Identifying Potentially Preventable Complications Using a Present on Admission Indicator

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This article describes the development of Potentially Preventable Complications (PPCs), a new method that uses a present on admission (POA) indicator to identify in-hospital complications among secondary diagnoses that arise after admission. Analyses that used PPCs to obtain risk-adjusted complication rates for California hospitals showed that (1) the POA indicator is essential for identifying complications, (2) frequency of complications varies by reason for admission and severity of illness (SOI), (3) complications are associated with higher hospital charges, longer lengths of stay, and increased mortality, and (4) hospital complication rates tend to be stable over time.

INTRODUCTION

The Institute of Medicine's 2000 report on the human and financial costs of medical errors, accelerated efforts to improve patient safety in the U. S. (Kohn, Corrigan, and Donaldson, 2000). Since then, an increasing number of policymakers have advocated not only public reporting of quality measures, but also linking payment to quality measures (Midwest Business Group on Health 2002; Medicare Payment Advisory Commission, 2005; National Committee for Quality Assurance, 2004). Performance-based payment proposals include rewards not only based on processes of care guidelines, but also on outcome measures such as mortality and complication rates. Performance measures are seen as a way to focus quality improvement efforts and to achieve a safer health care system.

In order to determine hospital complication rates, several investigators have created methods using computerized discharge abstract data as an alternative to the time and expense of detailed chart review (Brailer et al., 1996; DesHarnais et al., 1990; Iezzoni et al., 1994; Iezzoni 1992; Romano et al., 2003). The ability to identify complications from discharge abstract diagnoses has been limited, however, because in most of the U.S. it is not possible to distinguish diagnoses that were present at the time of admission from those that arose after admission. As a result, the identification of complications has been limited to secondary diagnoses that are either unlikely to have been present on admission or are complications by definition (e.g., post-operative wound infection). Therefore, complications screening methods have tended to focus on patients that would be unlikely to have had a major complicating problem at the time of admission, such as those undergoing elective surgery. Even with these limits, however, complications screening methods still identify many cases where the condition was preexisting rather than hospital acquired (Lawthers et al., 2000, Naessens and Huschka, 2004).

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The lack of a POA indicator also limits the use of risk-adjustment methods for complications screening. Risk of complications varies by the reason for admission, the severity of the underlying illness, and the presence of coexisting diagnoses at the time of admission (Thomas and Brennan, 2000). If present on admission, secondary diagnoses can be used to adjust for a patient's risk of complications; if not present on admission, they could represent complications of care, and should not be used for risk adjustment.

The reason for admission is an important determinant of a patient's risk of complications. Patients treated for medical conditions will be at risk for different complications, and at different rates, than patients admitted for surgery. Among surgical patients, the type of surgery will strongly influence the type and frequency of complications. For example, a patient admitted for coronary bypass grafting will be more likely to develop heart failure than one admitted for a hernia repair. Susceptibility to complications also varies widely among medical patients; a patient admitted with a stroke will be more likely to develop aspiration pneumonia than one admitted with acute urinary retention.

Risk of complications also depends on the severity of the illness that caused the admission, as well as the presence of coexisting illnesses. Patients hospitalized with a more severe form of the underlying illness or with multiple comorbid conditions have a higher risk of complications (Daley, Henderson, and Khuri, 2001; Rosen et al., 1995; Rothschild, Bates, and Leape, 2000). Fair comparisons of complication rates across hospitals require the use of risk-adjustment methods that account for each of these factors.

A POA indicator is currently required on all hospital discharge abstracts by New York and California. It has been proposed as an additional data element on the Uniform Billing form commonly referred to as the UB-04, and has been mandated by the Deficit Reduction Act of 2005 to be used on all bills submitted to Medicare beginning in October 2007. This article describes a new method of reporting risk-adjusted in-hospital complication rates using discharge abstract data and a present on admission indicator for secondary diagnoses. The POA indicator serves two purposes: (1) to create a method for identifying potentially preventable complications from among diagnoses not present on admission, and (2) to allow only those diagnoses designated as present on admission to be used for assessing the risk of incurring complications.

PPC SYSTEM METHODS

Overview

In developing the PPC System it was first necessary to identify the subset of diagnoses that, if not present on admission, would represent potentially preventable complications, and assemble them into groups containing similar diagnoses. The next step was to determine the types of patients for whom each group of complications was potentially preventable. The final step was to adjust for susceptibility to complications based on the reason for admission, SOI, and comorbid conditions. We could then calculate and compare actual and expected risk-adjusted complication rates for individual hospitals using norms derived from statewide average complication rates. This study in particular examines the effect of

the reason for admission and admission SOI on patients' susceptibility to potentially preventable complications, and the effect of complications on costs and mortality.

Identifying and Classifying Diagnosis Codes

A core group of three physicians (two general internists and one pediatrician) supplemented by surgical, medical, obstetric, and pediatric specialists as needed, was responsible for creating a list of potentially preventable complications. The core panel first reviewed the existing literature and incorporated most of the diagnosis codes used in the Complications Screening Program (CSP) developed by Iezzoni and colleagues (1994; 1992) and the Patient Safety Indicators (PSI) from the Agency for Healthcare Research and Quality (2005). The physician panel then conducted its own review of all *International Classification of Diseases Ninth Revision-Clinical Modification* (ICD-9-CM) diagnosis codes to identify additional potentially preventable complications (Centers for Disease Control and Prevention, 2006).

We defined in-hospital complications as harmful events (e.g., accidental laceration during a procedure, improper administration of medication) or negative outcomes (e.g., hospital-acquired pneumonia, Clostridium Difficile Colitis) that may result from the processes of care and treatment rather than from natural progression of the underlying illness.

Complications do not necessarily represent medical errors, since they are not always preventable even with optimal care. In deciding which complications to classify as potentially preventable, the physician panel developed the following conceptual guide: If a hospital or other health care facility were to have a statistically significant, higher rate of a particular complication than comparable hospitals, reasonable clinicians would suggest further investigation for possible problems with quality of care.

