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# Hospital Costs by Cost Center of Inpatient Hospitalization for Medicare Patients Undergoing Major Abdominal Surgery



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- BACKGROUND:** This study aims to describe the magnitude of hospital costs among patients undergoing elective colectomy, cholecystectomy, and pancreatectomy, determine whether these costs relate as expected to duration of care, patient case-mix severity and comorbidities, and whether risk-adjusted costs vary significantly by hospital. Correctly estimating the cost of production of surgical care may help decision makers design mechanisms to improve the efficiency of surgical care.
- STUDY DESIGN:** Patient data from 202 hospitals in the ACS-NSQIP were linked to Medicare inpatient claims. Patient charges were mapped to cost center cost-to-charge ratios in the Medicare cost reports to estimate costs. The association of patient case-mix severity and comorbidities with cost was analyzed using mixed effects multivariate regression. Cost variation among hospitals was quantified by estimating risk-adjusted hospital cost ratios and 95% confidence intervals from the mixed effects multivariate regression.
- RESULTS:** There were 21,923 patients from 202 hospitals who underwent an elective colectomy (n = 13,945), cholecystectomy (n = 5,569), or pancreatectomy (n = 2,409). Median cost was lowest for cholecystectomy (\$15,651) and highest for pancreatectomy (\$37,745). Room and board costs accounted for the largest proportion (49%) of costs and were correlated with length of stay,  $R = 0.89$ ,  $p < 0.001$ . The patient case-mix severity and comorbidity variables most associated with cost were American Society of Anesthesiologists (ASA) class IV (estimate 1.72, 95% CI 1.57 to 1.87) and fully dependent functional status (estimate 1.63, 95% CI 1.53 to 1.74). After risk-adjustment, 66 hospitals had significantly lower costs than the average hospital and 57 hospitals had significantly higher costs.
- CONCLUSIONS:** The hospital costs estimates appear to be consistent with clinical expectations of hospital resource use and differ significantly among 202 hospitals after risk-adjustment for preoperative patient characteristics and procedure type. (J Am Coll Surg 2015;220:207–217. © 2015 by the American College of Surgeons)
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The amount of money the US spends on health care is typically expressed as charges or costs.<sup>1-4</sup> In some studies, cost is the amount of money a payer, such as Medicare or Blue Cross, pays for health care. In other studies, costs might represent the amount of resources a geographically based population uses on health care, such as how much money is expended on health care in California.

Rarely discussed is how much it costs for a hospital to provide care for an individual patient with a specific problem, such as a patient undergoing a cholecystectomy—what herein will be referred to as hospital costs. Hospital costs are the sum of the hospital's expenditures in caring for the patient. This can be derived in at least 2 ways. One is directly through the hospital's accounting database.<sup>5,6</sup>

**Abbreviations and Acronyms**

ASA = American Society of Anesthesiologists  
CBSA = core-based statistical area  
IQR = interquartile range

This is done by calculating individual patient costs based on the itemized clinical care activity recorded for each patient in the database. In addition, costs for hospital infrastructure such as administration, billing, and electricity are included. However, because access to these data is usually available only to personnel within the hospital organization, studies based on accounting databases have typically been limited to single hospitals or hospital systems. A second way to estimate hospital costs is to convert patient charges reported in publicly available Medicare claims data to costs using hospital cost-to-charge ratios.<sup>7-12</sup> This method has the substantial advantage that it can be used to determine the hospital costs for patients cared for in diverse hospitals. These individual patient costs can be disaggregated into cost centers.<sup>9</sup>

There were 3 aims for this work. The first was to describe the distribution and magnitude of costs a hospital incurs to care for patients with 1 of 3 common surgical conditions, in aggregate and by cost center. The second was to examine whether costs varied with length of stay, operating room time, patient case-mix severity, and other patient comorbidities (measured using ACS-NSQIP data), as was anticipated from clinical experience. The third was to assess the extent to which there was significant residual variation in hospital cost after risk adjusting for patient case-mix severity, comorbidities, and procedure type.

**METHODS****Data sources and measures**

Three data sources were used: a clinical data source, an administrative data source, and Medicare cost reports. The clinical data source was the American College of Surgeons' National Surgical Quality Improvement Program (ACS-NSQIP). The ACS-NSQIP is a voluntary clinical registry that uses dedicated full-time trained surgical clinical reviewers who use strict data definitions to collect preoperative demographic and comorbidity patient variables, procedural, and postoperative 30-day patient outcomes data. Regular audits of a sample of hospitals are performed to ensure accuracy of data collection. This clinical dataset was merged with an administrative dataset, the Medicare Provider Analysis and Review File (Medpar), from 2005 to 2008, using indirect patient identifiers and a deterministic linkage algorithm, previously

described.<sup>13</sup> The data elements in this file included demographics (sex, race or ethnicity, and age), dates of admission and discharge, ICD-9 diagnosis codes, ICD-9 procedure codes, and disaggregated cost-center charges. The third data source was the Medicare cost reports that are an annual compilation of all hospitals' reported costs and charges by cost centers. These data can be used to generate a cost-to-charge ratio for each cost center for each hospital for each fiscal year. These hospital, fiscal year, cost center-specific cost-to-charge ratios were merged with the Medicare claims data and used to estimate hospital costs from patient disaggregated cost-center charges in the Medicare inpatient claims file.

