios. Odds ratios in this regression reflected the likelihood of a reported CAUTI HAC as conditional on having a urinary catheter. They do not include the effects that factors such as case mix might have on the likelihood of needing a catheter. They do, however, reflect the compound effects of both incurring a true CAUTI and having it reported (or not) during the admission. Patients who received between 21and 24 hours of paid registered nurse hours per patient day were almost 4 times more likely to experience a CAUTI HAC (OR=3.945, p=<.05). This higher rate may have been due to a lower urinary catheter per admission rate. The rate remained higher when holding patient demographics, length of stay, and severity of illness constant. Patients who received between 15 and 19 hours of care were three times more likely to experience a CAUTI HAC (OR=3.114, p=<.05).

SOI remained strong, albeit an attenuated, predictor of CAUTI HACs. Patients in both the medium and high SOI categories were about six times more likely to incur an HAC (medium: OR=6.059, p=<.10; high: OR=6.482, p=<.05). A reduction in SOI odds ratios of one-third to two-thirds implies substantial roles of case mix in explaining both the likelihood of receiving a catheter as well as having a CAUTI HAC.

Unlike patients with a reported CAUTI HAC during hospitalization, there was no statistically significant finding for LOS-DRG or for patients undergoing an orthopedic or cardiac procedure. The DRG exposure instrumental variable appears to have captured case mix effects that influence the likelihood of needing a urinary catheter and not actually incurring a CAUTI. The insignificant LOS-DRG odds ratio in the at-risk model may also be due to a systematic lack of reporting of CAUTIs to Medicare, which could potentially mask a positive exposure effect on the true CAUTI rate.

Female gender was no longer a risk factor for a CAUTI HAC among patients actually receiving a urinary catheter in this regression. It appears that gender was a strong predictor of needing a catheter but did not raise the probability of an infection once receiving the catheter.

Patients treated in an urban area were also 6 times more likely to incur a CAUTI HAC, although the effect was significant only at the 10% level of confidence.

CLABSI

The reported CLABSI HAC rate at the admission level can be decomposed as follows:

Equation 8: $pb\ [HAC_{CLABSI}|ADM] = pb\ [HAC_{CLABSI} * pb_{CLABSI} \mid VC] * pb\ [VC \mid ADM$

$pb\ [HAC_{CLABSI}|ADM] = pb\ [VC|ADM] * pb[CLABSI|VC * pb[HAC_{CLABSI}|CLABSI]$

where the probability of reporting a CLABSI-related HAC once admitted, pb $[HAC_{CLABSI}|ADM]$, is decomposed into (a) the probability of having a vascular catheter (VC) inserted during an admission, pb [VC| ADM, times (b) the probability of experiencing a CLABSI given the insertion of a VC, pb [CLABSI | VC], times (c) the probability of a CLABSI actually being reported by the hospital as a HAC *during the admission* conditional on an infection actually occurring, pb $[HAC_{CLABSI}|CLABSI]$ (many go undetected before discharge). The first right-hand-side term requires that a patient have a vascular catheter inserted during the stay (most do not) which varies by patient diagnosis and treatment regimen (i.e., case mix). Patients who are at risk for a vascular catheter infection have a variety of confounding medical conditions and/ or procedures. Such medical conditions include hematological and immunological deficiencies and cardiovascular and gastrointestinal diseases (JCAHO, 2012). Risk factors associated with central venous catheter insertion and maintenance include lack of maximal sterile barriers for CVC insertion, prolonged hospitalization before catheter insertion, multiple catheters and femoral or internal jugular access site (JCAHO, 2012). Male gender is also a reported risk factor.

The second right-hand term is the *true* rate of CLABSI once a catheter is inserted, but not all CLABSIs are actually reported as a HAC during the same admission; hence, the third right-hand term.

A hospital may exhibit a higher CLABSI HAC rate because (a) its case mix more often requires the insertion of a vascular catheter, (b) measures to prevent a vascular catheter infection failed, or (c) the infection is reported prior to discharge possibly due to a longer length of stay. The equation can be re-arranged to solve for the meaningful *true* CLABSI rate only among patients actually receiving a vascular catheter:

Equation 9: $pb\,[CLABSI \mid VC] = [CLABSI/HAC_{CLABS}]^{*}\{pb\,[HAC_{CLABSI} \mid ADM]/pb[VC \mid ADM]\}$. The true rate of catheter associated infections conditional on receiving a vascular catheter requires multiplying the number of true CLABSIs per HAC-reported CLABSI times the ratio of HAC CLABSIs per admission to Vascular Catheters per admission. Both probabilities are less than 1, implying that the reported CLABSI HACs under represent the number of true CLABSIs.

Two multivariate logistic regressions were specified, one with respect the hospital's overall CLABSI HAC rate pb[HAC_{CLABSI} | ADM], and a second, more focused model limited to at-risk patients actually receiving a vascular catheter. Odds ratios in the "admissions" model reflected patient and hospital differences in the likelihood of incurring a vascular catheter and being infected, while the "at-risk" model odds ratios narrowly focus on the CLABSI actually reported.

Equation 8 explains the CLABSI HAC rate at the hospital level (i.e., number of reported HAC CLABSIs per admission, which is commonly reported by researchers and policy makers. The equation can be re-arranged to solve for the meaningful, *true* CLABSI rate only among patients actually receiving a vascular catheter:

Equation 9: pb [CLABSI | VC] = pb [HAC_{CLABSI} |ADM]*{1/[pb[HAC_{CLABSI} |CLABSI*pb[VC | ADM]]}. From Table 25, last row N, the probability of inserting a vascular catheter was 0.00056 (=185.4 thousand/2.32 million), or slightly less than 8 percent of admissions. Thus, if all true CLABSIs incurred in hospitals were actually reported as HACs, i.e. CLABSI/HAC_{CLABSI}=1.0, the true CLABSI rate would be .00056/.07999 = .007 or 1,786 times the reported CLABSI HAC rate .00056. In other words, the true inpatient CLABSI rate would be 560 million per vascular catheter insertion and not the less meaningful 1.18 per 10,000 admissions. If only 50% of true CLABSIs were reported as HACs, then the true CLABSI rate would be .56, or 56 per 100 vascular catheter insertions.

Table 25.

Logistic Regression Central Line Associated Blood Stream Infections (CLABSI and Central Line Associated Blood Stream Infections (CLABSI) at Risk

	HAC CLABSI **Odds Ratio**	***CLABSI*/Central Line Odds Ratio**
Age	1.021	1.003
Age²	0.999***	0.999
Disabled	0.799**	0.868
Female	1.261***	1.125
Race		
Black	1.25***	1.222**
Other	0.755*	0.789
US Region		
Midwest	1.751***	1.662***
South	1.451***	1.173
West	1.642***	1.338*
Hospital Ownership		
Proprietary	1.224**	1.199
Public	1.065	1.135
Federal	0.66	0.649
Teaching Status		
Minor Teaching	1.011	1.161
Non-Teaching	0.993	1.12
Urban	1.284*	0.949
Bed Size		
$\geq$ 50 & <100	0.99	1.794
$\geq$ 100 & <400	1.78	2.853
$\geq$400	2.045	3.166
Occupancy Rate		
>35% &$\leq$54%	1.046	1.101
>54% & $\leq$71%	1.028	1.201
>71%	1.063	1.269
Magnet Length	0.836	0.815
Paid Registered Nurse Hours		
Medium (>15.15 & $\leq$ 20.14)	0.959	0.877
High (>20.14 & $\leq$24)	1.138	0.869

(continued)

Table 25. (continued)

Logistic Regression Central Line Associated Blood Stream Infections (CLABSI and Central Line Associated Blood Stream Infections (CLABSI) at Risk

	***HAC CLABSI* Odds Ratio**	***CLABSI*/ Central Line Odds Ratio**
Paid Licensed Practical Nurses	0.918***	0.971
Severity of Illness		
Medium (> .868 & ≤ 2.236)	5.308***	2.855***
High (> 2.236)	15.915***	4.009***
Cardiac DRG	0.837	0.443**
Orthopedic DRG	0.302**	0.934
Length of Stay DRG	1.118***	1.065***
_cons	.0000163***	.000***
R^2	0.1121	0.0301
Prob > chi^2	0.000	0.000
N	2,317,639	185,406

Notes:
*p<.10
** P<.05
*** p<.01
Source: Med PAR 2009-2011.