The following specific criteria also provided guidance in choosing PPC diagnoses. In order to be considered a PPC diagnosis, the secondary diagnosis should:

- Not be redundant with the diagnosis that was the reason for hospital admission (e.g., a diagnosis of stroke in a patient admitted with intracranial hemorrhage).
- Not be an inevitable, natural, or expected consequence or manifestation of the reason for hospital admission (e.g., stroke in a patient admitted with a brain malignancy).
- Be expected to have a significant impact on short- or long-term debility, mortality, patient suffering, or resource use.
- Have a relatively narrow spectrum of manifestations, meaning that the impact of the diagnosis on the clinical course or on resource use must not be significant for some patients, but trivial for others (e.g., iron deficiency anemia, atelectasis).

Of the 12,988 ICD-9-CM diagnosis codes, we identified 1,357 codes as PPC diagnoses. We then assigned each PPC diagnosis to one of 66 mutually exclusive complication groups based on similarities in clinical presentation and clinical impact (Table 1). The number of diagnosis codes in a complication group ranged from 1 (Clostridium Difficile Colitis) to 215 (Poisoning Due to Drugs and Biological Substances). Table 2 contains examples of three complication groups.

Use of Procedure Codes

In addition to diagnosis codes, we used procedure codes to create some of the complication groups. In some cases, the procedure by itself could assign a patient to a complication group. For example, in

Table 1

List of Potentially Preventable Complications Groups (PPCs)

Group	Description
1*	Stroke & Intracranial Hemorrhage
2*	Extreme CNS Complications
3*	Acute Lung Edema & Respiratory Failure
4*	Pneumonia, Lung Infection
5*	Aspiration Pneumonia
6*	Pulmonary Embolism
7	Complications of Thoracic Surgery & Other Pulmonary Complications
8*	Shock
9*	Congestive Heart Failure
10*	Acute Myocardial Infarct
11	Cardiac Arrythmias & Conduction Disturbances
12	Other Cardiac Complications
13*	Ventricular Fibrillation/Cardiac Arrest
14	Hypotension
15*	Peripheral Vascular Complications Except Venous Thrombosis
16	Venous Thrombosis
17	Major GI Complications without Significant Bleeding
18*	Major GI Complications with Significant Bleeding
19*	Major Liver Complications
20	Other GI Complications without Report Of Significant Bleeding
21*	Other GI Complications with Report Of Significant Bleeding
22	Clostridium Difficile Colitis
23	Urinary Tract Infection
24	Complications of GU Surgery & Other GU Complications Except UTI
25	Renal Failure without Dialysis
26*	Renal Failure with Dialysis
27	Diabetic Ketoacidosis & Coma
28	Endocrine & Metabolic Complications except Diabetic Ketoacidosis/Coma
29	Post-Hemorrhagic & Other Acute Anemia without Transfusion
30*	Post-Hemorrhagic & Other Acute Anemia with Transfusion
31	Limb Fractures
32	Poisonings Of Drugs & Biological Substances
33	Anesthesia Poisonings & Adverse Effects
34	Abnormal Reactions
35*	Decubitus Ulcer
36	Transfusion Incompatibility Reaction
37	Moderate Infectious Complications
38*	Septicemia & Severe Infection
39	Adverse Effects Of Drugs, Transfusions & Biological Substances
40	Acute Mental State Changes
41	Post-Op Wound Infection & Deep Wound Disruption without Procedure
42*	Post-Op Wound Infection & Deep Wound Disruption with Procedure
43*	Reopening Or Revision Of Surgical Site
44	Post-Op Hemorrhage & Hematoma without Hemorrhage Control Or I&D Procedure
45*	Post-Op Hemorrhage & Hematoma with Hemorrhage Control Or I&D Procedure
46	Accidental Puncture/Laceration During O.R. Procedure
47	Non-O.R. Procedure Laceration
48	Other Surgical Complication - Mod
49*	Post-Op Foreign Body & Inappropriate Operation
50	Post-Op Substance Reaction & Non-O.R. Procedure for Foreign Body
51*	Other Major Complications Of Medical Care
52	Other Complications Of Medical Care
53	Iatrogenic Pneumothrax
54*	Malfunction Device, Prosthesis, Graft
55	GI Ostomy Complications
56*	Infection/Inflammation & Other Complication Of Device/Graft ex Vascular Infection
57	Complications Of Peripheral Intravenous Catheters
58*	Complications Of Central Venous & Other Vascular Catheters & Devices
59	Obstetrical Hemorrhage without Transfusion
60*	Obstetrical Hemorrhage wtih Transfusion
61	Obstetric 3rd&4th Degree Lacerations & Other Trauma
62	Medical & Anesthesia Obstetric Complications
63*	Major Obstetrical Complications
64	Other Complications Of Delivery
65	Delivery with Placental Complications
66*	Post-Operative Respiratory Failure with Tracheostomy

*Major PPCs.

NOTE: The PPC System identifies in-hospital complications among secondary diagnoses not designated as present on admission (POA).

SOURCES: Hughes, J.S., Averill, R.F., Goldfield, N.I., Gay, J.C., Muldoon, J., McCullough, E., Xiang, J., 2005.

Table 2

Examples of the Diagnosis and Procedure Codes for Three Complication Groups in the Potentially Preventable Complications (PPCs) System

ICD-9-CM Code	Description
PPC 01	**Stroke and Intracranial Hemorrhage**
Any one of the following diagnosis codes:	
430	Subarachnoid Hemorrhage
431	Intracerebral Hemorrhage
4320	Nontraumatic Extradural Hemmorhage
4321	Subdural Hemorrhage
4329	Intracranial Hemorrhage NOS
43301	Occlusion of Basilar Artery with Infarction
43311	Occlusion of Carotid Artery with Infarction
43321	Occlusion of Vertebral Artery with Infarction
43331	Occlusion of Multiple and Bilateral Arteries with Infarction
43381	Occlusion of Other Specified Precerebral Artery with Infarction
43391	Occlusion of Unspecified Precerebral Artery with Infarction
43401	Cerebral Thrombosis with Infarction
43411	Cerebral Embolism with Infarction
43491	Cerebral Artery Occlusion, Unspecified, with Infarction
436	Acute Cerebrovascular Disease
99702	Iatrogenic Cerebrovascular Infarction or Hemorrhage
PPC 03	**Acute Lung Edema and Respiratory Failure**
Any one of the following diagnosis codes:	
5184	Acute Lung Edema NOS
5185	Post Traumatic Pulmonary Insufficiency
51881	Acute Respiratory Failure
51884	Acute & Chronic Respiratory Failure
7991	Respiratory Arrest
Or one of the Following Procedure Codes:	
(Occurring > 2 Days after Admission or > 1 Day after a Significant Surgical Procedure)	
9604	Insertion Of Endotracheal Tube
9670	Continuous Mechanical Ventilation for Unspecified Duration
9671	Continuous Mechanical Ventilation for Less than 96 Hours
Or the Following Procedure Code:	
(Occurring >2 Days after Admission (for Non-Surgical APR DRGs) or > 0 day post first significant surgery)	
9672	Continuous Mechanical Ventilation for at least 96 Hours
PPC 05	**Aspiration Pneumonia**
Any one of the following diagnosis codes:	
5070	Pneumonitis Due to Inhalation of Food or Vomitus
5071	Pneumonitis Due to Inhalation of Oils or Essences
5078	Pneumonitis Due to Other Solids or Liquids

