Estimating the Costs of Potentially Preventable Hospital Acquired Complications

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California and Maryland hospital data are used to estimate the incremental cost associated with 64 categories of hospital acquired complications. The reason for admission, severity of illness at admission and the presence of hospital acquired complications are used in a linear regression model to predict incremental per patient cost yielding an adjusted R^2 of 0.58 for Maryland data and 0.60 for California data. The estimated incremental cost due to each of the 64 categories of complications was consistent across both databases and accounted for an increase in total short term acute inpatient hospital cost of 9.39 percent in the California data and 9.63 percent in the Maryland data.

INTRODUCTION

With increasing medical care costs and a weakening economy more attention is being placed upon obtaining value from how health care dollars are spent. Initiatives to obtain increased value from health care purchases are especially focused upon perceived waste (Aaron, 2008). The frequency and cost of hospital acquired complications are at the forefront of perceived waste since hospitals, patients and payers are all adversely impacted by their occurrence.

Following the final implementation of the National Uniform Billing Committee changes (UB 04) on May 23, 2007, the standard claims form was modified to allow the submission of a present on admission (POA) indicator for each diagnosis. In October of 2007, Medicare began requiring that the POA indicator be submitted on all Medicare claims. This change has permitted, for the first time, the ability to distinguish, using standard claims data, complications that are hospital acquired from those developed prior to admission.

Both payers and hospital providers have responded to this newly acquired, and evolving, information source by developing initiatives to reassure stakeholders that they are focused upon meaningful change to improve the quality of health outcomes. As required by the Deficit Reduction Act of 2005 (P. L. 109-171), CMS has led the way for payers by enacting a policy whereby any payment increase due to the occurrence of a limited range of hospital acquired complications is eliminated. For CMS the anticipated reduction in spending is \$21million out of the total \$105 billion (.02%) that is currently paid for inpatient hospital operating payments within the inpatient prospective payment system for short term acute hospitals (Centers for Medicare & Medicaid Services, 2008). As preemptive initiatives, many hospital associations have responded by creating voluntary guidelines for specified adverse events (so called “never events”) where no charge is made to payers.

While the purpose of these payment reductions is to provide incentives to improve quality, the amount of payment

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currently associated with these efforts, relative to the total cost of hospital care, is very small. It is the purpose of this article to develop an estimate of the incremental cost of different types of hospital acquired complications and to determine the total incremental cost burden of hospital acquired complications on the health care system. Improved estimates of the magnitude of incremental cost incurred by short term acute hospitals due to hospital acquired complications should stimulate debate around the financial justification for supporting quality improvement efforts aimed at reducing hospital acquired complication rates. Further, the availability of estimates of the incremental cost of individual types of hospital acquired complications will expand the policy options open to CMS for broadening the range of the hospital acquired complications subject to payment reductions.

METHODS

While it is important to understand that not all hospital acquired complications can reasonably be thought of as being preventable, high complication rates at individual facilities, after adjusting for the mix and severity of illness of patient admissions, are indicative of low quality care and system waste (Peng, Kurtz, and Johannes, 2006). In order to identify the complete spectrum of hospital acquired complications the Potentially Preventable Complication (PPC) were used in this analysis (Hughes et al., 2006). PPCs identify potentially preventable harmful events or negative outcomes originating during inpatient care that result from the processes of care and treatment rather than from the natural progression of underlying disease. PPCs contain 64 mutually exclusive types of inpatient complications that are identified from 1,450 ICD-9-CM secondary diagnosis codes not present on admission, and from selected ICD-9-CM procedure codes. A post admission complication may be preventable for some types of patients but not for others. Therefore, the PPC methodology includes a series of clinical exclusions that prevent a PPC from being assigned to a patient when there are other underlying diseases present at admission for which the complication would represent an inevitable, natural or expected progression, consequence or manifestation of a pre-existing underlying condition.

Patients having one or more PPCs present can be hypothesized as having additional costs in comparison to similar patients who do not. For example hospital costs will increase when a patient develops a urinary tract infection (UTI) due to an indwelling urinary catheter (IUC) during a hospital stay. Patient treatment costs vary depending upon the patient's reason for admission, severity of illness at the time of admission and the presence of post admission complications. Isolating and quantifying the incremental cost of a specific type of complication requires the disentangling of these interrelated factors.

In order to adjust for the mix and severity of illness of patients, All Patient Refined Diagnosis Related Groups (APR DRG) were used to classify patients in terms of their reason for admission and severity of illness at the time of admission (Averill et al., 2002; Sedman et al., 2004). Version 26.1 of the APR DRG system incorporates an admission APR DRG as standard output. The admission APR DRG differs from the discharge APR DRG in that only those conditions that were reported as present, or can be clinically assumed to be present, at the time of admission are used in making the APR DRG assignment. Conditions or complications that occurred during the hospital stay are not used to assign a patient to an admission APR DRG. Procedures that were clearly related to a post-admission event (i.e., complications) are also excluded from the admission APR DRG assignment. APR DRGs assign each patient to one of 314 base APR DRGs that describe the patient's reason for admission and further subdivides each base APR DRG into four levels of illness severity (SOI) subclasses. The term APR DRG is used to refer to the 1,256 base APR DRG and SOI subclass combinations.

DATA

Maryland and California require the reporting of the POA indicator for all short-term acute hospital patients. In Maryland, hospital data can be obtained from the Health Services and Cost Review Commission (HSCRC), while in California, hospital data can be obtained from the Office of Statewide Planning and Development. Fiscal year 2008 (July 2007 – June 2008) Maryland data and fiscal year 2006 (October 2005 – September 2006) California data were used in the analysis. The consistency of reporting of the POA data in the two data sets was evaluated using an extensive set of edits. Hospitals that did not pass the POA edits were removed from the analysis database. Of the 48 hospitals in the Maryland database, five hospitals comprising 83,863 patient claims were removed. Of the 353 hospitals in the California database, 118 hospitals comprising 505,206 patient claims were removed.