Table 25 presents the two CLABSI logistic regression results. The first regression is based on all admissions with available data (2.3 million). Several variables were significant controlling for all variables in the model. The model's explanatory power (R^2=0.112) is over twice that of CAUTI (R^2 =0.046) but is still low because of the very small number of CLABSIs actually reported as HACs and the heterogeneity of the nationally representative sample. Patients in hospitals reporting between 21 and 24 hours of paid registered nurse hours per patient day were more likely to experience a CLABSI HAC; however, this finding was insignificant (OR=1.138, p=0.167). SOI was a strong predictor of CLABSI HACs. Patients with a high SOI were 15.915 times more likely to incur a CLABSI HAC (OR=15.915, p=.01), similar to patients with a CAUTI HAC. Patients with a medium SOI were 5 times more likely to incur a CLABSI HAC (OR=5.308, p=.01). For patients undergoing an orthopedic procedure, the likelihood of incurring a CLABSI HAC (OR=.302, p=.05) was approximately eight times less than patients who incurred a CAUTI HAC. This finding was not surprising, as these patients were less likely to have a central vascular catheter in place. Patients who underwent a cardiac procedure were also less likely (not significant) to incur a CLABSI HAC (OR=.837, p=.333). This was an interesting result, as patients in cardiac surgical ICUs are more likely to have a centrally placed vascular catheter, placing them at higher risk for a CLABSI. This finding may be attributed to the implementation of prevention measures and the high intensity nursing hours delivered by registered nurses in an ICU.

DRG "exposure length of stay was also a powerful indicator of the likelihood of incurring a CLABSI HAC, and the odds ratio was higher than for CAUTI HACs (OR=1.118, p=.01). These findings were consistent with the hypothesis that patients who are in the hospital longer and have a higher severity of illness are more likely to incur a CLABSI HAC.

Females were 1.26 times more likely than males to experience a CLABSI (OR=1.261, p=.01) but the odds ratio was less for patients with a CAUTI HAC. African American patients were more likely to incur a CLABSI (OR=1.25, p=.01), similar to CAUTI.

Geographic region was also a strong predictor of CLABSI HACs. Patients cared for in the Midwestern United States were 75% more likely to incur a CLABSI HAC as patients cared for in the Northeastern region (OR= 1.751, p=.01). This finding is puzzling given the effort to reduce CLABSIs in Michigan ICUs, but perhaps the Northeast was an early adopter of implementing evidence-based standards for reducing CLABSIs. The probability of incurring a CLABSI HAC in the Midwest was 75% higher as compared to CAUTI (OR=1.751, p=.01, OR=1.06, p=.608).

Patients who were cared for in urban hospitals were significantly more likely to incur a CLABSI HAC (OR=1.284, P=.05) as patients cared for in proprietary hospitals (OR=1.224, p=.05). Disabled patients were less likely to incur a CLABSI HAC (OR=.799, p=.05).

In the second regression, there were almost 186,000 reported vascular catheter insertions, or roughly 8% of the 2.3 million reported admissions. Odds ratios in this regression reflected the likelihood of a reported CLABSI HAC conditional on having a vascular catheter. These ratios arise from factors that might influence the likelihood of needing a catheter, such as case mix. They do, however, reflect the "true" CLABSI rate adjusted for the likelihood of reporting the CLABSI during the admission.

SOI remained a strong, albeit attenuated, predictor of CLABSI HACs. Patients in both medium and high SOI categories were about four times and almost three times more likely to incur an HAC (medium: OR=4.009, p=.01; high: OR=2.855, p=.01). The reduction in odds ratios for the CLABSI and CLABSI at risk group was similar to the CAUTI and CAUTI at risk group. A reduction in SOI of 46% to 74% between Models (1) and (2) in Table 26 implies a substantial role of case mix differences in explaining both the likelihood of receiving a vascular catheter as well as having a CLABSI HAC.

Unlike patients with a reported CLABSI HAC during hospitalization, there was a statistically significant finding for patients undergoing a cardiac procedure (OR=.443, p=.01) but not for patients undergoing an orthopedic procedure (OR=.934, p=.894). LOS DRG remains a predictor of incurring a CLABSI HAC, but the odds ratio (OR=1.065, p=.01) was considerably less than the odds ratio for patients with a CLABSI HAC (OR=1.118, p=.01).

Geographic region remained a strong predictor of the at risk CLABSI HAC group. Patients cared for in the Midwestern United Sates were 66% more likely, and in the West 34% more likely, to incur a CLABSI HAC (OR=1.751, p=.01; OR=1.662, p=.01). The odds ratio for black patients at risk for a CLABSI HAC was similar to the group with a reported CLABSI HAC (OR=1.222, p=.05).

Falls

The reported falls and trauma HAC at the admission level can be decomposed as follows:

Equation 10: $pb[HAC_{fall}|ADM] = pb\,[HAC_{fall}\,|Fall] * pb[Fall|Dx]*pb[Dx|ADM$

where the probability of reporting a fall related HAC once admitted is decomposed into (a) the probability of a fall reported HAC given that such a fall occurred in the hospital, times (b) the true probability of experiencing a fall for high-risk diagnoses, times (c) the frequency of high-risk diagnoses among all admissions. The at-risk for falling group was constructed using medical conditions that place patients at risk for falling. They included bowel and bladder incontinence, cognitive impairment, disturbance of gait and balance and dizziness (Ackerman, Trousdale, Bieber, Henley, Pagnano, & Berry, 2008; Lakatos, et al. 2009).

Table 26 reports odds ratios from two models, one that includes all Medicare patients discharged from acute care hospitals during the analysis period, and a second one that narrows the sample to those determined at higher risk – as defined earlier. There were 243,532 patients at higher risk of falls, or 10.5% of the larger sample of discharges.

In both models, the severity of illness, surgical DRGs, and DRG average length of stay explain a majority of the 4.2% of variance explained in the overall model. Patients with high severity (>2.236) had nearly 3-times the likelihood of falling than one with mild severity – even controlling for age and length of stay which are positively correlated with severity. Patients who underwent cardiac and orthopedic surgical procedures show opposite likelihoods of falling. Cardiac surgery patients were roughly one-half as likely to fall as other patients while orthopedic surgery patients were 5.6 times (OR=5.61, p=.01) more likely, a range of 10:1. This may be due to (a) orthopedic patients having limited mobility postoperatively, and/ or (b) cardiac patients receiving higher levels of nursing hours and assistance to prevent falls.