NOTES: Table shows three complication groups of the 66 groups in the PPC system. APR DRGs are All-Patient Refined Diagnosis-Related Groups.

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addition to the five diagnosis codes shown in the second example in Table 2, the procedure codes for endotracheal intubation or mechanical ventilation, if they met the appropriate timing criteria, could also generate the complication groups Acute Pulmonary Edema and Respiratory Failure. In other cases, the procedure code was combined with a diagnosis code to differentiate complication groups with greater clinical impact. For example, a patient with a secondary diagnosis of acute post-hemorrhagic anemia, not present on admission, would be assigned to a PPC named Hemorrhage or Anemia without Transfusion. The same diagnosis accompanied by a code for blood transfusion (at least 2 days after admission) would assign the patient to a different complication group, hemorrhage or anemia with transfusion.

Table 3

Examples of Exclusion Criteria for Three Complication Groups in the Potentially Preventable Complications (PPCs) System

Group	Description
PPC 01	**Stroke and Intracranial Hemorrhage**
Will Not Count as a Complication for Patients Admitted with Any of the Following Conditions:	
	Intracranial Hemorrhage
	CVA, Cerebral Infarction
	Cerebral Artery Dissection
	Severe Non-Traumatic Brain Injury
	Brain Contusion/Laceration and Complicated Skull Fracture
And Will Not Apply to Patients with Ventilator Support Greater than 96 Hours	
PPC 03	**Acute Lung Edema and Respiratory Failure**
Will Not Count as a Complication for Patients Admitted with:	
	Pulmonary Edema and Respiratory Failure
	Septicemia and Disseminated Infections
And Will Not Apply to:	
	Patients with Ventilator Support Greater than 96 Hours
	Patients with Tracheostomy and Prolonged Mechanical Ventilation
And Will Not Count as Complications for Surgical and Obstetric Patients Admitted with:	
	Intracranial Hemorrhage
	Non-Traumatic Stupor and Coma
	Pulmonary Embolism
	Acute Myocardial Infarction
	Acute Heart Failure
PPC 05	**Aspiration Pneumonia**
Will Not Count as a Complication for Patients Admitted with:	
	Seizures
	Brain Contusions, Lacerations and Complicated Skull Fractures
	Uncomplicated Closed Skull Fractures with Concussion
	Hematologic Malignancies and Immunocompromised States
	Septicemia and Disseminated Infections
And Will Not Apply to Patients with Ventilator Support Greater than 96 Hours	

NOTE: Table shows three complication groups of the 66 groups in the PPC system.

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Exclusions by Reason for Admission

A PPC diagnosis may be preventable for some types of patients, but not for others. Therefore the physician panel created clinical exclusions for each complication group. Some complication groups apply to only certain types of patients; for example post-operative complications occur only in surgical patients, and obstetric complications occur only in females who deliver after admission. The panel created a series of more specific clinical exclusions, most commonly dealing with possible complication diagnoses that were redundant codes or a natural consequence of one of the diagnoses present on admission, and therefore unpreventable. For example, the complication group aspiration pneumonia was not considered preventable for patients admitted with seizures, head trauma, respiratory failure requiring ventilator support, or septicemia. Table 3 contains exclusion criteria for each of the complication groups shown in Table 2.

The application of the POA logic and exclusion criteria makes a complication group potentially preventable, and the result is called a PPC Group. The PPC Groups are the final product of the PPC system logic. Hereafter the PPC Groups will be referred to as PPCs.

The panel also created global exclusions for patients with certain severe or catastrophic illnesses that were particularly susceptible to a range of complications, including those with trauma, HIV, and major or metastatic malignancies. These analyses also excluded newborns, which will be addressed by future versions of the PPC System. Details of these global exclusions are available on request from the authors.

Patients that were not globally excluded and had no specific clinical exclusions were considered at risk for the PPC, and therefore were included in the PPC rate calculation.

Differences from Previous Methods

The PPC System incorporates the great majority of the diagnosis codes used in both the CSP and PSI. PPCs use 502 of the 532 diagnosis codes (94 percent) and all 26 procedure codes used in CSP, and use 116 of 123 possible diagnosis codes (94 percent) and all 29 procedure codes used by the PSI. PPCs omit 1 complication of anesthesia code used by PSI, and 6 codes relating to obstetric lacerations (out of a total of 15) that our consultants thought would have only a minor impact on patient care. We added 524 diagnosis codes that were present in neither system. The most important difference with CSP and PSI was that the POA indicator allowed the PPCs to apply the complications to a larger group of patients—mainly to patients admitted with medical diagnoses. Most of the complications detected by both CSP and PSI occur in post-operative patients. Details of differences with CSP and PSI are available on request from the authors.