Patient claims with a discharge status of transferred (2) or expired (20) were excluded from analysis, as were claims that were classified within "error" APR DRGs due to incomplete or inaccurate data. Claims that had total charge values below $200 or above $2,000,000 were similarly excluded because extraordinarily high and low cost claims have the potential to introduce significant estimation error into the regression model. Further, the dollar exclusion threshold was introduced in the absence of a systematically applied policy to determine outliers within APR DRGs and the lack of availability of hospital specific cost to charge ratios for the California data.

Maryland's HSCRC regulates hospital charges to closely track "efficient" hospital costs thereby obviating the need to incorporate cost to charge ratios. In applying its rate setting methodology the HSCRC creates approved base rate values, Charge Per Case (CPC), that factor in estimates for Indirect Medical Education (IME), Disproportionate Share (DSH), Uncompensated Care, Capital and Labor variations. Additionally, charge patterns are constrained so as to match reported cost at a service level. Maryland claims charges were standardized using hospital specific CPCs to equate individual hospital charges with the statewide average.

The California data lacked both the hospital specific payment variables available in the Maryland data and a hospital specific identifier that could be linked to hospital cost data made public through the Medicare Program. Instead a single standard approximation of a statewide cost to charge ratio was applied to all charges to transform charge values to more closely approximate actual cost. The cost to charge ratio used was 0.264 and derived from the hospital unweighted median cost to charge ratio used by California's Division of Workers Compensation effective April 1, 2007 (Division of Workers Compensation, 2007). This is a linear transformation with the singular purpose of simplifying subsequent interpretation of coefficient values rather than correcting estimation error.

California data was therefore not adjusted for the effect of variation in cost to charge ratios across hospitals and service lines. Similarly, the known effects upon costs posed by teaching programs, the prevalence of indigent patients and geographically induced input cost variation was not adjusted for. As with any predictive estimate attempting to relate costs to charge patterns, the inability to adjust for these factors in the California data reduces the accuracy of the incremental cost estimates. The final Maryland analysis database contained 43 hospitals comprising 659,816 patients. The final California analysis database contained 235 hospitals comprising 1,836,396 patients.

Inpatient hospital claims for the Maryland and California data sets were grouped using APR DRG V26.1. All complications on each patient claim were identified using the PPC methodology. A patient claim could have none or one or more PPCs assigned. No adjustment, other than the specified $200/$2 million exclusion, was made to exclude extraordinarily high or low cost claims

MODEL

Having created two independent analysis databases (Maryland and California), with admission APR DRGs assigned, approximate claim level costs calculated and PPCs identified, a simple linear regression was specified of the form:

$$\text{Cost}_i = \alpha + \beta_j \, \text{PPC}_{j,i} + \gamma_k \, \text{APR DRG}_{k,i} + \varepsilon_i$$

Where:

Cost_i is the adjusted charge for claim i

$\text{APR DRG}_{k,i}$ is a binary variable (0,1) indicating which of the 1,256 admission APR DRG K was assigned to the i^{th} claim

PPC_{ji} is a binary variable (0,1) indicating which of the j PPCs were present on the i^{th} claim

α is the average "cost" for a reference APR DRG, excluding the incidence of PPCs, which acts as a constant cost contribution to each claim

γ_k is the coefficient associated with APR DRG_k and measures the incremental cost above α due to the patient's reason for admission and admission severity of illness level

β_j is the coefficient associated with PPC_j and measures the incremental cost for patients with PPC_j relative to patients that do not have PPC_j

ε_i is the residual error of the model for discharge i

As specified, the regression model hypothesizes that cost increases associated with PPCs are both uniform and act independently of the base APR DRG and severity level to which they are assigned.

The hypothesized model treats the cost of complications as both additive and uniform across APR DRGs. Estimates of incremental cost associated with a specific PPC can therefore be interpreted as constant amounts independent of the specific APR DRG in which they occur and independent of the presence of other PPCs.

To calculate stable estimates two statistical conditions were applied to the data. First, if an APR DRG had fewer than 21 claims assigned, all patients assigned to the APR DRG were omitted from the analysis. Correcting for low volume APR DRGs is particularly important because an imprecise estimate of the average cost in an APR DRG could impact the estimate of the constant coefficient for a PPC applied across all APR DRGs.

Second, a *t*-test was applied to identify APR DRGs that had coefficients that were not statistically significant at the 0.05 level. Such APR DRGs were omitted from the analysis database because lack of statistical significance implies excessive cost volatility in those APR DRGs. No attempt was made to retain APR DRGs by introducing a synthetic outlier policy to reduce the impact of extraordinary costly claims. To do so would be to import assumptions surrounding the causation of outliers and potentially their relationship with PPCs. As detailed below, the application of these statistical edits had minimal impact on the final retention of claims within the analysis database.

The Maryland analysis database contained 659,816 claims. Twenty-nine of the possible 1,256 APR DRGs had no claim volume while 217 APR DRGs had fewer than 21 claims, resulting in 1,920 claims being removed from the analysis database. An additional 22 APR DRGs were not statistically significant resulting in an additional 5,914 claims to being removed from the analysis database. In total 7,834 (1.2%) claims were excluded leaving 651,982 claims assigned to 988 APR DRGs within the analysis database. After standardization the sum of adjusted charges (approximate cost) for the remaining claims was $6,504,557,501, approximately $9,980 per included claim. In the Maryland database 36,474 patients had one PPC (5.6%) and 14,518 patients had multiple PPCs (2.2%).