Across all patients and after controlling for severity, length of stay, and other characteristics, hospitals with higher RN hours exhibited lower falls rates. Patients in hospitals with a higher RN skill mix had approximately a 15% less likelihood of falling, *ceteris paribus.* Controlling for RN intensity, the reverse was true for LPN-intensive hospitals in which patients were 5.5% more likely to fall. Once patients are sub-setted to those at higher falls risk, RN-to-patient intensity is no longer significant- although the odds ratio for high RN-intensive hospitals is above 1.0. However, the odds of falling in hospitals using more LPNs per patient actually increases to about 14%. This implies that patients in hospitals with higher RN-to-LPN staffing may be less likely to experience falls.

When sub-setting to patients deemed higher risk for falling, column 2, one would expect variables related to age and severity to play less of a role because some of their effect on falling has been accounted for in the sub-sampling process. This is what happens. The high-severity odds ratio declines by about one-third and the age effect on falling is no longer statistically significant. Conversely, the likelihood of orthopedic surgery patients actually increases by 50% (8.42/5.61). This implies that, although their comorbid conditions did not put them at particularly higher risk, they made up a higher percentage of falls than across all patients.

Table 26.

Logistic Regression Falls/Trauma and Falls/Trauma at Risk

	Falls per Admission Odds Ratio	Falls Diagnosis at Risk Odds Ratio
Age	1.072**	1.108
Age²	0.999*	0.999
Disabled	0.995	1.196
Female	1.513***	2.048***
Race		
Black	0.474***	0.397*
Other	1.016	1.589
US Region		
Midwest	0.995	1.188
South	1.064	1.435
West	1.026	0.966
Hospital Ownership		
Proprietary	0.971	0.778
Public	1.206**	1.581*
Federal	0.811	1(empty)
Teaching Status		
Minor Teaching	1.253	1.656
Non-Teaching	1.167	1.149
Urban	0.949	1.092
Bed Size		
≥ 50 & <100	1.008	3.545
≥ 100 & <400	0.931	1.859
≥400	1.049	2.247
Occupancy Rate		
>35% &≤54%	0.952	1.533
>54% & ≤71%	1.013	1.546
>71%	0.816	1.97
Magnet Years	0.882	0.324
Paid Registered Nurse Hours		
Medium (>15.15 & ≤ 20.14)	0.915	1.23
High (>20.14 & ≤24)	0.846*	1.413
Paid Licensed Practical Nurses	1.055***	1.141**
Severity of Illness		
Medium (> .868 & ≤ 2.236)	2.55***	1.838**
High (> 2.236)	2.941***	1.913*
Cardiac DRG	0.547**	1 (omitted)
Orthopedic DRG	5.61***	8.416***

(continued)

Table 26. (continued)

Logistic Regression Falls/Trauma and Falls/Trauma at Risk

	Falls per Admission Odds Ratio	Falls Diagnosis at Risk Odds Ratio
Length of Stay DRG	1.10***	1.123***
_cons	3.20e-06***	8.77e-08***
R^2	0.0421	0.0702
Prob > chi^2	0	0
N	2,317,639	243,532

Notes:
*p<.10
** p<.05
*** p<.01
Source: Med PAR 2009-2011.

As expected, for the instrumental variable, LOS-DRG, the odds ratio (OR=1.123, p=.01) is statistically significant and positive for patients who were at risk for a fall. This implies that after holding SOI and other variables constant, a patient staying in the hospital a week longer is 2.25 times more likely to fall (2.25=exp{ln(1.123)*7}).

Among patients at higher risk of falling, females were twice as likely to fall after controlling for severity, length of stay, and other characteristics (OR=2.05, p=<.01). Hence, the likelihood of falling doubles for females (1.05/.513) among high-risk patients. This suggests that the variables identifying high-risk patients eliminated some males more likely of falling. United States geographic region, teaching status, bed size, occupancy rate, and Magnet years were not predictors of falls for the high risk group.

Summary

Results from this study support confirmation or rejection of several hypotheses associated with patient and hospital characteristics:

H1: Patients with a longer LOS will be more likely to experience a reported HAC due to longer "exposure".

Patient length of stay and severity of illness were the most powerful and consistent predictor of the incidence of HACs. Patients who were in the hospital five days or more experienced a HAC rate that was 8 times higher than patients who were in the hospital less than five days (.41% vs. .05%). The occurrence of an HAC also was strongly associated with the patient's severity of illness, controlling for LOS and other variables.

H2: As patients age they will have a higher likelihood of experiencing a HAC.

The hypothesis that patients would be more likely to experience a HAC as they aged was partially supported by the data. Patients were more likely to experience a statistically significant HAC before controlling for LOS and SOI. The odds ratio for the quadratic age showed that the likelihood of incurring an HAC increased up to age 34 but then decreased as patients aged. This finding suggests that age is not a linear predictor of HACs and that age is confounded with being disabled.

H3: Medicare patients with a high severity of illness score will have a higher incidence of reported HACs.

Analysis strongly supported this hypothesis. Patients with a high SOI score were 9 times more likely than patients with a lower SOI to incur a reported HAC after controlling for LOS and all other variables in the models. The likelihood of a patient with a high SOI score incurring an HAC declined by almost a third when controlling for LOS.

H4: Hospitals with greater RN intensive staffing per inpatient day will exhibit lower hospital acquired condition (HAC) rates.

Analysis did not support the hypothesis that hospitals with greater intensive RN staffing would exhibit lower HAC rates. High (>20.1) paid RN hours per patient day were positively and significantly (p=.05) associated with a higher likelihood of incurring a HAC (Regression Model 1), prior to controlling for severity of illness and length of stay in Regression Models 2-4.

H5: Years of Magnet Status will be associated with a lower incidence of HACs

There were no statistically significant findings for the duration a hospital was designated as a Magnate hospital. Patients at hospitals that were later adopters (<6 years) were less likely to incur an HAC; however, this result was not significant.

H6: There will be geographic differences in the incidence of reported HACs because of care practice variations to prevent HACs.

The data support the hypotheses that geographic location plays a role in the incidence of a reported HAC. Controlling for patient-specific SOI and LOS, Northeast hospitals were 12-21% less likely to report a HAC.

H7: Public hospitals will have a higher incidence of reported HACs because of greater financial constraints.

The probability of a reported HAC was 10% higher in public hospitals as compared with private and voluntary hospitals.

H8: Teaching hospitals will have a higher incidence of reported HACs because they have a more severe longer length of stay (LOS) case mix.

The data showed no statistically significant evidence to support this hypothesis.

H9: Acute care hospitals with high occupancy will have a higher incidence of reported HACs because they will have higher case mix acuity.

This hypothesis was partially supported. Hospitals with 400 or more beds were 25% more likely than hospitals with less than 50 beds to report HACs, before controlling for nursing intensity, SOI, and LOS. The odds ratios were not significant for hospitals with over 400 beds when controlling for nursing intensity, patient LOS, and SOI.

H10: Hospitals with large bed-size will have a higher incidence of reported HACs because they will have higher case mix acuity.

This hypothesis was not supported by the data. The odds ratios across all occupancy rates showed that patients were less likely to experience a HAC; however, the result was not significant. The only statistically significant, albeit small, effect observed (p=.10) was for hospitals with an occupancy rate between 35 and 54%.