**Primary outcome**

The primary outcome was the estimated cost of the inpatient surgical hospitalization from the hospital's perspective. The claims data in the Medicare inpatient claims data file contain the disaggregated patient charges in 32 cost centers. Hospitals annually report all of their costs and charges by 44 cost centers to Medicare. These publicly available cost and charge data (by 44 cost centers) were aggregated into 12 discrete cost centers, as has been done in previous work (Appendix 1, online only), and were used to generate cost-to-charge ratios for each cost center for each hospital for each fiscal year. Extreme, unfeasible outliers in the cost-to-charge ratios were observed, as have been previously reported.<sup>9</sup> Cost-to-charge ratios within each of the 12 cost centers were therefore pulled in (winsorized) to the 2.5 and 96 percentiles, as previously done with these data.<sup>9</sup> These hospital, fiscal year, cost center-specific cost-to-charge ratios were merged with the Medicare claims data and used to estimate hospital costs from disaggregated patient charges in the Medicare inpatient claims file. All costs were inflated to 2013 dollars using the Medicare Market Basket Index. Regional differences in wage rates were adjusted for using the regional wage index. Finally, all patient costs at the cost center level were winsorized to the 0.25 percentile and the 99.75 percentile cost, to minimize the influence of extreme cost outliers.

Hospital cost allocation to cost centers was then examined by calculating the proportion of total annual hospital costs allocated to 5 of 12 of the largest cost centers: intensive care, operating room, supply, pharmacy, and laboratory. Although the variation in proportion of total annual hospital costs depended on the cost center, the interquartile ranges (IQR) were fairly narrow. A median of 5% of total hospital annual costs were attributed to intensive care, with a narrow IQR of 4% to 6%. A median of 10% of total hospital annual costs were attributed to operating room, with an IQR of 8% to 14%. A median of 8%

of total hospital annual costs were attributed to supply, with an IQR of 3% to 14%. A median of 8% of total hospital annual costs were attributed to pharmacy, with an IQR of 7% to 10%. A median of 6% of total hospital annual costs were attributed to laboratory, with an IQR of 5% to 7%. There was not a great deal of variation in how hospitals allocated direct costs to cost centers.

### Patient sample

We identified all 27,971 Medicare beneficiaries 65 years and older undergoing 1 of the 3 most common elective abdominal operations (colectomy, cholecystectomy, pancreatectomy: defined by current procedural terminology [CPT] codes in [Appendix 2](#), online only) at participating ACS-NSQIP hospitals, from 2005 until the end of 2008. From this number, patients recorded as undergoing an emergent operation in ACS-NSQIP ( $n = 5,352$ ) and patients who sought care at a hospital without a recorded regional wage index for the year the patient encounter occurred ( $n = 696$ ) were excluded. The final sample consisted of 13,945 colectomy patients, 5,569 cholecystectomy patients, and 2,409 pancreatectomy patients who were operated on between 2005 and 2008 at one of 202 ACS-NSQIP participating hospitals.

### Statistical analysis

Descriptive statistics of patient case-mix severity measures, comorbidities, and costs were performed. In this analysis, case-mix severity is used to describe American Society of Anesthesiologists (ASA) class and functional status, 2 ordinal scoring systems that attempt to capture the general gestalt picture of a patient's overall health. The descriptive statistics included counts and frequencies for patient case-mix severity and comorbidities. Median and IQR were calculated for the duration of care in terms of length of stay and operative time for each operation type. Median and IQR total costs, and for individual cost centers, were calculated for each of the 3 operations.

The correlations of cost center costs (room and board and operating room) with established measures of duration of care (length of stay and operative time) were determined using the Spearman correlation. The associations between cost and patient case-mix severity, comorbidities, and procedure type were determined using multivariable regression. Initial bivariate ordinary least squares regressions were run for each of the patient characteristics, case-mix severity, and comorbidities captured in ACS-NSQIP against log-transformed hospital cost. The CPT code variable was created as a single nominal categorical variable with laparoscopic cholecystectomy serving as the reference category for the other procedures and was

used to estimate the influence of procedure type on cost. All patient and procedural variables significantly associated with log-transformed hospital cost on bivariate regressions were included in multivariable ordinary least squares regression using stepwise selection to identify variables associated with log-transformed hospital costs. The  $R^2$  of this model assessed how much variance the model explained. In total, 21 variables (sex, age, functional status, ASA classification, previous surgery within 30 days, open wound at time of surgery, greater than 10% body weight loss in previous 6 months before surgery, CPT code, wound classification, COPD, preoperative ventilator use, preoperative dialysis use, ascites, hypertension, myocardial infarction, congestive heart failure, cancer, steroid use preoperatively, bleeding disorder, preoperative transfusion, and preoperative sepsis) selected were included in a mixed effects multivariate gamma regression to obtain precise estimates of how each variable was associated with cost (with a strongly right skewed distribution), while adjusting for hospital level clustering using a random intercept.