Use of APR DRGs for Risk Adjustment

We used All-Patient Refined Diagnosis Related Groups (APR DRGs) version 20 to classify patients according to their reason for admission and SOI at admission. (Averill et al., 2002) APR DRGs use data from computerized discharge abstracts to assign patients to one of 314 base APR DRGs that are determined either by the principal diagnosis, or for surgical patients, the most important surgical procedure performed in an operating room. Each base APR DRG is then divided into four risk subclasses, determined primarily by secondary diagnoses that reflect both comorbid illnesses and severity of the principal diagnosis, creating the final set of 1,256 groups. The risk subclasses take two different forms: (1) risk of mortality, and (2) SOI. SOI was used to stratify the risk of complications in all of the analyses that follow, except that risk of mortality was used in examining the association of complications with increased mortality. The combination of the base APR DRG and the risk subclass is referred to as the APR DRG. In ordinary use, APR DRGs use all diagnoses from the hospitalization, whether present on admission or not. For risk adjustment of PPC rates in the analyses that follow, however, we used an admission APR DRG that is based on the principal diagnosis from the discharge abstract, but excludes all secondary diagnoses that are not present on admission. Thus, complications and other conditions that arise during the hospitalization are not used for risk adjustment.

ANALYSIS

Data Sources

We analyzed discharge abstract data for 5.15 million discharges from all California hospitals for 1999 and 2000. A total of 520,885 discharges from 99 hospitals that had not recorded the present on admission indicator accurately or consistently were eliminated (screening criteria available on request from the authors). These hospitals tended to be smaller, with an average of 5,304 discharges in the 2-year period compared to an average of 15,646 discharges for the included hospitals, but had similar distributions of age and sex. Another 16,501 discharges from 40 hospitals with fewer than 1,000 discharges and 5 hospitals with a death rate over 15 percent (compared to an average of 2.3 percent for included hospitals) were eliminated out of concern that they would not be representative of acute care hospitals. Thus, we were left with a total of 294 hospitals and 4.62 million discharges. From the eligible hospitals we then excluded 665,782 patients with charges less than $200 or greater than $2 million, or who had lengths of stay (LOS) recorded as zero. We excluded 314,881 patients with certain severe or catastrophic illnesses that were particularly susceptible to a range of complications, including those with trauma, HIV, and major or metastatic malignancies (global exclusions). We also excluded 602,114 newborns from these analyses.

Identifying Patients

This study focused on a subset of 29 major PPCs (Table 1). The major PPCs were selected by consensus of the physician panel as those most likely to have a consistent and significant impact on a patient's clinical course. The ICD-9-CM (Centers for Disease Control and Prevention, 2006) diagnosis and procedure codes that comprise each of the major PPCs are available on request from the author.

We calculated the total number of California patients who had each one of the major PPCs, as well as all patients who had any one of the major PPCs. In order to gauge the impact of the POA indicator, we also identified the number of patients with a PPC secondary diagnosis code that was present on admission, and therefore not counted as a PPC.

Calculating Observed and Expected Rates

We calculated a statewide PPC norm—the average rate for each PPC for each admission APR DRG across all patients who were at risk for the PPC—using data only from those hospitals that passed the POA coding quality screens. Then, using indirect standardization, for each hospital we calculated the expected number of patients for each PPC by multiplying the statewide average rate for each PPC/APR DRG combination by the number of patients in the hospital in each admission APR DRG. The expected number of patients with a PPC in each admission APR DRG summed across all APR DRGs is the hospital's overall expected number of patients with that PPC. In the same manner, we calculated expected rates for combinations of PPCs, and for all patients with any one of the major PPCs noted in Table 1. Any patient with more than one major PPC was only counted once when calculating rates for combinations of PPCs. We calculated differences in actual minus expected rates for individual PPCs and combinations of PPCs, for individual hospitals and for all hospitals in the State. We

determined statistical significance using the Cochrane-Mantel-Haenzel (CMH) test (Agresti, 1990).

Evaluating the Impact

In order to examine the impact of the occurrence of a PPC on hospital outcomes, we computed the statewide average charges, LOS, and death rates for each admission APR DRG. Then, using the statewide averages for each admission APR DRG, we computed the expected average charges, LOS and death rates by means of indirect rate standardization for patients with specific PPCs, and for all patients with any of the major PPCs. We then calculated the actual average charges, LOS, and death rates for the same sets of patients, and determined the ratio of actual values to expected values. We determined statistical significance using the CMH test for differences in actual and expected death rates, and Student's *t*-test for average LOS and charge differences.

Evaluating Stability of Rates Over Time

We calculated actual minus expected rates of patients with any major PPC for the first 6 months of 1999 and the first 6 months of 2000 for all eligible California hospitals. We examined the stability of the actual minus expected rate differences for all hospitals that had a statically significant difference in 1999, 2000, or in both years. We calculated an R^2 value for the correlation of actual minus expected differences in the 2 years.

RESULTS

Table 4 contains, for each of the major PPCs, the number of California patients at risk, the total number of patients with a PPC diagnosis, whether present on admission or not, the number of patients excluded because the PPC diagnosis was POA, and the number of patients with a PPC diagnosis not POA, but excluded by a clinical exclusion rule. Table 4 also shows the number of patients with a true PPC and the positive predictive value, calculated as the proportion of true PPCs (not POA and without a clinical exclusion) among all patients with a PPC diagnosis.

As shown in Table 4, there is considerable variation in the occurrence of PPCs, ranging from a low of 0.15 per 1,000 for Post-Operative Respiratory Failure with Tracheostomy to a high of 7.26 per 1,000 for Acute Lung Edema and Respiratory Failure. The overall rate for patients with at least one major PPC is 27.6 per 1,000.

The POA indicator is more important for determining some PPCs than others. For most of the PPCs, the majority of the PPC diagnosis codes were present on admission, as reflected in the low positive predictive values. For those PPCs, screening for complications without the POA indicator would be impractical. For both of the Major Obstetrical PPCs and three of the Major Post-Operative PPCs, however, the number of false positives would have been much lower. The POA indicator is therefore of less value for these PPCs.

The effect of the POA indicator and the exclusion criteria on the number of patients with at least one major PPC is demonstrated in Table 4. Almost 580,000 of the California hospital discharges had at least one secondary diagnosis belonging to a major PPC, but 487,826 were not considered to have a PPC because the PPC diagnosis was present on admission. Another 7,831 were not considered to have a PPC because of clinical exclusions.