CHAPTER 5

DISCUSSION

This study was designed to quantify the effects of hospital and patient characteristics and nursing care hours on the incidence of reported hospital acquired conditions (HACs). The study was conducted within the system and outcomes component of The Quality Health Outcomes Model. A Hospital-Acquired Conditions Path Model guided the study by identifying the variables of analysis. This chapter summarizes statistically significant and non-significant study findings by patient and hospital characteristics. The study's strengths and limitations, as well as nursing practice, future research, and policy implications are also discussed. The chapter ends with the study's conclusions.

Discussion of Main Findings

Patient Characteristics

In this study, multivariate logistic step-wise regression by type of HAC was used to investigate basic patient demographics and mediating variables from the Path Model to elucidate variables affecting the incidence of reported HACs. The HAC outcomes were measured in two ways: a) by any HAC, and b) by one of three specific HACs. When analyzing by specific HACs, two multivariate logistic regressions were specified, one on the hospital's overall CAUTI, CLABSI, or falls and trauma HAC rate and a second, more focused model limited to at-risk patients who received a vascular or urinary catheter, or at risk for falls and trauma. It was assumed that all patients were exposed to a fall.

Demographic Characteristics

Controlling for both SOI and LOS, female patients were 42% more likely to incur a HAC. In all of the individual HAC analyses (CAUTI, CLABSI, and falls and trauma), being female was a strong predictor for incurring these conditions. The result for CAUTI was expected, as the literature identifies women as being at risk for CAUTI (Halleberg, 2011). The result for CLABSI, however, was not expected, as being male has been identified as a risk factor for CLABSI (Lissauer, 2012). Duncan, Ackerman, Trousdale, Bieber, Henely, Pagnano, & Berru (2010) identified female gender and age (>65 years) as risk factors for falls in a study of 70 patients in an orthopedic inpatient unit.

In the present study the probability of an HAC increases with a patient's age but was not significant when controlling for SOI and LOS. This was an expected finding, as the study population is Medicare patients with co-morbidities that place them at risk for any HAC. The effect of age was positive and significant for patients who experienced a falls and trauma HAC when controlling for SOI and LOS. However, the same was not true for patients at high risk for a fall. Unlike CAUTI and CLABSI, which places patients at risk for an infection because of the indwelling catheter, all hospitalized patients are at risk for falling.

The statistically insignificant age finding in patients at high risk for falls may be attributed to the sensitivity of the DRGs associated with the risk used to construct the variable. Falls risk factors are also risk factors for other conditions. The quadratic age effect for patients with a CLABSI HAC was negative and significant, *ceteris paribus*, but age was not significant for patients with a CLABSI or CAUTI. Disabled patients were statistically less likely to incur an HAC, *ceteris paribus*. This finding was unexpected, as it was thought that disabled patients with multiple chronic co-morbidities would be more likely to incur an HAC.

Severity of Illness

As expected, the study analysis supported the hypothesis that Medicare patients with a high severity of illness score will have a higher incidence of reported HACs. The present study showed that as a patient's severity increased, the likelihood of incurring an HAC also increased significantly. Patients with a high SOI were 12 times more likely than patients with a low SOI to incur an HAC, *ceteris paribus*. Controlling for severity of illness and length of stay, patients with a high severity of illness remained highly likely to incur a reported HAC. The likelihood of a patient with a high SOI incurring an HAC declined almost a third when controlling for length of stay but remained positively significant. This suggests that length of stay and severity of illness are strong predictors for incurring an HAC.

This finding highlights the exposure treatment paradox inherent in the study of HACs. On the one hand, a patient's severity of illness, length of stay, or a combination of both raises the risk of the patient incurring an HAC. On the other hand, an HAC raises the patient's severity of illness and prolongs the length of stay to treat the newly acquired condition.

The orthopedic and cardiac surgery DRG variables were robust indicators for the incidence of reported HACs. Controlling for SOI and patient DRG LOS, patients who underwent total hip or total knee replacement procedures were thirteen times (OR=13.644, p=<.01) more likely to experience an HAC. This robust finding suggests that other HACs in the model, DVT/PE and infection after orthopedic surgery, may be confounding the orthopedic DRG variable, as patients are at risk for both of these adverse events when undergoing these surgeries. It is also possible that patients may have had more than one HAC, which was not accounted for in this study. For example, a patient who underwent orthopedic surgery could have experienced either a DVT/PE, surgical site infection, or other HAC.

The odds ratio for the cardiac DRG indicator was not as robust as the orthopedic DRG variable; however, patients were still more likely to experience a HAC when controlling for SOI. The odds ratios declined by 20% (OR=1.781, p=.01) when controlling for the patient's reported length of stay (OR=1.438, p=.01), and decreased another 15% (OR=1.235, p=.01) when controlling for DRG length of stay.

Findings from the present study are consistent with findings from two studies that showed a statistically positive association between SOI and the likelihood of incurring an HAC. Controlling for length of stay, gender, and nurse staffing, Cremasco, Wenzel, Zanei, & Whitaker (2012) showed a positive association between severity of illness and the development of pressure ulcers in intensive care unit patients (OR=1.058, p=.035). A study by Baumgarten, Rich, Shardell, Hawkes, Margolis, Langenberg, Orwig, Palmer, Jones, Sterling, Kinosian, & Magaziner, (2012) also showed a positive association between the development of pressure ulcers and SOI in elderly patients who underwent surgery for a hip fracture (Rand Sickness score mean = 15.1 $\pm$ 8.1, p=<.001). Although these two studies used different methods to identify risk factors associated with the incidence of hospital acquired pressure ulcers, their results suggest that SOI plays a highly significant role in the incidence of reported HACs.

Length of Stay

Patient LOS and SOI were the most powerful and consistent predictors of the incidence of HACs. The likelihood of incurring an HAC increased by over 50% if a patient's LOS was 5 days or longer. Patients in longer "exposure" DRGs were more likely to incur an HAC. Patients who were in the hospital at least five days exhibited an HAC rate (.41%) that was 8 times higher than patients who were in the hospital less than five days (.05%), and the occurrence of an HAC was strongly associated with the patient's SOI. In this study, LOS had two different effects: 1) exposure time (length of stay from admission to the identification of a HAC), and 2) HAC treatment time (number of days between diagnosis of the HAC and discharge to treat the HAC). This phenomenon is referred to as a feedback effect. It was not possible to isolate the exposure effect, as the exact date the HAC occurred was not available. Having an exact date would have made it possible to factor out extra days that were attributed to treating the HAC. Using the reported average LOS for each DRG excluded the mostly longer stays that were presumably associated with treatment of the HAC.

To mitigate this feedback effect, the instrumental variable, LOS DRG, replaced the patient's own LOS to isolate the exposure effect of longer stays that raise the likelihood of a HAC. The instrumental variable was also thought to be a more accurate measure of expected exposure time to HACs by virtue of not including unexpectedly long stays that were due to an HAC. The odds ratio for DRG LOS (OR=1.098, p=.001) was more than 50% higher than the odds ratio for continuous LOS (OR =1.042, p= < .01). This was an unexpected finding, as it was anticipated that continuous LOS would be a stronger determinant of LOS, as it reflects the patient's actual LOS. This finding may be attributed to the lower odds ratio for SOI (OR=8.910, p= < .01) in this specification as compared to SOI (OR=9.461, p= < .01) in Model 4 with DRG LOS.