The California database contained 1,836,396 claims. Nineteen of the possible 1,256 APR DRGs had no claim volume while 150 APR DRGs had fewer than 21 claims, resulting in 1,214 claims to being removed from the analysis database. An additional 10 APR DRGs were not statistically significant resulting in an additional 1,147 claims to being removed from the analysis database. In total 2,361 (0.1%) claims were excluded leaving 1,834,035 claims assigned to 1,077 APR DRGs within the analysis database. After standardization the sum of adjusted charges (approximate cost) for these remaining claims was $18,509,876,873, approximately $10,090 per included claim. In the California database 72,819 patients had one PPC (4%) and 29,026 patients had multiple PPCs (1.6%).

RESULTS

The fit of the regression model for estimating per patient cost, measured by the adjusted R^2 statistic, was 0.58 for Maryland data and 0.60 for California data. This result is obtained by using the APR DRG assigned at admission with separate identification of PPCs that occur after admission to predict patient cost. The combination of admission APR DRGs and PPCs therefore offers a robust fit for the variation in per claim costs.

For each of the 64 PPCs in the second column of Table 1, the coefficient value (Coeff) measures the incremental patient cost (i.e., β_j) above that of patients in the same admission APR DRG associated with the presence of the PPC after accounting for the presence of other PPCs. This value is referred to as the incremental cost of the PPC. Since the regression model is additive, multiplying the frequency (Freq) of the PPC by its incremental cost calculates a total cost associated with each PPC. The total cost for all included claims in the Maryland data is $6,504,557,501, of which $626,416,710 (9.63%) is associated with PPCs.

The standard error (Std Error) is shown for each PPC. An asterisk in the standard error column indicates that the incremental cost estimate for the PPC is not statistically significant. Twelve PPCs were

Table 1
Estimated PPC Costs for Maryland Data

PPC	Description	Freq	Coeff	Std Error	% Total Cost	% Pat Cost
1	Stroke & Intracranial Hemorrhage	762	$13,006	$337	0.15%	28.30%
2	Extreme CNS Complications	559	$11,034	$407	0.09%	21.85%
3	Acute Pulmonary Edema and Respiratory Failure without Ventilation	4,863	$5,983	$140	0.45%	15.35%
4	Acute Pulmonary Edema and Respiratory Failure with Ventilation	815	$20,125	$333	0.25%	29.84%
5	Pneumonia & Other Lung Infections	4,615	$13,176	$143	0.93%	27.08%
6	Aspiration Pneumonia	1,598	$10,921	$236	0.27%	23.39%
7	Pulmonary Embolism	581	$9,646	$387	0.09%	20.24%
8	Other Pulmonary Complications	4,490	$7,333	$143	0.51%	18.03%
9	Shock	1,409	$11,012	$262	0.24%	16.39%
10	Congestive Heart Failure	2,296	$3,910	$196	0.14%	12.13%
11	Acute Myocardial Infarction	1,205	$5,463	$269	0.10%	14.24%
12	Cardiac Arrythmias & Conduction Disturbances	826	$2,779	$375	0.04%	5.69%
13	Other Cardiac Complications	520	$3,003	$404	0.02%	13.30%
14	Ventricular Fibrillation/Cardiac Arrest	637	$14,894	$372	0.15%	23.78%
15	Peripheral Vascular Complications Except Venous Thrombosis	310	$12,326	$528	0.06%	23.42%
16	Venous Thrombosis	1,602	$10,789	$236	0.27%	22.70%
17	Major Gastrointestinal Complications without Transfusion or Significant Bleeding	849	$10,009	$318	0.13%	24.37%
18	Major Gastrointestinal Complications with Transfusion or Significant Bleeding	257	$14,844	$576	0.06%	29.51%
19	Major Liver Complications	327	$8,813	$514	0.04%	15.97%
20	Other Gastrointestinal Complications without Transfusion or Significant Bleeding	444	$8,098	$441	0.06%	17.96%
21	Clostridium Difficile Colitis	1,282	$16,709	$261	0.33%	30.03%
22	Urinary Tract Infection	6,904	$6,345	$114	0.67%	19.61%
23	GU Complications Except UTI	545	$5,108	$396	0.04%	15.20%
24	Renal Failure without Dialysis	6,317	$7,748	$120	0.75%	22.25%
25	Renal Failure with Dialysis	183	$41,116	$685	0.12%	46.29%
26	Diabetic Ketoacidosis & Coma	73	($804)	$1,078 *	0.00%	-3.47%
27	Post-Hemorrhagic & Other Acute Anemia with Transfusion	1,104	$4,513	$280	0.08%	13.37%
28	In-Hospital Trauma and Fractures	313	$4,370	$525	0.02%	15.21%
29	Poisonings Except from Anesthesia	294	$1,577	$538	0.01%	9.66%
30	Poisonings due to Anesthesia	4	$116	$4,609 *	0.00%	0.43%
31	Decubitus Ulcer	1,009	$17,495	$295	0.27%	29.03%
32	Transfusion Incompatibility Reaction	7	$48,382	$3,505	0.01%	51.10%
33	Cellulitis	1,435	$2,346	$253	0.05%	6.76%
34	Moderate Infectious	1,179	$12,563	$274	0.23%	25.88%
35	Septicemia & Severe Infections	3,790	$13,156	$166	0.77%	23.74%
36	Acute Mental Health Changes	1,196	$3,980	$267	0.07%	15.05%
37	Post-Operative Infection & Deep Wound Disruption without Procedure	1,232	$14,446	$280	0.27%	24.22%