Table 5 presents the number and rate of patients per 1,000 who incurred at least one major PPC for a selected group of 20

Table 4

Major Potentially Preventable Complication (PPC) Groups and Their Occurrence Among California Hospitalizations: 1999-2000

	Major PPC Group	(1) Patients at Risk	(2) All Patients with any PPC Diagnosis**	(3) PPC Diagnoses Excluded Because POA	(4) PPC Diagnoses with Clinical Exclusions	(5) PPC Not POA, Not Excluded - Equals True PPC*	PPC Rate per 1,000***	PPV
Major Cardiovascular and Pulmonary PPCs								
1	Stroke & Intracranial Hemorrhage	2,969,740	15,743	9,797	414	5,532	1.86	0.35
2	Extreme CNS Complications	2,855,451	17,414	14,657	949	1,808	0.63	0.10
3	Acute Lung Edema & Respiratory Failure	2,919,995	135,341	110,404	3,745	21,192	7.26	0.16
4	Pneumonia, Lung Infection	2,704,448	87,366	71,777	3,391	12,198	4.51	0.14
5	Aspiration Pneumonia	2,865,642	20,344	12,033	1,536	6,775	2.36	0.33
6	Pulmonary Embolism	3,022,644	4,443	2,957	1	1,485	0.49	0.33
8	Shock	2,971,169	20,181	15,111	932	4,138	1.39	0.21
9	Congestive Heart Failure	2,686,676	209,524	197,815	890	10,819	4.03	0.05
10	Acute Myocardial Infarct	2,956,739	18,799	12,299	124	6,376	2.16	0.34
13	Ventricular Fibrillation/Cardiac Arrest	3,031,554	27,167	16,103	0	11,064	3.65	0.41
15	Peripheral Vascular Complications Except Venous Thrombosis	3,018,827	20,810	19,379	139	1,292	0.43	0.06
	At Least One Major Cardiovascular or Pulmonary PPC	3,031,554				59,850	19.74	
Other Major Medical PPCs								
18	Major Gastrointestinal Complications with Transfusion	2,614,013	19,552	18,065	190	1,297	0.5	0.07
19	Major Liver Complications	2,994,021	11,594	10,414	456	724	0.24	0.06
21	Other GI Complications with Transfusion Or Post-Hemorrhagic Anemia	2,622,763	7,675	6,447	570	658	0.25	0.09
26	Renal Failure with Dialysis	2,956,451	8,180	6,222	480	1,478	0.5	0.18
30	Post-Hemorrhagic & Other Acute Anemia with Transfusion	1,957,938	36,005	34,066	860	1,079	0.55	0.03
35	Decubitus Ulcer	2,995,583	38,272	35,686	7	2,579	0.86	0.07
38	Septicemia & Severe Infection	2,938,030	60,168	50,132	1,167	8,869	3.02	0.15
51	Other Major Complications Of Medical Care	3,014,401	27,255	22,388	75	4,792	1.59	0.18
	At Least One Other Major Medical PPC	3,031,554				19,416	6.4	
Major Peri-Operative PPCs								
42	Post-Op Wound Infection & Deep Wound Disruption with Procedure	1,083,363	1,634	920	39	675	0.62	0.41
43	Reopening Or Revision Of Surgical Site	1,098,260	14,163	12,917	0	1,246	1.13	0.09
45	Post-Op Hemorrhage with Hemorrhage Control or I&D Procedure	1,098,260	4,381	2,004	23	2,354	2.14	0.54
49	Post-Op Foreign Body & Inappropriate Operation	1,098,260	291	109	9	173	0.16	0.59
66	Post-Op Respiratory Failure with Tracheostomy	2,332,281	1,558	1,215	0	343	0.15	0.22
	At Least One Major Peri-Operative PPC	2,595,252				4,732	1.82	
Major Complications of Devices, Grafts, Etc.								
54	Malfunction Device, Prosthesis, Graft	2,967,872	8,425	6,002	175	2,248	0.76	0.27
56	Infection, Inflammation & Other Complications of Devices & Grafts	2,967,872	9,365	6,529	106	2,730	0.92	0.29
58	Complications Of Central Venous & Other Vascular Catheters & Devices	2,986,171	14,164	8,340	388	5,436	1.82	0.38
	At Least One Major Complication Of Devices, Grafts, Etc.	2,986,171				10,136	3.39	
Major Obstetrical Complications								
60	Obstetrical Hemorrhage with Transfusion	618,708	1,187	159	121	907	1.47	0.76
63	Major Obstetrical Complications	626,438	3,750	310	12	3,428	5.47	0.91
	At Least One Major Obstetrical Complication	626,438				4,275	6.82	

See footnotes at the end of the table.

Table 4—Continued

Major Potentially Preventable Complication (PPC) Groups and Their Occurrence Among California Hospitalizations: 1999-2000

Major PPC Group	(1) Patients at Risk	(2) All Patients with any PPC Diagnosis**	(3) PPC Diagnoses Excluded Because POA	(4) PPC Diagnoses with Clinical Exclusions	(5) PPC Not POA, Not Excluded - Equals True PPC*	PPC Rate per 1,000***	PPV
At Least One Major PPC of any kind	3,031,554	579,424	487,826	7,831	83,767	27.63	0.14

*Includes only patients with PPC diagnosis codes not present on admission and without clinical exclusions.

**Includes all PPC diagnosis codes, both present on admission as well as not present on admission and with clinical exclusions (equals the sum of columns 3, 4, and 5).

***PPC Rate per 1,000 = (column 5 divided by column 1) x 1,000.

NOTES: Numbers in columns do not sum to numbers in subtotal and total rows due to patients with multiple PPCs. POA is present on admission. PPV is positive predictive value (equals column 5 divided by column 2).

SOURCE: Hospital data from California Office of Statewide Health Planning and Development.