Previous studies have suggested the connection between LOS and the probability of incurring an adverse event (Weingart, Ross, Wilson, Gibberd & Harrison, 2000; Bates, Miller, Cullen, Burdick, Williams, Laird, Petersen, Small, Sweitzer,Vander Vliet, & Leape, 1999). In a recent study, Hauck & Zhao (2011) used hospital administrative data to model adverse drug reactions, hospital-acquired infections, and pressure ulcers as a function of the direct effects of endogenous LOS using days and months of discharge as instrumental variables. They found the predicted probability of suffering an adverse event increased with the duration of the hospitalization; for an eight day LOS, the risk of suffering an adverse drug reaction was almost twice as high (6.1%) as for a LOS of 2 days (3.4%). This magnitude was similar for both hospital-acquired infections (20.6% [8 day LOS] vs. 11.1% [2 day LOS]) and pressure ulcers (2.5% [8 day LOS], vs. 0.4% [2 day LOS]). Of interest in this study was the discussion of LOS as a risk factor that can be modified in the short run by discharging patients earlier and substituting part of their stay using alternative care methods such as home care (Hauck & Zhao, 2011).

The positive association between LOS on hospital-acquired *clostridium difficile*, an infection previously considered an HAC by Medicare, was demonstrated by Forster Taljaard, Oake, Wilson, Roth & Walraven (2012) using Cox proportional hazards regression models. Hospital-acquired *clostridium difficile* increased patients' LOS, proportional to the patient's baseline risk of death. On day 7 of hospitalization, the hazards ratio measuring the association between *C. difficile* acquisition and discharge of patients in the lowest decile (10%) of baseline risk of death was 0.55 (95% CI 0.39-0.70). For the highest decile (90%), the hazards ratio was 0.45 (95% CI 0.32-0.85) and on day 28 the hazards ratios were 0.74 (95% CI 0.60-0, 87) and 0.61 (95% CI 0.53-0.68). Therefore, *C. difficile* had a larger impact on LOS for those patients who were at higher risk of death at baseline (Forster et al., 2012). This finding is consistent with the present study, which showed a positive association between LOS and HACs.

Hospital Characteristics

Nurse Staffing

Raising RN staffing levels alone is unlikely to materially reduce hospital complications. Indeed, the multivariate analysis did not support the hypothesis that hospitals with more intensive RN staffing would exhibit lower HAC rates. Prior to controlling for SOI and LOS, high (> 20.1) paid RN hours per patient day were positively and significantly (p=.05) associated with a higher likelihood of incurring an HAC (Model 2). In this model, nursing hours were upwardly biased, as SOI and LOS were accounted for in the nursing hours. Patients with a longer LOS were more likely to have a higher

SOI, and nursing hours were adjusted upwards to account for these factors. The odds ratios (OR= .986 - .989) for patients cared for by an LPN were consistent across all 4 models. Patients were less likely to incur an HAC if they were cared for by a licensed practical nurse; however, the results were not statistically significant.

The impact of high RN hours in the multivariate analysis of CAUTI, CLABSI, and falls or trauma demonstrated conflicting results. Patients in hospitals reporting between 21 and 24 hours of paid registered nurse hours per patient day were more likely to experience a statistically significant CAUTI HAC. Patients with a urinary catheter, at risk for a CAUTI, were almost four times more likely to experience a CAUTI. In contrast, patients, who had a CLABSI or were at high risk for one, and received the higher level of nursing hours per patient day, were more likely to incur this HAC. However, these results were insignificant. One possible explanation is a potential smaller variation in nursing hours per patient day, as patients with a CLABSI are cared for in intensive care units, where staffing ratios are either one to one or one to two RNs per patient.

Patients who received a range of 21-24 hours RN hours per patient day were 15% less likely to experience a falls and trauma HAC (OR=.846, p=<.10). In contrast, patients cared for by an LPN were significantly more likely to incur a falls or trauma HAC (OR=<1.055, p=.01). This finding suggests that patients are less likely to experience a fall or trauma HAC when nurse staffing mix comprises a higher percentage of RNs to LPNs.

The relationship between nurse staffing and patient outcomes has been reported in numerous research reports, with often divergent conclusions (Lake & Cheung, 2006). Cimiotti, Aiken, Sloane, & Wu (2012) studied the association between nurse staffing, burnout, urinary tract, and surgical site infections. They reported that adding one additional patient to a nurse's hospital assignment was associated with an increase of nearly 1 per 1,000 in the rate of urinary tract and surgical site infections. The study also showed a positive association between nurse burnout and both urinary tract infections and surgical site infections. When controlling for patient severity and nursing and hospital characteristics, only nurse burnout remained significantly associated with urinary tract and surgical site infections (Cimiotti et al., 2012). Liu, Lee, Chia, Chi, & Yin (2012) also reported a positive association between nurse workload and patient outcomes of falls and pressure ulcers.

Frith et al., 2010 found a positive relationship between the effects of nurse staffing and HACs, in community hospitals. Their results showed a significant decrease in adverse events when the percentage of RN staffing was increased. A 1% increase in RN staffing reduced the number of adverse events by 3.4%, and a 5% increase in the RN percentage would decrease the number of adverse events by 15.8%. The effect of LPN staffing on the total number of adverse events was not significant (Frith et al., 2010).

The association between rates of un-assisted falls and levels of registered and non-registered nurse staffing and variation by unit type was studied by Staggs & Dunton (2013). They found that RN staffing and the rate of unassisted falls varied by unit type. Higher nurse staffing on medical-surgical units was weakly associated with lower rates of falls. The fall rates for patients in step-down units and medical units depended on the level of staffing. Units staffed initially at a lower level were more likely to experience a fall as staffing was increased. However in units where staffing was initially at a moderate or higher level, the fall rate decreased as staffing increased. This suggests that the unassisted fall rate cannot be lowered by simply increasing RN staffing without taking into consideration the type of unit and the existing level of staffing (Staggs & Dunton, 2013). Previous studies have also shown the association between higher total fall rates when the nursing skill mix includes higher levels of LPN and nursing assistant staffing (Staggs & Dunton, 2013; Lake, Shang, Klaus, & Dunton, 2010).

The relationship between nursing staffing, nursing workload, work environment, and outcomes potentially sensitive to nursing care was studied by Duffield, Diers, O'Brien-Pallas, Aisbett, Roche, King, & Aisbett (2011). They found that more hours of care required per patient day was linked to fewer falls, and nurse staffing, workload, and working environment variables were associated with lower rates of urinary tract infections, central nervous system derangement, as well as failure to rescue (Duffield et al., 2011).

One of the possible reasons that studies involving nurse staffing levels obtain different results is a difference in the method employed to measure nurse staffing, as well as the unit of measurement—patient care unit or hospital level. (Spetz, Donaldson, Aydin, & Brown, 2008). Alternative nurse staffing measures include nursing hours per patient day, full time equivalent employment, or staff to patient ratios at the hospital level, type of unit, or specific unit (Spetz et al., 2008; Chin, 2013). These measures provide information about the utilization of nurse staffing in terms of the number of nursing staff per patient day. Another major staffing component is nurse staffing skill mix referring to the ratio of RNS to LPNS and nursing assistants (Chin, 2013; Thungjaroenkul, Cummings, & Embleton, 2007).