Table 1 — Continued
Estimated PPC Costs for Maryland Data

PPC	Description	Freq	Coeff	Std Error		% Total Cost	% Pat Cost
38	Post-Operative Wound Infection & Deep Wound Disruption with Procedure	61	$31,387	$1,189		0.03%	39.43%
39	Reopening Surgical Site	104	$14,298	$909		0.02%	24.75%
40	Post-Operative Hemorrhage & Hematoma without Hemorrhage Control Procedure or I&D Procedure	3,391	$6,190	$161		0.32%	17.64%
41	Post-Operative Hemorrhage & Hematoma with Hemorrhage Control Procedure or I&D Procedure	210	$11,602	$639		0.04%	23.11%
42	Accidental Puncture/Laceration During Invasive Procedure	1,641	$3,830	$236		0.10%	12.87%
43	Accidental Cut or Hemorrhage During Other Medical Care	104	$409	$919	*	0.00%	1.51%
44	Other Surgical Complication – Mod	458	$13,632	$433		0.10%	28.26%
45	Post-procedure Foreign Bodies	24	$3,688	$1,965	*	0.00%	9.68%
46	Post-Operative Substance Reaction & Non-O.R. Procedure for Foreign Body	2	$8,692	$6,801	*	0.00%	27.23%
47	Encephalopathy	1,255	$9,659	$264		0.19%	20.48%
48	Other Complications of Medical Care	1,420	$9,240	$246		0.20%	26.11%
49	Iatrogenic Pneumothrax	855	$7,633	$324		0.10%	19.52%
50	Mechanical Complication of Device, Implant & Graft	554	$13,244	$393		0.11%	29.14%
51	Gastrointestinal Ostomy Complications	347	$20,069	$498		0.11%	32.85%
52	Inflammation & Other Complications of Devices, Implants or Grafts Except Vascular Infection	1,151	$8,417	$276		0.15%	19.95%
53	Infection, Inflammation and Clotting complications of Peripheral Vascular Catheters and Infusions	732	$15,001	$348		0.17%	26.14%
54	Infections due to Central Venous Catheters	297	$22,304	$542		0.10%	29.90%
55	Obstetrical Hemorrhage without Transfusion	3,553	$162	$160	*	0.01%	2.37%
56	Obstetrical Hemorrhage with Transfusion	380	$2,058	$480		0.01%	17.53%
57	Obstetric Lacerations & Other Trauma without Instrumentation	1,528	$262	$239	*	0.01%	4.44%
58	Obstetric Lacerations & Other Trauma with Instrumentation	596	$634	$379	*	0.01%	10.38%
59	Medical & Anesthesia Obstetric Complications	647	$527	$367	*	0.01%	5.38%
60	Major Puerperal Infection and Other Major Obstetric Complications	285	$266	$552	*	0.00%	2.09%
61	Other Complications of Obstetrical Surgical & Perineal Wounds	207	$92	$645	*	0.00%	0.95%
62	Delivery with Placental Complications	263	$534	$571	*	0.00%	7.99%
63	Post-Operative Respiratory Failure with Tracheostomy	55	$120,579	$1,255		0.10%	59.02%
64	Other In-Hospital Adverse Events	730	$2,326	$343		0.03%	13.57%

NOTE: Change in total cost associated with PPCs is 9.63%.

SOURCE: Fuller,R.L., McCullough,E.C., Bao,M.Z., and Averill,R.F, 3M Health Information Systems, calculations using FY2008 Inpatient Acute Hospital Data, Maryland Health Services and Cost Review Commission.

found not to be statistically significant. PPC 32 "Transfusion Compatibility Reaction" is statistically significant but should be interpreted cautiously due to the low volume of observations. The impact upon total costs of the 13 PPCs that are not statistically significant is minimal.

In column 6 the total estimated cost for each PPC, (Freq*Coeff), is expressed as a percentage of total hospital costs. Thus, "Pneumonia and other lung factors", PPC 5, contributes 0.93% to total inpatient cost.

In column 7 the total estimated cost for each PPC, (Freq*Coeff), is divided by the total cost of all patients who had that PPC expressed as a percentage. Thus, for patients who had the PPC, column 7 is the average per patient cost increase due to the PPC. For example, UTIs (PPC 22) account for 0.67% of total inpatient hospital costs (column 6) and on average when a UTI occurs patient level cost increases by 19.6% (column 7).

Table 2 contains similarly derived estimates for the California data. California claims constitute a similar percentage of total costs associated with PPCs (9.39% percent for California versus 9.63% for Maryland). As shown in Table 2, 3 PPCs have no volume and 8 PPCs lacked statistical significance. As with Maryland data the impact of these PPCs upon total cost is minimal.

Table 3 ranks 48 PPC coefficient estimates that are considered statistically significant in both databases. Ranking is from low to high values. The Spearman's rank correlation coefficient is 0.90 indicating that the relative value of coefficient estimates is highly correlated between the two States.

The coefficient estimates for both California and Maryland data in Table 3 show significant bunching around PPC types. For example the eight PPCs with the lowest predicted values of incremental cost in the California data (Ranks 48 – 41) correspond with the same eight PPCs in Maryland data and occupy a range of $2,720 in California and $2,312 in Maryland.

The California PPC coefficients are larger for 41 of the 48 PPCs while the estimation of the percentage of total cost associated with complications is greater in Maryland. Given the independence of the two data sources it is not to be expected that the two sets of results would be identical, but it is worth addressing these findings in more detail.

Firstly, while the estimated incremental cost per PPC is generally higher in California than Maryland, the cost per claim utilized in the estimates for California is also higher ($10,090 versus $9,980). Moreover, to interpret the difference in coefficient magnitude from the two databases, the average claims value for each needs to be adjusted for case mix intensity. Relative weights for this purpose were calculated using the Healthcare Cost and Utilization Project (HCUP) claims data for CY2006. APR DRG V26.1 weights were calculated from claims data based upon time of discharge for this portion of the analysis. The resultant average statewide case mix value, case mix index (CMI), was computed for California and Maryland.