Hospital variation in risk-adjusted cost was examined by calculating the hospital cost ratio as the exponentiated best linear unbiased predictor of the hospitals (random) intercept, with 95% confidence intervals. This value will be referred to as the (risk-adjusted) hospital cost ratio estimate. The hospital cost ratio estimate is interpreted as the ratio of that hospital's costs over the average hospital's costs with equivalent patient case-mix severity, comorbidities, and procedure type. Confidence intervals for these hospital cost ratio estimates were sorted from lowest to highest point estimate into a caterpillar plot. If the lower 95% confidence limit was greater than 1, then the hospital had significantly higher costs than the "average", or grand mean of all, hospitals in this analysis. If the upper 95% confidence limit was less than 1, then the hospital had significantly lower costs than the grand mean of all hospitals in the analysis. It should be reinforced that the cost ratio estimate quantifies how hospitals performed with respect to the grand mean of all hospitals in the analysis, not with respect to one another.

In order to further qualify variation in cost based on hospital setting, patient costs were compared across core-based statistical areas (CBSA). Initial nonparametric bivariate comparisons (Kruskal-Wallis tests) were done to determine whether unadjusted costs varied among division metropolitan, metropolitan, micropolitan, and rural CBSAs. An adjusted comparison was then performed using the same mixed effects multivariate gamma regression described above, including CBSA type and comparing the adjusted change in cost among CBSAs.

**Table 1.** Demographic and Clinical Preoperative Characteristics of Patients by Elective Operation

Patient characteristics	Colectomy (total n = 13,945)		Cholecystectomy (total n = 5,569)		Pancreatectomy (total n = 2,409)	
	n	%	n	%	n	%
Demographic variables						
Male sex	6,188	44.4	2,646	47.5	1,176	48.8
Age category, y						
65–74	6,176	44.3	2,438	43.8	1,311	54.4
75–84	5,813	41.7	2,338	42.0	985	40.9
≥85	1,956	14.0	793	14.2	113	4.8
Procedural variables						
Wound class						
Clean	0	0.0	2	0.0	93	3.9
Clean-contaminated	11,973	85.9	3,716	66.7	2,115	87.8
Contaminated	1,260	9.0	1,377	24.7	162	6.7
Dirty/infected	712	5.1	474	8.5	39	1.6
Metabolic conditions						
BMI, kg/m <sup>2</sup>						
<18.5	664	4.8	334	6.0	101	4.2
18.5–24	4,752	34.1	1,525	27.4	906	37.6
25–29	4,825	34.6	1,967	35.3	928	38.5
30–34	2,407	17.3	1,041	18.7	333	13.8
35–39	860	6.2	447	8.0	101	4.2
≥40	437	3.1	255	4.6	40	1.7
Diabetes						
No diabetes	11,344	81.4	4,285	76.9	1,811	75.2
Non-insulin dependent	1,818	13.0	850	15.3	365	15.2
Insulin dependent	783	5.6	434	7.8	233	9.7
Cardiac conditions						
Hypertension	9,644	69.2	4,176	75.0	1,623	67.4
Myocardial infarction	139	1.0	62	1.1	10	0.4
Congestive heart failure	263	1.9	165	3.0	9	0.4
Percutaneous coronary intervention	1,268	9.1	662	11.9	234	9.7
Cardiac surgery	1,491	10.7	884	15.9	220	9.1
Pulmonary conditions						
Preoperative pneumonia	69	0.5	56	1.0	5	0.2
Dyspnea on exertion	2,411	17.3	924	16.6	287	11.9
COPD	1,199	8.6	540	9.7	144	6.0
Smoker	1,394	10.0	443	8.0	284	11.8
Ventilator dependency	63	0.5	18	0.3	2	0.1
Hematology and oncology conditions						
Chemotherapy	173	1.3	45	0.8	21	0.9
Disseminated cancer	636	4.6	87	1.6	64	2.7
Transfusion	88	0.6	5	0.1	2	0.1
Bleeding disorder	906	6.5	642	11.5	81	3.4
Steroid	537	3.9	205	3.7	55	2.3
Liver conditions, ascites	210	1.5	117	2.1	21	0.9
Renal conditions						
Renal failure	47	0.3	32	0.6	5	0.2
Dialysis	42	0.3	37	0.7	2	0.1

(Continued)

**Table 1.** Continued

Patient characteristics	Colectomy (total n = 13,945)		Cholecystectomy (total n = 5,569)		Pancreatectomy (total n = 2,409)	
	n	%	n	%	n	%
Acuity of illness						
Functional status						
Independent	12,522	89.8	4,795	86.1	2,324	96.5
Partially dependent	1,150	8.3	619	11.1	77	3.2
Fully dependent	273	2.0	155	2.8	8	0.3
American Society of Anesthesiologists Class						
I	130	0.9	47	0.8	14	0.6
II	4,924	35.3	1,751	31.5	558	23.2
III	7,788	55.9	3,289	59.1	1,701	70.7
IV	1,079	7.7	479	8.6	134	5.6
V	22	0.2	1	0.0	0	0.0
Weight loss in previous 6 mo	778	5.6	219	3.9	425	17.6
Open wound	316	2.3	128	2.3	22	0.9
Previous surgery	214	1.5	90	1.6	50	2.1
Impaired sensorium	186	0.9	86	1.5	3	0.1
Sepsis						
No sepsis	13,128	94.1	4,577	82.2	2,370	98.4
Systemic inflammatory response	591	4.2	804	14.4	33	1.4
Sepsis	161	1.2	150	2.7	5	0.2
Septic shock	65	0.5	38	0.7	1	0.0

Last, to further explain some of the variation in patient cost of surgical care, patient costs were compared among patients who had no complications, patients who had at least one morbidity, and patients who had a mortality. Nonparametric bivariate comparisons (Kruskal-Wallis test) were done to determine whether unadjusted costs varied among patients who had no complications, those who had at least one morbidity, and those who had a mortality. The RAND Corporation institutional review board approved this study. All data management and analyses were performed in SAS 9.3.