Studies that use hospital-level data have found that higher levels of nurse staffing are associated with improved patient outcomes and lower mortality rates (Aiken et al., 2002; Needleman et al., 2002). In a study of nursing staffing levels in nursing units in a Belgian acute care hospital that treats postoperative cardiac surgery patients, Van den Heede, Lesaffre, Diya, Vleugels, Clarke, Aiken, & Sermeus (2009) found that a greater number of registered nursing hours per patient day (NHPPD) in general care units, where cardiac surgery patients were treated, was associated with a statistically significant reduction in postoperative in hospital mortality, controlling for procedure volume, intensity of nursing care, patient characteristics, and proportion of RNs with a Bachelor's degree. This finding was not validated for nurse–staffing levels of the post-operative intensive care units (ICU). They attributed this finding to the smaller variation in NHPPD in ICUs versus general units and the differences in nursing intensity between ICUs and general care units (Van den Heede et al., 2009).

Van den Heede et al. (2009) suggest that hospital level staffing analyses are appropriate when nurse-staffing levels vary more between hospitals than within hospitals. There was a wide range of paid nursing hours per patient day across hospitals included in the two national administrative data bases that were used in the present study.

Studies conducted at the unit level have also reported conflicting results. Donaldson et al. (2005) found a weak or no relationship between unit level nurse-staffing and patient outcomes, while Van den Heede et al.'s (2009) results add to the growing body of research that there is an association between favorable staffing and better patient outcomes. It may be better to study RN staffing effects at the unit level, as different types of units may show different results. Unit-level nursing data collection may be more precise, but it may also be limited to a select set of hospitals and the data may not be as readily available as the hospital-level data included in publicly available, administrative data sources (Van den Heede et al, 2009).

In the present study, paid hours per patient day versus direct or productive hours per patient day at the hospital level were used for both the RN and LPN staffing measures. Although productive or direct hours per patient day are more commonly used in research studies of nurse staffing, it has been hypothesized that these metrics are correlated with paid hours per patient day. As the staffing data were reported at the hospital level and not restricted to inpatient volume, adjustments should have been made to take outpatient volume into account in estimating inpatient staffing (Needleman, Buerhaus, Mattke, Stewart, & Zelevinsky, 2003).

Geographic Region

In all five regression models, patients receiving care in the Midwest, South, and West regions were significantly more likely to incur an HAC than patients receiving care in the Northeast region, before and after controlling for nurse staffing, SOI, and LOS. Northeast hospitals had a lower HAC rate, controlling for patient and hospital characteristics. Northeast hospitals were also 12-21% less likely to report an HAC when controlling for patient-specific SOI and LOS. Although no previous studies addressing the association between geographic location and the incidence of reported HACs were identified in the review of the literature, one study by Wald, Epstein, Radcliff & Kramer (2008) reported an association between the extended use of indwelling urinary catheters and geographic location in patients discharged to a skilled nursing facility after major surgery when controlling for patient characteristics.

Patients cared for in the Northeast and South regions were less likely to have an indwelling urinary catheter as compared with patients cared for in the West region. As patients who are at high risk for CAUTI must have an indwelling catheter in place, this finding may help to explain why patients in the West region were almost one and a half times more likely to incur a CAUTI HAC as patients cared for in the Northeast, and one and a quarter times more likely to incur a CAUTI HAC as patients in the South region.

During the period of this study, a national program to eliminate CLABSIs in adult intensive care units (ICUs) was undertaken across 44 states, the District of Columbia, and Puerto Rico. “The goal of the national program was to achieve a unit-level mean CLABSI rate of less than 1 case per 1,000 catheter-days and to improve safety culture” (Berenholtz et al., 2014). The program was successful in reducing and sustaining the overall CLABSI rate across ICUs in the United States by 43%. The implementation of this program may have impacted the overall number of CLABSIs in this current study, but it is difficult to explain why the Midwest, Southern, and Western regions were more likely to incur a statistically significant CLABSI HAC rate than the Northeastern region.

A potential explanation may be the early adoption of performance improvement strategies in the Northeast, although research to support this notion was not forthcoming. Separate previous studies conducted in Michigan and mirrored in Rhode Island, using a checklist of evidence-based practices to prevent CLABSIs, showed a reduction in mortality among Medicare patients admitted to ICUs (Lipitz-Snyderman, Steinwachs, Needham, Colantuoni, Morlock, & Pronovost, 2011; Depalo, McNicoll, Cornell, Rocha, Adams, & Pronovost, 2010). However, these states only represent one state in their respective geographic regions, and the Midwest had the highest odds ratio for the likelihood of a CLABSI HAC in this study. Shuller, Probst, Hardin, Bennett & Martin (2014) in a five year time (2005-2009) series study of the impact of the HAC/POA policy on the rates of CAUTIs found an association between the incidence of CAUTIs and geographic region. They found no significant difference in rate of CAUTIs by region but hospitals in the Midwest, South, and West had higher rates of CAUTIs than the Northeast after policy implementation. This finding, as the authors suggest, may be attributed to the availability of better resources, access to care, number of hospitals, and providers per capita) and better population health in the Northeast (Shuller et al.,2014).

Hospital Ownership

Hospital ownership type was not a major predictor of the incidence of a reported HAC. Only public hospitals showed a greater likelihood of incurring an HAC, *ceteris paribus*. Public hospitals were 10% more likely to incur any HAC as compared to voluntary hospitals. This stands to reason, as public hospitals are often located in urban areas, care for patients with lower socioeconomic status patients who live in urban areas, and are likely to have fewer resources to implement patient safety measures.

There is little reported research on the association between hospital ownership and the incidence of reported HACs. Lee, Kleinman, Soumerai, Tse, Cole, Fridkin, Horan, Platt, Gay, Kassler, Goldmann, Jernigan, and Jha, (2012) used a quasi-experimental design to examine changes in the rates of CAUTI, CLABSI, and ventilator-acquired pneumonia infections prior to and following implementation of the HAC-POA policy. A sensitivity analysis of the effect of hospital characteristics, including hospital ownership, on the rate of infections showed consistent patterns across all hospital types. The investigators found that the rates of these infections had started to decrease prior to the implementation of the policy and that there were no further decreases in rates for all three infections after implementation of the policy (Lee et al., 2013).

Other Findings

Several non-statistically significant yet interesting findings were observed in the present study.

Hospital Characteristics

Magnet Hospital Years

The duration a hospital was designated as a Magnet hospital demonstrated no significant association to the incidence of reported HACs (controlling for all other variables). Patients at hospitals that were later adopters (<6 years) were less likely to incur an HAC; however, this result was also not significant although it was expected that patients in hospitals designated as having a higher quality of care, more nurse staffing, and a solid nursing leadership team would be less likely to incur an HAC.

A search of the literature regarding the Magnet Recognition Program yielded very few reports addressing patient outcomes in Magnet Hospitals. Goode, Blegen, Park, Vaughn, and Spetz (2011) compared patient outcomes in 19 Magnet versus 35 non-Magnet Hospitals. Patient outcomes from discharge data using AHRQ PSIs and inpatient quality indicators known to reflect the quality of nursing care included mortality rates for congestive heart failure (CHF) and myocardial infarction (MI), failure to rescue, hospital acquired pressure ulcers, infections, postoperative sepsis and LOS. Using the ratio of observed to expected, pressure ulcer rates were slightly lower in Magnet hospitals and statistically significant (p=.10). Infection and postoperative sepsis rates were statistically significantly lower in non-Magnet hospitals. Mortality rates for MI and CHF, as well as failure to rescue rates and LOS, were not significantly different between Magnet and non-Magnet hospitals (Goode et al., 2011).