Table 5

Percent of Patients with at Least One Major Potentially Preventable Complications Group (PPC) in Selected All-Patient Refined Diagnosis-Related Groups (APR DRGs)

APR DRG Description		Admission Severity of Illness (SOI) Level				Total
		SOI 1	SOI 2	SOI 3	SOI 4	
Surgical APR DRGs						
Craniotomy except for Trauma	PPCs	264	553	663	150	1,630
	At Risk	4,339	3,642	2,313	533	10,827
	Percent	6.1	15.2	28.7	28.1	15.1
Extracranial Vascular Procedures	PPCs	238	297	161	6	702
	At Risk	9,850	4,525	822	27	15,224
	Percent	2.4	6.6	19.6	22.2	4.6
Coronary Artery Bypass Graft with Catheterization	PPCs	336	1,998	1,433	99	3,866
	At Risk	3,430	13,260	4,946	348	21,984
	Percent	9.8	15.1	29.0	28.5	17.6
Percutaneous Cardiovascular Procedures with Acute MI	PPCs	361	550	335	105	1,351
	At Risk	27,295	19,407	4,366	517	51,585
	Percent	1.3	2.8	7.7	20.3	2.6
Major Large & Small Bowel Procedures	PPCs	320	1,156	1,416	353	3,245
	At Risk	8,617	11,017	5,187	894	25,715
	Percent	3.7	10.5	27.3	39.5	12.6
Appendectomy	PPCs	99	292	70	9	470
	At Risk	24,599	13,122	700	47	38,468
	Percent	0.4	2.2	10.0	19.2	1.2
Laparoscopic Cholecystectomy	PPCs	200	350	245	21	816
	At Risk	20,928	12,065	3,057	138	36,188
	Percent	1.0	2.9	8.0	15.2	2.3
Hip Joint Replacement	PPCs	184	775	654	32	1,645
	At Risk	3,506	18,675	10,357	119	32,657
	Percent	5.3	4.2	6.3	26.9	5.0
Intervertebral Disc Excision	PPCs	89	135	38	1	263
	At Risk	22,454	6,073	436	9	28,972
	Percent	0.4	2.2	8.7	11.1	0.9
Uterine & Adnexal Procedures Except for Leiomyoma Excision	PPCs	263	138	53	4	458
	At Risk	34,974	6,828	482	20	42,304
	Percent	0.8	2.0	11.0	20.0	1.1

See footnotes at the end of the table.

Table 5—Continued

Percent of Patients with at Least One Major Potentially Preventable Complications Group (PPC) in Selected All-Patient Refined Diagnosis-Related Groups (APR DRGs)

APR DRG Description		Admission Severity of Illness (SOI) Level				Total
		SOI 1	SOI 2	SOI 3	SOI 4	
Medical APR DRGs						
Cerebrovascular Accidents	PPCs	34	590	813	245	1,682
	At Risk	4,056	21,231	8,307	1,192	34,786
	Percent	0.8	2.8	9.8	20.6	4.8
Major Pneumonia	PPCs	41	400	826	729	1,996
	At Risk	2,803	11,786	14,329	4,852	33,770
	Percent	1.5	3.4	5.8	15.0	5.9
Other Pneumonia	PPCs	101	891	1,027	807	2,826
	At Risk	24,694	57,313	28,300	3,892	114,199
	Percent	0.4	1.6	3.6	20.7	2.5
COPD	PPCs	144	432	400	400	1,376
	At Risk	20,224	27,677	10,845	2,211	60,957
	Percent	0.7	1.6	3.7	18.1	2.3
Acute MI	PPCs	155	976	873	420	2,424
	At Risk	6,925	20,510	8,959	2,530	38,924
	Percent	2.2	4.8	9.7	16.6	6.2
Congestive Heart Failure	PPCs	177	1,366	1,137	369	3,049
	At Risk	18,151	59,203	18,390	2,195	97,939
	Percent	1.0	2.3	6.2	16.8	3.1
Peptic Disease & Gastritis	PPCs	45	274	325	63	707
	At Risk	10,099	14,467	6,229	393	31,188
	Percent	0.5	1.9	5.2	16.0	2.3
Cellulitis	PPCs	24	152	123	23	322
	At Risk	15,395	16,089	4,275	187	35,946
	Percent	0.2	0.9	2.9	12.3	0.9
Urinary Tract Infection	PPCs	35	299	382	61	777
	At Risk	10,759	21,556	10,416	655	43,386
	Percent	0.3	1.4	3.7	9.3	1.8
Septicemia	PPCs	6	288	669	321	1,284
	At Risk	1,878	11,064	11,329	2,842	27,113
	Percent	0.3	2.6	5.9	11.3	4.7

SOURCE: Hospital data from California Office of Statewide Health Planning and Development.

Table 6

Actual and Expected Death Rate, Length of Stay (LOS), and Charges for Patients With Selected Potentially Preventable Complications Groups (PPCs)

	PPC Rate		Deaths*			Mean Length of Stay**			Mean Charges**		
PPC Title	At Risk	PPC/ 1,000	Actual/ 1,000	Expected/ 1,000	Actual/ Expect	Actual (Days)	Expected (Days)	Actual/ Expect	Actual Dollars	Expected Dollars	Actual/ Expect
Stroke & Intracranial Hemorrhage	2,969,740	1.86	0.53	0.13	4.15	15.3	8.2	1.86	114,337	61,158	1.87
Acute Lung Edema & Resp. Failure	2,919,995	7.26	2.74	0.52	5.24	18.1	9.2	1.97	143,872	62,436	2.30
Pneumonia, Lung Infection	2,704,448	4.51	0.75	0.23	3.22	17.9	7.7	2.33	125,302	50,749	2.47
Aspiration Pneumonia	2,865,642	2.36	0.64	0.20	3.27	18.8	8.1	2.32	128,798	50,145	2.57
Pulmonary Embolism	3,022,644	0.49	0.13	0.03	4.90	16.9	7.9	2.15	113,503	51,345	2.21
Congestive Heart Failure	2,686,676	4.03	0.69	0.25	2.71	14.1	7.8	1.81	98,507	53,084	1.86
Acute Myocardial Infarct	2,956,739	2.16	0.62	0.18	3.56	12.6	8.2	1.54	97,917	54,080	1.81
Major GI Complications with Transfusion	2,614,013	0.50	0.14	0.05	2.69	20.3	10.0	2.02	134,883	61,966	2.18
Major Liver Complications	2,994,021	0.24	0.13	0.03	5.14	21.0	10.3	2.04	179,045	70,323	2.55
Renal Failure with Dialysis	2,956,451	0.50	0.28	0.05	5.11	28.5	11.5	2.47	257,594	88,991	2.89
Decubitus Ulcer	2,995,583	0.86	0.17	0.09	1.76	27.9	10.7	2.60	191,603	68,583	2.79
Septicemia & Severe Infection	2,938,030	3.02	1.12	0.29	3.89	25.3	10.6	2.38	189,563	69,497	2.73
Reopening Surgical Site	1,098,260	1.13	0.18	0.08	2.37	18.5	10.3	1.80	149,176	76,704	1.94
Post-Op Hemorrhage with procedure	1,098,260	2.14	0.23	0.08	2.75	13.9	8.5	1.63	139,739	79,957	1.75
All patients with At Least One Major PPCG[1]	3,031,554	27.63	6.64	2.59	2.56	14.2	8.3	1.71	98,515	55,166	1.79

[1] Includes all 29 major PPCs.