## RESULTS

A total of 21,923 patients from 202 hospitals were determined to have undergone 1 of the 3 most common abdominal operations. Colectomies were the most common abdominal procedures, accounting for 64% of patients (Table 1). Of the 21,923 patients, the largest proportion of patients, 44%, were between the ages of 65 and 75, 44% were male, 2% of patients had congestive heart failure preoperatively, and 9% had COPD. Most patients (58%) had an ASA class of III, and 7% of patients had lost more than 10% of their body weight in the 6 months preceding surgery.

Patients' median length of stay was 7 days, with an IQR difference of 8 days. The median length of stay varied

with the type of abdominal surgery, from 5 days for a cholecystectomy (IQR difference, 5 days), 7 days for a colectomy (IQR difference, 5 days), and 9 days for a pancreatectomy (IQR difference, 8 days). Median operative time was 120 minutes for all operations (IQR difference, 99 minutes), but ranged from a median of 83 minutes (IQR difference, 61 minutes) for a cholecystectomy, 137 minutes (IQR difference, 88 minutes) for a colectomy, to 335 minutes (IQR difference, 160 minutes) for a pancreatectomy.

Total costs varied among the different abdominal operations. The median total cost of care ranged from \$15,651 (IQR, \$9,923 to \$25,289) for cholecystectomy, to \$37,745 (IQR, \$28,193 to \$57,213) for a pancreatectomy (Table 2). Patient room and board costs accounted for the largest proportion of total patient costs, accounting for 50% of costs in colectomy patients and 46% of costs in both cholecystectomy and pancreatectomy patients. The median room and board cost among all abdominal operations was \$10,747 (IQR, \$6,496 to \$18,255). Median room and board costs ranged from \$7,232 (IQR, \$3,859 to \$12,791) for cholecystectomy to \$17,250 (IQR, \$11,651 to \$28,332) for pancreatectomy. Room and board costs were highly correlated with length of stay ( $R = 0.89$ ,  $p < 0.0001$ ). Operating room costs accounted for the next highest proportion of

**Table 2.** Distribution of Unadjusted Hospital Cost by Cost Centers by Type of Abdominal Operations

Cost center	Mean, \$*	Median, \$*	Interquartile range, \$*
<b>All operations</b>			
Total cost	32,402	21,980	14,504–35,821
Room and board	15,744	10,747	6,496–18,255
ICU	3,546	0	0–3,137
Operating room	4,075	3,514	2,473–4,979
Supply	3,147	2,176	1,114–3,880
Pharmacy	2,183	1,055	559–2,141
Laboratory	1,349	734	348–1,575
Other	832	229	0–835
Radiology	732	172	0–948
Respiratory	356	10	0–185
Therapy	265	71	0–348
Anesthesia	365	269	156–470
Cardiology	181	31	0–120
<b>Colectomy</b>			
Total cost	32,659	22,193	15,467–35,150
Room and board	16,208	11,214	7,163–18,477
ICU	3,391	0	0–2,800
Operating room	4,019	3,582	2,616–4,852
Supply	3,403	2,511	1,323–4,178
Pharmacy	2,168	1,062	585–2,092
Laboratory	1,249	649	336–1,399
Other	816	94	0–798
Radiology	640	82	0–792
Respiratory	370	14	0–193
Therapy	273	108	0–360
Anesthesia	338	266	157–436
Cardiology	180	27	0–114
<b>Cholecystectomy</b>			
Total cost	22,557	15,651	9,923–25,289
Room and board	10,756	7,232	3,859–12,791
ICU	2,049	0	0–1,073
Operating room	3,017	2,696	1,886–3,718
Supply	2,164	1,438	791–2,484
Pharmacy	1,448	795	408–1,517
Laboratory	1,033	591	257–1,241
Other	690	418	0–826
Radiology	827	467	97–1,151
Respiratory	203	0	0–84
Therapy	162	0	0–185
Anesthesia	270	205	134–340
Cardiology	185	37	0–122
<b>Pancreatectomy</b>			
Total cost	53,672	37,745	28,193–57,213
Room and board	24,565	17,250	11,651–28,332
ICU	7,940	3,635	0–8,269

(Continued)

**Table 2.** Continued

Cost center	Mean, \$*	Median, \$*	Interquartile range, \$*
Operating room	6,845	6,248	4,662–8,356
Supply	3,929	2,636	1,247–5,029
Pharmacy	3,974	2,131	1,076–4,345
Laboratory	2,678	1,794	1,182–2,874
Other	1,249	353	0–1,050
Radiology	1,045	266	67–1,223
Respiratory	636	56	0–460
Therapy	456	273	0–572
Anesthesia	712	645	363–950
Cardiology	179	38	0–136

\*Unadjusted for patient case-mix severity or comorbidities.

costs, 16% in colectomy patients, 17% in cholecystectomy patients, and 10% in pancreatectomy patients. Median operating room cost was \$3,514 (IQR, \$2,473 to \$4,979) across all abdominal procedures. Median operating room costs ranged from \$6,248 (IQR, \$4,662 to \$8,356) for pancreatectomy to \$3,582 and \$2,696 for colectomy and cholecystectomy, respectively. Operating room costs were correlated with operative time ( $R = 0.63$ ,  $p < 0.0001$ ).