The CMI for the California claims was found to be 1.08, while the CMI for Maryland claims was 1.12. Deflating the average value observed for each database by its CMI yields adjusted values of $9,323 for California and $8,929 for Maryland. A more accurate comparison of coefficients is therefore obtained by reducing the magnitude of coefficients in the California data by 4.4% ($9,323/$8,929). This adjustment results in PPC 14 having a larger estimated coefficient for Maryland than California while the estimation differences between other PPCs is narrowed.

Table 2
Estimated PPC Costs for California Data

PPC	Description	Freq	Coeff	Std Error		% Total Cost	% Pat Cost
1	Stroke & Intracranial Hemorrhage	2,066	$14,013	$251		0.16%	22.54%
2	Extreme CNS Complications	675	$23,526	$442		0.09%	24.02%
3	Acute Pulmonary Edema and Respiratory Failure without Ventilation	5,712	$7,109	$153		0.22%	14.69%
4	Acute Pulmonary Edema and Respiratory Failure with Ventilation	2,725	$27,134	$227		0.40%	30.08%
5	Pneumonia & Other Lung Infections	10,781	$16,901	$115		0.98%	24.89%
6	Aspiration Pneumonia	4,483	$13,932	$174		0.34%	22.26%
7	Pulmonary Embolism	1,057	$16,331	$353		0.09%	25.44%
8	Other Pulmonary Complications	6,250	$11,566	$148		0.39%	18.32%
9	Shock	2,393	$10,996	$247		0.14%	12.25%
10	Congestive Heart Failure	5,922	$5,801	$151		0.19%	11.94%
11	Acute Myocardial Infarction	2,980	$8,147	$210		0.13%	16.79%
12	Cardiac Arrythmias & Conduction Disturbances	2,892	$4,431	$234		0.07%	6.68%
13	Other Cardiac Complications	1,029	$4,642	$353		0.03%	13.06%
14	Ventricular Fibrillation/Cardiac Arrest	1,759	$15,241	$275		0.14%	20.51%
15	Peripheral Vascular Complications Except Venous Thrombosis	732	$10,429	$421		0.04%	15.99%
16	Venous Thrombosis	3,376	$15,976	$201		0.29%	23.68%
17	Major Gastrointestinal Complications without Transfusion or Significant Bleeding	1,663	$12,574	$279		0.11%	21.15%
18	Major Gastrointestinal Complications with Transfusion or Significant Bleeding	530	$21,923	$492		0.06%	29.86%
19	Major Liver Complications	770	$12,217	$411		0.05%	16.63%
20	Other Gastrointestinal Complications without Transfusion or Significant Bleeding	910	$17,886	$377		0.09%	26.17%
21	Clostridium Difficile Colitis	2,478	$25,401	$230		0.34%	31.11%
22	Urinary Tract Infection	12,677	$9,637	$103		0.66%	21.48%
23	GU Complications Except UTI	796	$7,643	$401		0.03%	17.09%
24	Renal Failure without Dialysis	8,834	$9,934	$125		0.47%	18.50%
25	Renal Failure with Dialysis	620	$47,888	$459		0.16%	38.53%
26	Diabetic Ketoacidosis & Coma	48	$3,118	$1,629	*	0.00%	8.20%
27	Post-Hemorrhagic & Other Acute Anemia with Transfusion	1,492	$7,604	$294		0.06%	18.60%
28	In-Hospital Trauma and Fractures	429	$5,370	$547		0.01%	15.29%
29	Poisonings Except from Anesthesia	204	($574)	$790	*	0.00%	-2.50%
30	Poisonings due to Anesthesia	3	($7,457)	$6,508	*	0.00%	-41.58%
31	Decubitus Ulcer	1,668	$28,272	$280		0.25%	31.16%
32	Transfusion Incompatibility Reaction	3	$5,859	$6,508	*	0.00%	44.96%
33	Cellulitis	2,907	$4,950	$220		0.08%	10.20%
34	Moderate Infectious	2,483	$16,063	$231		0.22%	23.51%
35	Septicemia & Severe Infections	7,018	$23,451	$154		0.89%	26.59%
36	Acute Mental Health Changes	2,174	$3,206	$243		0.04%	10.08%
37	Post-Operative Infection & Deep Wound Disruption without Procedure	2,776	$14,347	$227		0.22%	20.50%