The first study of the association between Magnet status and Medicare mortality was reported by Aiken, Smith, & Lake (1994). That study reported 0.9 to 9.4 fewer deaths per 1000 discharges in Magnet hospitals, with a 7.7% lower observed mortality rate (Aiken, Smith & Lake, 1994). Neither one of these studies compared the length of time the hospital had been designated as a Magnet hospital. Given the mixed findings among Magnet versus non-Magnet hospitals, further study is required to study the association between Magnet status and nursing intensity on the incidence of the CMS

HACs, particularly in light of the two procedure-oriented HACs added in 2012, which have not been studied (surgical site infection following cardiac implantable electronic device [CIED] and iatrogenic pneumothorax with venous catheterization).

Teaching Status

Contrary to the hypothesis that academic medical centers would have a higher incidence of reported HACs (due to treating a greater proportion patients with a higher SOI, who are at risk for an HAC), the data revealed no statistically significant odds ratios by teaching status. This finding was also true for the analysis of CAUTI, CLABSI, and falls.

Schuller et al. (2014), in a study of the association between CAUTI and hospital characteristics, found that teaching and urban hospitals had significantly higher mean rates of CAUTIs during a five year period as compared to non-teaching and rural hospitals. This published finding would seem to lend credence to the hypothesis in this study. It was expected that patients with a higher SOI and living in urban areas would have access to teaching hospitals, as major teaching hospitals are traditionally located in urban areas and care for more acutely ill patients. It followed, then, that the rates of infections and adverse events might be higher in such centers based strictly on patient acuity and co-morbidities. However, teaching hospitals are often early adopters of patient safety and preventive measures, which may have mitigated the incidence of adverse events and HACs.

In this study teaching status was measured at the hospital level versus at the patient level. An interesting avenue of future exploration would be the potential differences in infection rates, should such data be available at the patient level.

Bed Size

Hospitals with 400 or more beds were 25% more likely than hospitals with less than 50 beds to report HACs, before controlling for nursing intensity, SOI, and LOS. After adjusting for nursing intensity, SOI, and LOS, hospitals with 400 or more beds were still more likely to report an HAC than hospitals with less than 50 beds; however, the likelihood decreased to 2.8% in Model 4 and 4.9% in Model 5.

Findings comparing bed size with the incidence of reported HACs have been mixed. Lee et al., (2012) found no association between bed size CAUTI rates, while Schuller (2014) reported hospitals with more beds had higher mean rates of CAUTIs as compared to small and medium sized hospitals. In a study of the effect of bed size on CLABSI infections, Berenholtz et al. (2014) reported a CLABSI infection rate incidence ratio in intensive care units that was 18% higher in hospitals with 400 or more beds (1.18) as compared to hospitals with less than 200 beds (1.00); for hospitals with bed sizes between 200 and 399, the ratio was less than 1 (.93 & .98).

Occupancy Rate

Hospital occupancy rate had very little influence on the incidence of reported HACs. Patients were less likely to experience an HAC; however, the result was not significant. This was contrary to the hypothesis that occupancy rate would be positively correlated with the incidence of reported HACs; under the reasoning that high occupancy increases staff workload, which in turn places patients at higher risk for experiencing an adverse medical event. The only statistically significant, albeit small, effect (p=.10) observed was for hospitals with an occupancy rate between 35 and 54%, unadjusted for nurse staffing, SOI, and LOS. This finding is inconsistent with previous studies of healthcare-associated infections (HCAIs) and bed occupancy rates.

In a United Kingdom study of hospital-acquired *Clostridium Difficile* (CDI) infection, a CMS previously considered HAC, Ahyow, Lambert, Jenkins, Neal, & Tobin (2013) found a positive and statistically significant association between bed occupancy rates and risk of hospital-acquired CDI. Controlling for age, ethnicity, type of unit, medical or surgical, and antibiotic policy period, patients in units with occupancy rates of 80%-90% had rates of CDI that were 56% higher compared with baseline occupancy (0-69.9 occupancy); rates of CDI were 55% higher on units that were at one hundred percent occupancy (Ahyow et al., 2013). Bed occupancy as a predictor of methicillin-resistant *Staphylococcus aureus* (MSRA), another CMS previously considered healthcare acquired infection (HCAI), has also been associated with high occupancy rates (Borg, Suda, & Scicluna, 2008; Cunningham, Kernohan, & Rush, 2006; Cunningham, Kernohan, Sowney, 2003).

In this study, the average hospital occupancy rate was approximately 40%. The highest HAC rate (0.20%) occurred in hospitals with an occupancy rate of greater than 54% and less than or equal to 71%. The percentage of pressure ulcers showed a slight increase from the lowest occupancy rate (7.45%) to the highest (8.12%), while the highest percentage of CAUTI (24%) occurred at an occupancy rate greater than 35% and less than 54%. There was very little variation in the percentage of CLABSI HCAIs with increasing occupancy rates (24.20%, 24.29%, and 24.35%, respectively), except in the less than 35% occupancy rate category (20.61%). This finding may be attributed to the very low incidence of HCAIs in the data. It is also possible that the less than one odds ratio, observed across all of the regression models, is attributed to the low average bed occupancy rate of the hospitals represented in this data set.

Study Strengths and Limitations

The present study has several strengths. One is the large sample size, encompassing three years of Medicare administrative claims data, with adequate power to detect statistically significant differences. Using an administrative database allowed for a cohort study design (2009-2011), a substantial sample size, and robust power (Gravrielov-Yusim & Friger, 2013).

Another strength was the use of multilevel regression, which enabled adjustment for patient (LOS, SOI) and hospital characteristics. Using multivariate regression helped to statistically control extraneous variables, thus enhancing the validity of the results (Thungjaroenkul, Cummings, & Embleton, 2007).

A further advantage of the present study was the national representativeness of the sample, which encompassed all four major United States regions (Northeast, Midwest, South, and West) and thus comprised a heterogeneous and representative pool of Medicare patients at risk for a reported HAC.

Although the results of this study represent an important contribution to the literature regarding factors that influence the incidence of reported HACs, several limitations should be noted. Firstly, the number of reported HACs in the sample was very small, equivalent to just nineteen HACs per 10,000 patients. This low rate was attributed to the under reporting of HACs during hospitalization, as many HACs are not apparent or do not manifest until the patient has been discharged from the hospital. Another limitation is the potential estimation bias of the LOS odds ratio due to the nature of exposure, detection, and feedback inherent to HACs. The longer a patient is in the hospital, the more likely they are to experience an HAC and a prolonged LOS.

A third limitation may stem from the secondary analysis of the administrative data used to investigate the relationships between study variables and to identify the incidence of HACs. Administrative data can provide valuable insights into the incidence, adverse impacts, and risks of medical errors; however, not without certain drawbacks (Zhan & Miller, 2003). Zhan & Miller (2003) warn of the analytic issues in using large size administrative data for patient safety research. They suggest that the sheer size of administrative data can give the illusion of great precision and power in the context of the relative rarity of safety events. Needleman, Beurhaus, Mattke, Stewart, & Zelevinsky (2003) express similar views when correlating all-patient data and Medicare data in eleven States with the national Med PAR sample among 8 adverse medical patient outcomes. For measures associated with nurse staffing, LOS, urinary tract infection, pneumonia, and shock/ cardiac arrest in that study, complete agreement between the three data sources was observed, suggesting that Med PAR data were a reliable substitute for measuring hospital quality.