Patient case-mix severity and comorbidities as well as procedure type were significantly associated with patient hospital costs (Table 3). Patient case-mix severity variables associated with greater than a 1.5-fold increase in adjusted hospital cost included being partially dependent (estimate, 1.50, 95% CI 1.46 to 1.55) or fully dependent (estimate, 1.63, 95% CI 1.53 to 1.74) in comparison with being independent preoperatively; and ASA class IV (estimate, 1.72, 95% CI 1.57 to 1.87) or ASA class V (estimate, 1.53, 95% CI 1.18 to 1.98) in comparison with ASA class I. There were 3 procedure types associated with a 3-fold or greater increase in adjusted cost in comparison with laparoscopic cholecystectomy; cholecystectomy with stone extraction (estimate, 4.24, 95% CI 1.36 to 13.19), partial removal of pancreas (estimate, 3.65, 95% CI 3.50 to 3.82), and pancreatectomy (estimate, 3.33, 95% CI 3.17 to 3.49). The total variance explained by the model detailed in Table 3 was 37%.

After risk-adjustment for patient case-mix severity, comorbidities, and procedure type, there was still substantial variation in cost among hospitals (Fig. 1). Of the 202 hospitals, 79 were classified as “average” cost hospitals, meaning that costs were not statistically significantly different from the grand mean of hospitals in the analysis after controlling for patient case-mix severity, comorbidities, and procedure type. Median hospital cost of care was \$26,285. Sixty-six hospitals had significantly lower

**Table 3.** Clinical and Procedural Characteristics Associated with Total Hospital Cost of Care

Clinical characteristics	Estimate*	95% Confidence interval*		p Value*
		Lower	Upper	
<b>Demographics</b>				
Male	1.07	1.06	1.09	<0.0001
Age, y	—	—	—	—
65–75	0.89	0.86	0.91	<0.0001
75–85	0.95	0.92	0.97	<0.0001
>85	—	—	—	—
<b>Acuity of illness</b>				
<b>Functional status</b>				
Independent functional status	—	—	—	—
Partially dependent functional status	1.50	1.46	1.55	<0.0001
Fully dependent functional status	1.63	1.53	1.74	<0.0001
<b>American Society of Anesthesiologists class</b>				
I	—	—	—	—
II	1.09	1.00	1.18	0.04
III	1.33	1.23	1.45	<0.0001
IV	1.72	1.57	1.87	<0.0001
V	1.53	1.18	1.98	0.001
Previous surgery	1.19	1.12	1.27	<0.0001
Open wound	1.24	1.18	1.31	<0.0001
Greater than 10% weight loss in previous 6 mo	1.14	1.10	1.18	<0.0001
<b>Current procedure terminology code</b>				
Partial removal of colon	1.94	1.89	2.00	<0.0001
Partial colectomy with ostomy	2.24	2.09	2.41	<0.0001
Partial colectomy with end ostomy	2.22	2.11	2.34	<0.0001
Partial colectomy with mucus fistula	2.49	2.29	2.72	<0.0001
Partial colectomy with coloproctostomy	1.97	1.90	2.04	<0.0001
Colectomy with coloproctostomy and ostomy	2.20	2.06	2.35	<0.0001
Partial removal of colon old code	2.25	1.98	2.57	<0.0001
Total colectomy without proctectomy	2.52	2.36	2.70	<0.0001
Total colectomy without proctectomy with pouch	2.34	1.58	3.47	<0.0001
Partial colectomy with ileocolostomy	1.91	1.84	1.97	<0.0001

(Continued)