*All differences statistically significant by Cochrane-Mantel-Haenzel (CMH) test at $p < 0.01$.

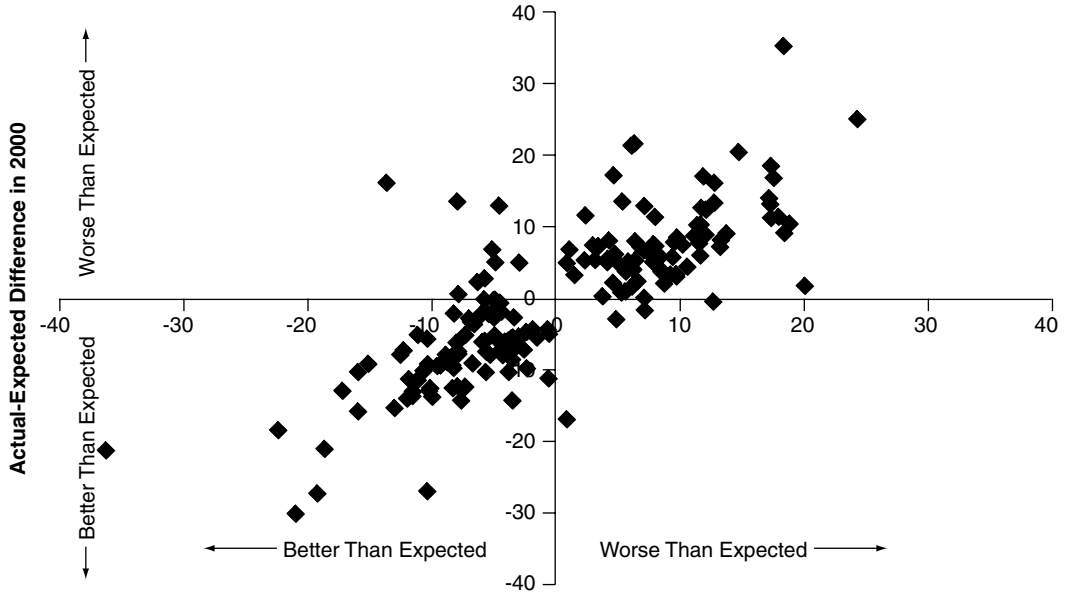
**All differences statistically significant by t-test at $p < 0.01$.

NOTES: Expected deaths: calculated based on All-Patient Refined Diagnosis Related Group (APR DRG) risk of mortality at admission, using statewide California data for all patients at risk for each PPC. Expected mean LOS and mean charges: calculated based on APR DRG severity of illness at admission, using statewide California data for all patients at risk for each PPC.

SOURCE: Hospital data from California Office of Statewide Health Planning and Development.

Figure 1

Correlation of the Difference Between Actual and Expected Hospital Major Potentially Preventable Complication (PPC) Rates per 1,000 Patients: 1999 and 2000



NOTES: This figure plots the actual minus expected major PPC rate for the first 6 months of 1999 and the first 6 months of 2000 for each of the 179 hospitals that had a statistically significant difference in either of those years (97 of the 179 hospitals had a statistically significant difference in both years). It shows that hospitals that performed worse than expected in one year tended to perform worse in both years, and conversely, those that performed better than expected in one year tended to do so in both years. The R^2 value was 0.55 for the correlation between the 2 years.

SOURCES: Hughes, J.S., Averill, R.F., Goldfield, N.I., Gay, J.C., Muldoon, J., McCullough, E., Xiang, J., 2005; Hospital data from California Office of Statewide Health Planning and Development.

admission base APR DRGs, sorted by SOI subclass (the APR DRGs severity subclasses were assigned using only secondary diagnoses present on admission). It shows that the rate of major complications varies not only by the reason for admission (categorized by base APR DRG), but also by the admission SOI. The monotonic increases in major PPC rates with increasing admission SOI are representative of all but a few combinations of base APR DRGs and individual PPCs or groups of PPCs. Across all reasons for admission, patients with greater SOI on admission were more susceptible to complications.

Table 6 shows the impact of several individual PPCs on death rates, LOS, and charges. In this table, the actual average charges, LOS, and death rates for patients with each PPC are compared to their expected values, which were derived by indirect standardization from the statewide APR DRG averages. The presence of a major PPC is associated with large increases in charges, LOS, and deaths over what would have been expected based on SOI at admission. For example, patients with a PPC of Acute Lung Edema and Respiratory Failure had death rates that were five times higher than expected, and mean LOS and charges twice as high as expected. Although they showed a very strong association with complications, these data cannot be assumed to represent the impact of medical errors on costs, deaths, and LOS. This analysis could not identify the number of true medical errors because, although it identified the number of complications that

were potentially preventable, it could not determine how many of those complications were actually preventable.

Calculation of the difference in the actual minus expected rate of major PPCs for each of the California hospitals yielded a range from -2.48 per 1,000 (better than expected) to 2.79 per 1,000 (worse than expected). Sixty hospitals were classified as having PPC rates significantly lower than expected at a p value of <0.05, and 45 hospitals were classified as having significantly higher PPC rates than expected for the 2-year period.

Stability of Hospital Performance Over Time

Figure 1 plots the actual minus expected major PPCs rate for the first 6 months of 1999 and the first 6 months of 2000 for each of the 179 hospitals that had a statistically significant difference in either of those years (97 of the 179 hospitals had a statistically significant difference in both years). It shows that hospitals that performed worse than expected in one year tended to perform worse than expected in both years, and conversely, those that performed better than expected in one year tended to do so in both years. The R^2 value was 0.55 for the correlation between the 2 years.