Additional weaknesses in using administrative claims data relates to the accuracy of coding, which may result from a misunderstanding of codes or errors by physicians and coders, or miscommunication between them. Moreover, incomplete coding due to limited fields for coding secondary diagnoses may also undermine the administrative claims data. Thirdly, assignment of ICD-9-CM codes is variable, owing mostly to the absence of precise clinical definitions and contexts. Finally diagnoses are not dated in administrative data systems, making it difficult to determine whether a secondary diagnosis occurred before admission or during the hospital stay (Zhan & Miller, 2003). This last issue was addressed with the introduction of present on admission codes in claims data in 2007.

Another limitation of the present study may have been missing variables in the regression models, which might have made a difference in the sensitivity of the nurse staffing measure and the association with the incidence of reported HACs. Nurse education, years of experience, work environment, skill mix, and years of employment were not available within the data set. Better work environments where, among other things, doctors and nurses have good working relationships, management listens to patient care problems identified by nurses and invests in quality improvement for patient care, and a higher percentage of Baccalaureate prepared nurses practice decreases the odds of patient mortality and failure to rescue (Aiken, Cimiotti, Sloane, Smith, Flynn, & Neff, 2011). Paid registered nurse hours, paid licensed practical nurse hours, and paid nursing aides, orderlies, and attendants were discreet variables in CMS' Occupational Mix Survey. The nurse staffing data were at the hospital level. Therefore, it was not possible to determine nurse staffing at the unit level or determine the skill mix by unit or hospital level.

The present study also did include an analysis of the association between RN and LPN skill mix on the incidence of reported HACs. However, including the impact of paid nursing assistant hours or other health care provider hours (e.g., physical therapists) may have produced different results.

In future studies of the incidence of HACs, it may be beneficial to use clinical unit staffing levels by different type of unit, ICU versus general versus intermediate care versus specialty unit, as well as data regarding which days a patient was in which unit.

A further limitation of the present study was the inability to measure hospital safety culture and its relationship to the incidence of HACs. This is attributed to the difficulty in obtaining proprietary hospital data, such as the AHRQ Hospital Survey on Patient Safety Culture. Currently, the prevailing method for assessing safety climate in healthcare organizations is through surveys. Flin, Burns, Mearns, Yule, & Robertson, (2006) performed a systematic literature review of twelve studies to study sample and questionnaire design characteristics of safety culture surveys including psychometric criteria. They found a lack of an explicit theoretical underpinning for most questionnaires and observed that many instruments did not report standard psychometric criteria.

Surveying a hospital's safety climate is another way to assess work force perceptions of procedures and behaviors that indicate the priority given to safety relative to other organizational goals (Flin et al., 2006). Developing a culture of safety is thought to be a core element for improving patient safety and care quality in acute care settings. Weaver, Lubomski, Wilson, Pfoh, Martinez, & Dy (2013) conducted a systematic review of the peer-reviewed literature to identify interventions used to promote safety culture in health care and assess the evidence for their effectiveness in improving both safety culture and patient outcomes. They concluded that patient safety culture is a constellation of interventions grounded in principles of leadership, teamwork, and behavioral change, and that the best strategies appeared to incorporate team training, mechanisms to support team communication, and included executive engagement in front-line safety walks (Weaver et al., 2009). With respect to the present study, an analysis of the association of hospital safety climate on the incidence of reported HACs may have provided a more nuanced understanding of the results.

Another potential limitation of the present study was the inability to quantitatively measure the implementation of evidence-based guidelines (EBGs) on the reported incidence of HACs. The use of EBGs is a primary criterion for the HAC/POA program, as they are thought to reasonably prevent the incidence of HACs. However, there is very little strong evidence available to suggest that the routine implementation of EBGs prevents HACs (Jarrett, Holt & La Bresh, 2013). Observation of nurses' practice and/ or surveys and interviews regarding nurses' implementation of EBGs would have added a qualitative component to the quantitative findings.

The exclusion of an analysis of the economic impact of the HAC/POA policy is a final limitation of the present study as the HAC payment penalty is a major premise of the policy.

Implications for Nursing Practice

Nurses play a pivotal role in implementing the intent of the HAC/POA health policy. Nurses have regular and frequent contact with patients throughout hospitalization, which facilitates ongoing assessment of the risk and prevention of an HAC as well as the identification of an adverse event when it occurs. As many of the Medicare HACs are amenable to preventive nursing care (e.g., CAUTI, CLABSI, pressure ulcers, falls and trauma), emphasis should be placed at the point of care to apply evidence-based standards aimed at preventing HACs, a main tenet of the policy.

Nurses can also contribute to the accuracy of the coding of HACs by assuring that conditions are documented accurately and appropriately and at the time they are identified. Nursing documentation ensures that healthcare providers document secondary diagnoses in the medical records used to determine hospital reimbursement.

Implications for Future Research

This study is an initial exploration of the factors that influence the incidence of reported HACs in acute care hospitals. Despite the millions of dollars and extensive work to reduce medical errors and adverse events over the last ten years, medical errors remain a significant and costly outcome in the United States. A longitudinal study is needed to analyze the impact of the Medicare non-payment policy over a longer period of time to see if it has made a difference in improving the quality and cost of care, as the findings of previous studies have been inconclusive. An examination of the literature returned no study which comprehensively evaluated the association of safety culture, evidence-based practice, and hospital, patient, and nursing characteristics on the incidence of reported HACs. The analysis of safety culture and evidence-based practice could be addressed in a mixed methods study to add qualitative context to the quantitative data presented here.

As the HAC/POA policy has been in place for six years, a qualitative study of healthcare leaders, including hospital administrators, could also be undertaken to elucidate the quality and economic impacts of the policy on hospitals.

Policy Implications

As Medicare continues to add HACs for which it will not reimburse, CMS needs to determine the appropriate penalty to hospitals to motivate the reduction of HACs. CMS may also wish to incorporate lessons learned from value-based purchasing and pay-for-performance programs in making such decisions, so as to reward hospitals for preventing these adverse events rather than penalizing them for failing to do so. Furthermore, the HAC/POA policy should be adjusted to account for the bias against hospitals with caseloads which include patients with more severe disease and/or lengthier hospitalizations.

This study also has implications for regulations governing nurse staffing. Regulations and incentive programs that set staffing ratios are unlikely to have any material effect in reducing hospital complication rates, as this and previous studies have shown. The inclusion of HACs as quality measures to determine pay for reporting and pay for performance in any Accountable Care Organization (ACO) program should be included as a means to determine if ACOs are truly making a difference in improving patient outcomes and reducing costs.

Conclusion

This study was an important first analysis that identified the impact of patient and hospital characteristics and nurse staffing on a composite HAC variable as well as three specific HACs. This study showed that patients' length of hospitalization and severity of illness were the strongest predictors for incurring a HAC. The difficulty in isolating the "true" length of stay attributed to a HAC was elucidated through the feedback effect of length of stay. Length of stay needs to be decomposed to identify the impact of "exposure" time on the incidence of reported HACs and the true length of stay associated with treatment when a HAC occurs. The role of nurse staffing in predicting the incidence of reported HACs remains inconclusive and replication studies are needed to flesh out nursing's unique contribution to preventing HACs. The HAC-POA policy is an important contribution towards improving healthcare quality and has the potential to lower healthcare costs with adjustments to the policy that provide incentives versus penalties for preventing hospital acquired adverse events.

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