**Table 3.** Continued

Clinical characteristics	Estimate*	95% Confidence interval*		p Value*
		Lower	Upper	
Laparoscopic partial colectomy	1.61	1.55	1.66	<0.0001
Laparoscopic partial colectomy with ileocolostomy	1.64	1.58	1.71	<0.0001
Laparoscopic Hartmann's end colostomy	2.17	1.94	2.42	<0.0001
Laparoscopic colectomy/coloproctostomy	1.71	1.63	1.79	<0.0001
Total colectomy with coloproctostomy	1.88	1.67	2.13	<0.0001
Total colectomy without proctectomy	1.91	1.64	2.22	<0.0001
Laparoscopic cholecystectomy with cholangiogram	1.05	1.01	1.09	0.01
Laparoscopic cholecystectomy with common bile duct exploration	1.44	1.23	1.68	<0.0001
Laparoscopic cholecystectomy with cholecystoenterostomy	1.52	0.92	2.50	0.10
Laparoscopic cholecystectomy with biliary tract	1.88	1.08	3.27	0.03
Laparoscopic cholecystectomy	—	—	—	—
Removal of gallbladder	1.38	1.33	1.44	<0.0001
Cholecystectomy with cholangiogram	1.47	1.37	1.57	<0.0001
Cholecystectomy with common bile duct exploration	1.71	1.54	1.91	<0.0001
Cholecystectomy with choledochoenterostomy	1.75	1.48	2.09	<0.0001
Cholecystectomy with transduodenal sphincterotomy	1.59	1.15	2.19	0.005
Cholecystectomy with stone extraction	4.24	1.36	13.19	0.01
Partial removal of pancreas	2.33	2.20	2.46	<0.0001
Partial removal of pancreas	3.65	3.50	3.82	<0.0001
Pancreatectomy	3.33	3.17	3.49	<0.0001
<b>Wound classification</b>				
Clean	—	—	—	—
Clean-contaminated	1.18	1.04	1.34	0.0095
Contaminated	1.32	1.16	1.50	<0.0001
Dirty/contaminated	1.50	1.32	1.71	<0.0001

(Continued)

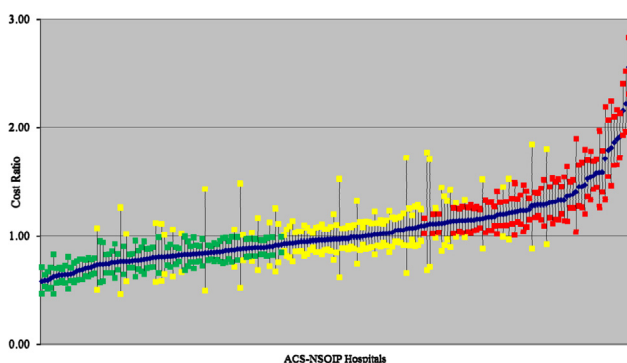


**Table 3.** Continued

Clinical characteristics	Estimate*	95% Confidence interval*		p Value*
		Lower	Upper	
Pulmonary conditions				
COPD	1.19	1.16	1.23	<0.0001
Ventilator dependency	1.39	1.20	1.61	<0.0001
Renal conditions				
Dialysis	1.49	1.31	1.69	<0.0001
Hepatic conditions				
Ascites	1.23	1.15	1.30	<0.0001
Cardiovascular conditions				
Hypertension	1.05	1.03	1.07	<0.0001
Myocardial infarction	1.20	1.11	1.30	<0.0001
Congestive heart failure	1.34	1.27	1.42	<0.0001
Hematologic and immunologic conditions				
Cancer	1.15	1.10	1.19	<0.0001
Steroid use	1.10	1.05	1.14	<0.0001
Bleeding disorder	1.19	1.15	1.23	<0.0001
Transfusion	1.32	1.17	1.48	<0.0001
Sepsis				
No sepsis	—	—	—	—
Systemic inflammatory response syndrome	1.23	1.19	1.27	<0.0001
Sepsis	1.34	1.25	1.43	<0.0001
Septic shock	1.06	0.94	1.19	0.37

\*Derived from mixed effect multivariate gamma regression with random intercepts.

costs than the average hospital with comparable patients and procedure types. Median hospital cost of care was \$34,556 at high outlier hospitals. Fifty-seven hospitals had significantly higher costs than the average hospitals



**Figure 1.** Risk-adjusted hospital cost ratios for elective abdominal operations. Adjusted for procedure type and patient case-mix severity and comorbidities that were present on admission. Hospitals with confidence limits depicted in red had adjusted costs higher than the average hospital. Hospitals with confidence limits depicted in green had adjusted costs lower than the average hospital.

with comparable patients and procedure types. Median hospital cost of care at low outlier hospitals was \$21,081.

To further determine what underlay variation in cost among hospitals, a subanalysis of cost by hospitals setting was performed. There was significant variation in the unadjusted cost by hospital setting across all cost centers (Table 4). The median total cost for patients in division metropolitan areas was \$24,090 (IQR, \$15,648 to \$39,826). The median cost for patients in metropolitan areas was \$21,365 (IQR, \$14,281 to \$34,460). The median cost for patients in micropolitan areas was \$15,161 (IQR, \$10,945 to \$23,604). The median cost of patients in rural areas was \$15,901 (IQR, \$11,970 to \$24,112). After adjusting for regional wage index, patient case-mix severity and comorbidities, and procedure, hospitals in division metropolitan areas had 1.23 times higher total adjusted costs than hospitals in simple metropolitan areas (95% CI 1.11 to 1.37) and 1.58 times higher total adjusted costs than micropolitan areas (95% CI 1.21 to 2.06).

Lastly, the average morbidity and mortality rates were 22.8% (n = 4,993) and 3.1% (n = 673), respectively. When the unadjusted costs were compared among patients who did not have complications with those who had at least one morbidity and those who had mortality, there was significant variation across all cost centers (Table 5). The median total cost for patients without complications was \$19,375 (IQR, \$13,349 to \$29,280). The median total cost for patients with at least one morbidity was \$37,033 (IQR, \$22,418 to \$65,674). The median cost for patients with mortality was \$50,465 (IQR, \$29,657 to \$86,221).