Table 2 — Continued

Estimated PPC Costs for California Data

PPC	Description	Freq	Coeff	Std Error		% Total Cost	% Pat Cost
38	Post-Operative Wound Infection & Deep Wound Disruption with Procedure	200	$27,814	$804		0.03%	29.67%
39	Reopening Surgical Site	408	$19,442	$562		0.04%	29.16%
40	Post-Operative Hemorrhage & Hematoma without Hemorrhage Control Procedure or I&D Procedure	6,925	$6,758	$138		0.25%	16.33%
41	Post-Operative Hemorrhage & Hematoma with Hemorrhage Control Procedure or I&D Procedure	614	$16,481	$458		0.05%	25.67%
42	Accidental Puncture/Laceration During Invasive Procedure	4,133	$5,651	$179		0.13%	15.13%
43	Accidental Cut or Hemorrhage During Other Medical Care	0					
44	Other Surgical Complication – Mod	925	$14,677	$373		0.07%	25.28%
45	Post-procedure Foreign Bodies	86	$10,846	$1,217		0.01%	24.15%
46	Post-Operative Substance Reaction & Non-O.R. Procedure for Foreign Body	2	$4,634	$7,972	*	0.00%	20.26%
47	Encephalopathy	2,164	$11,260	$246		0.13%	17.14%
48	Other Complications of Medical Care	1,128	$21,307	$339		0.13%	25.69%
49	Iatrogenic Pneumothrax	1,797	$7,508	$270		0.07%	15.68%
50	Mechanical Complication of Device, Implant & Graft	1,405	$15,655	$302		0.12%	26.04%
51	Gastrointestinal Ostomy Complications	732	$25,882	$420		0.10%	31.33%
52	Inflammation & Other Complications of Devices, Implants or Grafts Except Vascular Infection	3,289	$12,832	$201		0.23%	21.69%
53	Infection, Inflammation and Clotting complications of Peripheral Vascular Catheters and Infusions	3,399	$22,747	$205		0.42%	26.32%
54[1]	Infections due to Central Venous Catheters	0					
55	Obstetrical Hemorrhage without Transfusion	6,817	$441	$139		0.02%	9.19%
56	Obstetrical Hemorrhage wtih Transfusion	821	$3,081	$398		0.01%	27.32%
57	Obstetric Lacerations & Other Trauma without Instrumentation	6,194	$181	$145	*	0.01%	4.95%
58	Obstetric Lacerations & Other Trauma with Instrumentation	2,612	$617	$222		0.01%	15.70%
59	Medical & Anesthesia Obstetric Complications	1,812	$558	$268		0.01%	6.88%
60	Major Puerperal Infection and Other Major Obstetric Complications	1,133	$1,200	$338		0.01%	11.49%
61	Other Complications of Obstetrical Surgical & Perineal Wounds	892	($688)	$383	*	0.00%	-8.09%
62	Delivery with Placental Complications	1,130	$497	$337	*	0.00%	10.86%
63	Post-Operative Respiratory Failure with Tracheostomy	164	$118,841	$892		0.00%	50.78%
64	Other In-Hospital Adverse Events	0					

[1] The lack of an estimate for PPC 54 in the California data results from the timing of the data source. PPC 54 was created using the increased specificity afforded by the creation of the code 999.31 within the ICD-9-CM classification system. The California data predates the creation of this code.

NOTE: Change in total cost associated with PPCs is 9.39%.

SOURCE: Fuller,R.L., McCullough,E.C., Bao,M.Z., and Averill,R.F, 3M Health Information Systems, calculations using FY2006 Inpatient Acute Hospital Data, California Office of Statewide Health Planning and Development.

Table 3
Ranking of PPC Cost for California and Maryland Data

PPC	Description	Fqcy	Coeff	CA Rank	Fqcy	Coeff	MD Rank
63	Post-Operative Respiratory Failure with Tracheostomy	164	$118,841	1	55	$120,579	1
25	Renal Failure with Dialysis	620	$47,888	2	183	$41,116	2
31	Decubitus Ulcer	1,668	$28,272	3	1,009	$17,495	6
38	Post-Operative Wound Infection & Deep Wound Disruption with Procedure	200	$27,814	4	61	$31,387	3
4	Acute Pulmonary Edema and Respiratory Failure with Ventilation	2,725	$27,134	5	815	$20,125	4
51	Gastrointestinal Ostomy Complications	732	$25,882	6	347	$20,069	5
21	Clostridium Difficile Colitis	2,478	$25,401	7	1,282	$16,709	7
2	Extreme CNS Complications	675	$23,526	8	559	$11,034	21
35	Septicemia & Severe Infections	7,018	$23,451	9	3,790	$13,156	16
53	Infection, Inflammation and Clotting complications of Peripheral Vascular Catheters and Infusions	3,399	$22,747	10	732	$15,001	8
18	Major Gastrointestinal Complications with Transfusion or Significant Bleeding	530	$21,923	11	257	$14,844	10
48	Other Complications of Medical Care	1,128	$21,307	12	1,420	$9,240	28
39	Reopening Surgical Site	408	$19,442	13	104	$14,298	12
20	Other Gastrointestinal Complications without Transfusion or Significant Bleeding	910	$17,886	14	444	$8,098	31
5	Pneumonia & Other Lung Infections	10,781	$16,901	15	4,615	$13,176	15
41	Post-Operative Hemorrhage & Hematoma with Hemorrhage Control Procedure or I&D Procedure	614	$16,481	16	210	$11,602	20
7	Pulmonary Embolism	1,057	$16,331	17	581	$9,646	27
34	Moderate Infectious	2,483	$16,063	18	1,179	$12,563	18
16	Venous Thrombosis	3,376	$15,976	19	1,602	$10,789	24
50	Mechanical Complication of Device, Implant & Graft	1,405	$15,655	20	554	$13,244	14
14	Ventricular Fibrillation/Cardiac Arrest	1,759	$15,241	21	637	$14,894	9
44	Other Surgical Complication - Mod	925	$14,677	22	458	$13,632	13
37	Post-Operative Infection & Deep Wound Disruption Without Procedure	2,776	$14,347	23	1,232	$14,446	11
1	Stroke & Intracranial Hemorrhage	2,066	$14,013	24	762	$13,006	17
6	Aspiration Pneumonia	4,483	$13,932	25	1,598	$10,921	23
52	Inflammation & Other Complications of Devices, Implants or Grafts Except Vascular Infection	3,289	$12,832	26	1,151	$8,417	30
17	Major Gastrointestinal Complications without Transfusion or Significant Bleeding	1,663	$12,574	27	849	$10,009	25
19	Major Liver Complications	770	$12,217	28	327	$8,813	29
8	Other Pulmonary Complications	6,250	$11,566	29	4,490	$7,333	34
47	Encephalopathy	2,164	$11,260	30	1,255	$9,659	26
9	Shock	2,393	$10,996	31	1,409	$11,012	22
15	Peripheral Vascular Complications Except Venous Thrombosis	732	$10,429	32	310	$12,326	19
24	Renal Failure without Dialysis	8,834	$9,934	33	6,317	$7,748	32
22	Urinary Tract Infection	12,677	$9,637	34	6,904	$6,345	35
11	Acute Myocardial Infarction	2,980	$8,147	35	1,205	$5,463	38