DISCUSSION

This article describes the development of a new method for evaluating in-hospital complication rates, the first to use the POA indicator applied to statewide data. The PPC method builds on existing complication screening methods, substantially expanding the number of diagnoses that can be considered complications, as well as expanding the number of patients for whom the occurrence of complications can be assessed. These analyses confirm the value of the POA indicator for identifying complications, particularly for those that are neither obstetric nor specific postoperative complications.

These analyses also demonstrate that the reason for admission, comorbid conditions, and admission SOI—measured here by APR DRGs—have a dramatic effect on the risk of complications. The findings emphasize that any comparisons of hospital complication rates, if they are to be fair, require not only the POA indicator to identify complications, but also the availability of adequate risk-adjustment methods. The PPC System provides a built-in risk-adjustment method with APR DRGs assigned using only diagnoses present on admission. PSIs use age, sex, and an updated version of AHRQ comorbidity software for risk adjustment. In contrast, the CSP provided no mechanism for risk adjustment.

These findings also demonstrate the association of complications with increased costs, LOS, and mortality, an association that has been shown previously (Naessens and Huschka, 2004).

Limitations and Next Steps

The PPC System has the limitations inherent in any system that uses discharge abstract codes, since the accuracy and completeness of coding can vary across hospitals, and may vary from one diagnosis to another within a hospital (Iezzoni, 1997). Furthermore, any system that relies on diagnosis coding can be subject to systematic coding bias in response to the inherent incentives in the system. Hospitals would have two strong incentives to code actual complications as present on admission: first to minimize their complication rates, and second to increase their patients' SOI at admission. Furthermore, the fact that almost 20 percent of California hospitals had to be eliminated from these

analyses because of poor coding of the POA indicator emphasizes that attention would have to be directed to coding compliance. Compliance can be a particular problem for smaller hospitals that may lack the resources to upgrade their coding accuracy. The identification of statistically significant differences in individual PPC rates may also be problematic for smaller hospitals, and it may be necessary to examine only aggregate PPC rates for these hospitals. The applicability of screening algorithms to small hospitals will require more examination.

The PPC method will need to be validated in a variety of ways to ensure that the identification of hospital complications is accurate, and also useful in improving quality of care and patient safety. Validation can take the form of chart review studies to examine the association of various complications with quality problems, and review by expert panels and quality review organizations to examine face validity and content validity.

Acceptability of Complications Methods

If complications screening methods such as PPCs are to be used for performance assessment, they must first address whether ICD-9-CM (Centers for Disease Control and Prevention, 2006) discharge abstract codes can identify in-hospital complications with reasonable accuracy. Several authors have reported low sensitivity, meaning large numbers of unrecorded complications (Best et al., 2002; Geraci et al., 2002, 1997; Romano et al., 2002; Romano, Schembri, and Rainwater, 2002). False-positive rates, on the other hand, have been shown to be lower in several studies, and further reducible if complications were distinguished from comorbidities using chart review (Hannan et al., 1997; Lawthers et al., 2000; Naessens and Huschka, 2004).

Another issue is whether presence of complications correlates with problems in quality of care. Several studies have linked poorer quality of care with in-hospital complications (Geraci et al., 1999; Weingart et al., 2000) but others have identified problems with reproducibility of reviewer judgments (Caplan, Posner, and Cheney, 1991; Goldman, 1992; Hayward, McMahon, and Bernard, 1993; Iezzoni et al., 1999; Rubin et al., 1992), discordance between implicit and explicit assessments of quality, and judgments about whether complications resulted from error and/or negligence (Thomas et al., 2002; Weingart et al., 2002). Despite the uncertain state of current literature, it makes intuitive sense that complications are often related to substandard care. In hospitals where potentially preventable complication rates are significantly higher than average, the expectation of quality problems is higher, and the processes of care at those institutions should be scrutinized more closely.

Complications screening can prompt hospitals to focus indepth reviews either on individual patient records or on processes of care that are potentially deficient. For example, a hospital with a higher than expected rate of aspiration pneumonia or decubitus ulcer among stroke patients might need to review the nursing care on its neurology service. Alternatively, complications screening could be used to create public reports for hospital comparisons, which many quality advocates have endorsed in addition to reports on process measures, mortality rates, LOS, and costs (Berwick, 2002; Steinberg, 2003). Others, perceiving a perverse incentive in paying hospitals more for patients who have complications, have suggested tying

reimbursement to complication rates as well as other performance measures (Midwest Business Group on Health, 2002; National Committee for Quality Assurance, 2004).

Although some commentators have raised concerns about the effectiveness and possible negative consequences of such proposals (Mello, Studdert, and Brennan, 2003; Werner and Asch, 2005), and others have been more cautiously optimistic (Marshall, Romano, and Davies, 2004), it is clear that momentum for public performance reporting and pay-for-performance initiatives is increasing. Federal efforts, in addition to the Patient Safety Indicators (Agency for Healthcare Research and Quality, 2005), include a CMS requirement that participating hospitals report selected performance data or face a reduction in payments. CMS has also started several pay-for-performance demonstration projects, and the Medicare Payment Advisory Commission (2005) has recommended a range of pay for performance measures and also endorsed the use of POA indicators. In the Deficit Reduction Act of 2005, Congress required that the POA indicator be reported on all Medicare claims beginning in fiscal year 2008, and further instructed CMS, beginning in fiscal year 2009, to select at least two types of post admission infectious complications that would to no longer be allowed to affect DRG assignment.

Given the level of public and governmental scrutiny, and the considerable resources and effort expended to date on these issues, it is likely that public reporting and financial incentives related to patient safety performance measures in general, and hospital complication rates in particular, will only increase. The effectiveness of these efforts will depend on the integrity of the data and the validity of the methods used in any public reports and performance-based payment systems. Our study suggests that the ability to identify diagnoses present at the time of admission is necessary not only for the proper identification of complications, but also for adequate risk stratification based on patient type and SOI. This ability is critical to the fairness and usefulness of any evaluations of hospital complication rates.

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