## DISCUSSION

This study determined the median cost for an inpatient elective colectomy, cholecystectomy, and pancreatectomy to be \$22,193, \$15,651, and \$37,745, respectively. These estimates are comparable to those in previous studies.<sup>14-16</sup> Furthermore, this study found that room and board costs accounted for nearly half of all costs and were highly correlated with length of stay. Similarly, operating room time was associated with operating room costs. In addition, multivariate analysis demonstrated that patient case-mix severity, comorbidities, and procedure type were correlated in expected ways with hospital costs. The relationship between the hospital costs and the duration of clinical care, the invasiveness of procedures, and the patient case-mix severity reinforces the soundness of this cost estimate. These data suggest that it is feasible to use Medicare cost-to-charge ratio data to obtain reasonable estimates of patient hospital costs at the cost center level. Not only does the cost estimate seem consistent with clinical expectations but there also seems to be

**Table 4.** Distribution of Unadjusted Hospital Cost by Cost Centers by Core Based Statistical Area

Cost center	Division metropolitan (n = 7,714)		Metropolitan (n = 13,377)		Micropolitan (n = 693)		Rural (n = 134)		p Value <sup>†</sup>
	Median, \$*	Interquartile range, \$*	Median, \$*	Interquartile range, \$*	Median, \$*	Interquartile range, \$*	Median, \$*	Interquartile range, \$*	
Total cost	24,090	15,648–39,826	21,365	14,281–34,460	15,161	10,945–23,604	15,901	11,970–24,112	<0.001
Room and board	12,507	7,711–21,138	9,986	6,082–17,129	6,685	4,560–11,022	10,221	6,720–14,631	<0.001
ICU	0	0–3,944	0	0–3,017	0	0	0	0–2,220	<0.001
Operating room	3,827	2,631–5,630	3,459	2,489–4,780	2,126	1,754–2,822	2,240	1,611–2,847	<0.001
Supply	1,975	934–3,573	2,356	1,248–4,152	1,607	1,141–2,476	1,102	764–1,436	<0.001
Pharmacy	906	426–1,915	1,159	632–2,276	878	523–1,593	594	345–1,123	<0.001
Laboratory	756	367–1,688	743	342–1,555	541	291–1,028	466	219–809	<0.001
Other	242	0–928	203	0–761	695	11–2,797	0	0–525	<0.001
Radiology	199	0–1,048	164	0–929	68	0–482	108	0–612	<0.001
Respiratory	0	0–110	17	0–219	56	35–250	20	0–182	<0.001
Therapy	104	0–354	64	0–348	0	0–247	0	0	<0.001
Anesthesia	291	166–484	265	156–474	119	27–275	152	106–244	<0.001
Cardiology	37	0–163	29	0–107	18	0–54	41	0–86	<0.001

\*Unadjusted for patient case-mix severity or comorbidities.

<sup>†</sup>Generated from a Kruskal-Wallis test.**Table 5.** Distribution of Unadjusted Hospital Cost by Cost Centers by the Occurrence of Complications

Cost center	No complications (n = 16,788)		Morbidity (n = 13,377)		Mortality (n = 693)		p Value <sup>†</sup>
	Median, \$*	Interquartile range, \$*	Median, \$*	Interquartile range, \$*	Median, \$*	Interquartile range, \$*	
Total cost	19,375	13,349–29,280	37,033	22,418–65,674	50,465	29,657–86,221	<0.001
Room and board	9,508	5,850–15,011	18,205	10,369–31,809	21,466	11,819–34,317	<0.001
ICU	0	0–1,592	2,563	0–9,182	7,635	1,648–18,140	<0.001
Operating room	3,337	2,376–4,658	4,282	2,913–6,322	4,051	2,651–6,032	<0.001
Supply	1,985	1,039–3,501	2,900	1,453–5,211	3,408	1,863–6,092	<0.001
Pharmacy	895	492–1,623	2,102	974–4,951	3,492	1,717–7,465	<0.001
Laboratory	585	302–1,187	1,529	711–2,919	2,517	1,333–4,604	<0.001
Other	86	0–645	610	35–1617	1,466	619–3,489	<0.001
Radiology	104	0–700	715	96–1,867	1,350	549–2,596	<0.001
Respiratory	0	0–84	117	0–782	860	146–2,257	<0.001
Therapy	0	0–264	320	0–712	243	0–492	<0.001
Anesthesia	257	152–429	333	176–611	309	163–553	<0.001
Cardiology	25	0–81	58	9–332	266	52–576	<0.001

\*Unadjusted for patient case-mix severity or comorbidities.

<sup>†</sup>Generated from a Kruskal-Wallis test.

considerable variation among hospitals costs even after risk-adjustment. Some of this variation may be further explained by hospital setting as well as the occurrence of complications. These cost estimates may therefore be valuable information to feed back to hospitals.

These results are important because first, they may enable all personnel who work in a hospital, from receptionist to CEO, to understand where costs of care accumulate and how their hospitals compare with other hospitals after controlling for patient case-mix severity, comorbidities, and procedure type. A comprehensive list of services ascribed to each cost center can be found readily in existing revenue code reference manuals and in the health services literature.<sup>9</sup> Understanding what services fall into each cost center may further help hospitals focus efforts on identifying low value expenditures that can be reduced.