Table 3 — Continued
Ranking of PPC Cost for California and Maryland Data

PPC	Description	Fqcy	Coeff	CA Rank	Fqcy	Coeff	MD Rank
23	GU Complications Except UTI	796	$7,643	36	545	$5,108	39
27	Post-Hemorrhagic & Other Acute Anemia with Transfusion	1,492	$7,604	37	1,104	$4,513	40
49	Iatrogenic Pneumothrax	1,797	$7,508	38	855	$7,633	33
3	Acute Pulmonary Edema and Respiratory Failure without Ventilation	5,712	$7,109	39	4,863	$5,983	37
40	Post-Operative Hemorrhage & Hematoma without Hemorrhage Control Procedure or I&D Procedure	6,925	$6,758	40	3,391	$6,190	36
10	Congestive Heart Failure	5,922	$5,801	41	2,296	$3,910	43
42	Accidental Puncture/Laceration During Invasive Procedure	4,133	$5,651	42	1,641	$3,830	44
28	In-Hospital Trauma and Fractures	429	$5,370	43	313	$4,370	41
33	Cellulitis	2,907	$4,950	44	1,435	$2,346	47
13	Other Cardiac Complications	1,029	$4,642	45	520	$3,003	45
12	Cardiac Arrythmias & Conduction Disturbances	2,892	$4,431	46	826	$2,779	46
36	Acute Mental Health Changes	2,174	$3,206	47	1,196	$3,980	42
56	Obstetrical Hemorrhage wtih Transfusion	821	$3,081	48	380	$2,058	48

SOURCE: Fuller,R.L., McCullough,E.C., Bao,M.Z., and Averill,R.F, 3M Health Information Systems, calculations using FY2006 Inpatient Acute Hospital Data, California Office of Statewide Health Planning and Development and FY2008 Inpatient Acute Hospital Data, Maryland Health Services and Cost Review Commission.

A second contributing factor to the observed differences is the relationship between patient severity at the time of admission and the frequency of complications (Hughes et al., 2006; Thomas and Brennan, 2000). Academic Medical Centers (AMCs) tend both to treat patients of higher severity and to be higher cost hospitals. The combination of these two factors means that complications at AMCs are likely to be more frequent and to be relatively more costly as they originate in settings with relatively more expensive cost structures. Maryland data was adjusted for the inflationary effects of IME and DSH while California data was not. The lack of standardization acts to increase the estimated coefficients within California relative to Maryland. The magnitude of this bias is unknown.

A third contributing factor to the observed differences is the relative completeness with which diagnoses are coded upon claims. Within the California database secondary diagnosis codes were submitted at an average rate of 5.1 per claim. For the Maryland database this figure rises to 9.1 per claim. Unsurprisingly the frequency with which PPCs are submitted on Maryland claims is greater than that observed in California, both for claims with single (5.6% versus 4.0%) and multiple (2.2% versus 1.6%) PPCs. Maryland's all-payer claims data is the basis for hospital payment and uses the APR DRG classification system. The change to APR DRG based payment has been accompanied by an increase in coding completeness (Health Services Cost Review Commission, 2005). Variation in coding completeness impacts both the estimation of per PPC cost and the estimate of total cost associated with complications. The regression model can not distinguish increased cost attributed to complications where no complication is reported. Since the incremental cost associated with a PPC is estimated relative to the underlying average APR DRG cost, the estimate of incremental PPC costs will be reduced if no complications are reported. This results because the cost of unreported complications within the regression is attributed to the APR DRG average cost. This effect is likely to be relatively small as claims with PPCs make up relatively small percentages of claims within an APR DRG. However, for claims with at least one PPC, the failure to code all PPCs which are truly present causes the incremental cost associated with other uncoded PPCs to be attributed to the incremental cost estimate of coded PPCs. This effect may have a more substantial impact on the estimate of incremental PPC cost than the costs of some PPCs being incorrectly attributed to the APR DRG average cost. If complications are being more consistently reported in Maryland then the expectation would be for the estimate of incremental PPC cost in Maryland to be lower than that for California.

Data limitations and differences in the pattern of coding may therefore explain variations in both the frequency of complications and their associated contribution to total hospital cost. The source of variation may also stem from real differences being observed in the data. For example, the increased frequency of complications may result from lower quality hospital care in Maryland an interpretation that can neither be rejected nor supported in this analysis; however, there is no externally corroborating evidence that lower quality care in Maryland is a causal factor. External rankings of statewide hospital quality tend to indicate that the opposite is in fact true (HealthGrades, 2007). Alternatively the frequency of reported complications may be higher in Maryland due to a greater underlying complexity in patient mix. This statement does find some support in the observed difference in CMI.

DISCUSSION

The accuracy of the incremental cost estimates for the PPCs assumes that APR DRGs provide an adequate measure of patient severity of illness. It is particularly important that there are no unmeasured aspects of severity of illness with strong correlation to the presence of PPCs that would serve to increase costs and upwardly bias estimates of the incremental cost of PPCs. If such unmeasured aspects of severity of illness existed then it can be hypothesized that patients with unmeasured severity would be concentrated in hospitals with certain characteristics. One study simulated an APR DRG based payment system using California data in which payments were reduced when a major PPC was present (Averill et al., 2006). Using the hospital payment reduction due to PPCs as the dependent variable, the impact of the reduction upon the hospital case-mix index and number of hospital discharges was estimated using a regression model. The adjusted R^2 for the model was only 13.28 indicating a weak association between PPC related payment reductions and these hospital characteristics. While not conclusive, the results suggest that the extent to which unmeasured severity influences the estimates of incremental cost associated with PPCs is minimal.

Central to the analysis is an assumption that the post admission complications identified by the PPCs are preventable. One study demonstrated that catheter-related blood stream infections, PPC 54, could be reduced by 66 percent through evidence based interventions (Pronovost, Goeschel, and Wachter, 2008). Unfortunately, there is very little data like that for catheter-associated blood stream infection that explicitly quantifies the preventability of specific types of complications. The New York Department of Health has provided comparative reports on PPC rates to New York hospitals for several years. Some hospitals have reported that they have been able to use the PPC reports to lower the occurrence of complications (Editorial Board, 2009). Except for a few so-called "never events" that are almost always related to preventable medical errors—such as foreign objects left in after surgery—complications will never be totally preventable even with optimal care (Averill et al., 2009). Most post-admission complications (such as pulmonary embolism or post-operative MI) are not clearly linked to medical errors, and although they may relate to errors in judgment or lapses in execution that reflect poor quality care, they cannot be considered always preventable.

Of the 64 categories of preventable complications (PPCs) evaluated with the Maryland and California data, statistically significant estimates for incremental costs were obtained for 48. Incremental PPC costs are estimated to account for more than 9% of total inpatient hospital cost. Earlier studies have estimated the cost of catheter-related blood stream infections at $18,000 compared to the $22,000 observed in the Maryland data found here which offers a measure of reasonableness for the results (Perencevich and Pittet, 2009). The impact PPCs are seen to have on hospital cost demonstrates that there are substantial opportunities for both hospitals and payers to improve quality while reducing expenditure. The Medicare inpatient PPS fully incorporates PPC related cost into relative weights. The narrow definition of HACs, as currently employed by CMS, has such a limited impact on payments that the Medicare inpatient PPS essentially continues to pay the full MS DRG payment rate for virtually all patients. Thus, if hospitals can reduce their PPC rates, they can substantially increase their per case profit margins. Conversely, payers are paying hospitals at a level that includes substantial costs associated with PPCs. Payers need to provide hospitals greater incentive to reduce complications by reducing payments when a PPC occurs.

Hospital payment systems can be complex with many interrelated adjustments, necessitating payment redesign to be carried out with care. For example, in the Medicare inpatient PPS, the removal of a PPC diagnosis from MS DRG assignment can be used to assign the patient to a lower paying MS DRG. However, the assignment to a lower paying MS DRG may make the hospital eligible for outlier payments which could entirely or partially offset the payment reduction. Thus, as payment adjustments for complications are imposed, the impact on outlier payments must be taken into consideration by adjusting outlier threshold levels. Data on the cost of specific types of complications, such as those presented in this article, will be essential to such adjustments. Identifying the cost of specific complication types can also act as a basis for payers contracting under per diem arrangements to introduce actuarially representative quality incentives.

The inherent probabilistic nature of the preventability of complications presents significant problems for the expansion of the current CMS payment policy related to hospital acquired complications (HACs). For every case with an HAC, the HAC payment policy eliminates the entire payment increase generated by the HAC implying that HACs are always preventable. As a result, HACs have been limited to the relatively few complications that are, arguably, nearly always preventable but have minimal impact on Medicare inpatient hospital expenditures. In order to substantially increase the scope of HACs, the current HAC case-by-case payment reductions and the implied preventability of the HAC for an individual patient will need to be changed.

MedPAC has proposed a readmission payment policy that would "reduce payments to hospitals with relatively high readmission rates" (MedPAC, 2008). Similarly, the HAC payment policy could be revised to reduce payments for hospitals with high HAC rates. Assuming that the number of excess HACs in a hospital can be identified by comparison of risk-adjusted HAC rates then the number of excess HACs in a hospital will need to be converted into a payment adjustment amount for the hospital. Estimates of incremental costs for PPCs, like those computed here, can provide a basis for converting the excess complications observed in a hospital into a payment adjustment amount, thereby expanding the policy options open to CMS for expanding the range of complications applicable to a payment reduction.

It was beyond the scope of this analysis to include additional costs associated with a complication that are incurred beyond the inpatient stay. The end of a hospitalization does not mark the period where all hospital acquired complications have become apparent. The estimate of incremental PPC costs carried out here does not factor in the degree of preventability of a complication or how much of the identified hospital cost may be considered fixed rather than variable.

The use of claims data, whether to identify complications or to estimate incremental costs, is not free from criticism. Claims submissions are subject to variation in accuracy, both through the coding and documentation process. Hospital accounting functions are rarely sophisticated enough to identify and allocate patient level costs, while the standardizing of hospital cost data has already been described here as both imperfect and offering the potential for bias.

Variation in coding completeness can contribute to both bias in the total estimated cost of complications and the estimate of incremental costs for individual PPCs. Despite these potential data limitations the hypothesized model delivers statistically valid estimates for the incremental cost of complications within the data sets from which they are drawn. These results, obtained from two distinct sources, are generally consistent providing an indication of the robustness of both the method and results.

CONCLUSION

Two State's claims databases, from disparate regions of the country, with hospitals paid under different auspices and with cost standardized using different methods, independently yield very similar estimates for the cost of potentially preventable complications. At a patient level the impact of preventable complications on cost for many routinely observed complications, such as UTIs and catheter-related blood stream infections, is substantial.

Potentially preventable complications are estimated to add 9.4% - 9.7% to hospital inpatient costs. With national estimates of inpatient hospital care costs totaling $940 billion in 2006 (American Hospital Association, 2008), the 9.4% estimate is indicative of an $88 billion issue for the nation. The 0.02 % HAC payment reduction currently implemented by Medicare while very limited in scope is an important first step toward addressing a problem with substantial cost implications.

The robust incremental cost estimates for complications, obtained by treating hospital acquired complications as additive, categorical events, may open the door to alternative ways to design payment systems so as to provide greater incentives to significantly reduce hospital complications.

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