Although both cost and payment can be used to evaluate the economics of surgical care, there is a distinct advantage to using cost data. Payments are the more traditional cost metric in the literature and, unlike hospital costs, typically include hospital profits. Studies that have studied both payments and hospital costs have demonstrated that there is a strong correlation between the two, with payments being about 20% higher than hospital costs in normal situations, though this varies by payer.<sup>5,17</sup> However, the difference in payments and hospital costs decreases when a complication occurs,<sup>17</sup> and the magnitude of this decrease varies by the nature of payment (per discharge, per diem, proportion of charges) and payer type.<sup>5</sup> Payments are complex and are influenced by many variables other than how efficiently a hospital produces care.<sup>18</sup> As such, payments may be less helpful to hospitals as a feedback metric if the goal is to improve how efficiently hospitals provide care. Correctly estimating the cost of production of hospital care may help providers and policy makers design mechanisms to improve the value of surgical care while maintaining quality for all patients regardless of payer.

There are several limitations to this work. First, the external generalizability of this study is limited because this patient sample was exclusively Medicare patients 65 years and older seeking inpatient care at ACS-NSQIP hospitals. The ACS-NSQIP hospitals are known to be biased toward large academic centers and therefore may not be representative of the hospital population at large. Furthermore, because this study was limited to inpatient records, it captured patients with a higher comorbidity burden and likely more serious surgical disease. This can be seen by the relatively long median length of stay (5 days) for an inpatient cholecystectomy. Second, professional fees were not included in this analysis. As a result,

the full cost of care was underestimated. Third, the cost estimates are dependent on the existing publicly available Medicare cost-to-charge ratios. Hospitals may not accurately report the actual annual charges and costs of patient care. Cost-to-charge ratios rely on hospitals' internal cost accounting data, for which there is wide variability across institutions, and may not represent the actual cost of the delivered service. Although extensive data vetting procedures in accordance with established norms<sup>9</sup> were used in handling these data, it is possible that inaccuracies in these data may have led to misrepresentations of the hospital cost of the production of care. Additionally, certain indirect costs are deliberately factored into varying cost centers, often the daily rate for room and board, and cannot be further separated.<sup>19</sup> Finally, the timeliness of the MedPar and cost-to-charge ratio data is a concern because of the significant focus and emphasis on these data over the past 5 years. Future directions include obtaining more contemporaneous data to understand recent trends in cost of surgical care.

## CONCLUSIONS

This article identified the hospital costs derived from charges for 3 common elective abdominal operations among 202 hospitals. These cost estimates vary, as might be expected, by the type of abdominal surgery performed, duration of care, and patient case-mix severity and comorbidities. Furthermore, even after accounting for patient case-mix severity, comorbidities, and procedure type, there is significant variation in hospitals costs. Hopefully, these data can be used to encourage cooperation among hospitals so that the value of surgical care can be improved without sacrificing quality.

## Author Contributions

Study conception and design: Stey, Ko

Acquisition of data: Zingmond, Lawson

Analysis and interpretation of data: Brook, Needleman, Hall

Drafting of manuscript: Stey, Brook, Needleman, Hall, Zingmond, Lawson, Ko

Critical revision: Stey, Brook, Needleman, Hall, Zingmond, Lawson, Ko

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**Appendix 1.** Health Care Service Assignment to Cost Centers

<b>Department</b>	<b>Services</b>
1. Room and Board Cost Center	
All inclusive rate and board	General classification
	Ancillary
Private room and board	General classification
	Medical/surgical/GYN
	Obstetric
	Pediatric
	Psychiatric
	Hospice
	Detoxification
	Oncology
	Rehabilitation
	Other
Two-bed semi-private room and board	General classification
	Medical/surgical/GYN
	Obstetric
	Pediatric
	Psychiatric
	Hospice
	Detoxification
	Oncology
	Rehabilitation
	Other
Three- and 4-bed semi-private room and board	General classification
	Medical/surgical/GYN
	Obstetric
	Pediatric
	Psychiatric
	Hospice
	Detoxification
	Oncology
	Rehabilitation
	Other
Deluxe private	General classification
	Medical/surgical/GYN
	Obstetric
	Pediatric
	Psychiatric
	Hospice
	Detoxification
	Oncology
	Rehabilitation
	Other

(Continued)

**Appendix 1.** Continued

<b>Department</b>	<b>Services</b>
Room and board ward	General classification
	Medical/surgical/GYN
	Obstetric
	Pediatric
	Psychiatric
	Hospice
	Detoxification
	Oncology
	Rehabilitation
	Other
Other room & board	General classification
	Sterile environment
	Self care
	Other
Reserved	Hospice
Leave of absence	General classification
	Patient convenience charges billable
	Therapeutic leave
	ICF mentally retarded any reason
	Nursing home hospitalization
Subacute care	Other
	General classification
	Level 1
	Level 2
	Level 3
	Level 4
Behavioral health	Other
	Accommodations
Residential treatment	Psychiatric
	Chemical dependency
Supervised living	
Halfway house	
Group home	
2. Pharmacy Cost Center	
Pharmacy	Generic drug
	Nongeneric drug
	Take home drugs
	Incident to other diagnostic services
	Incident to radiology
	Experimental drugs
	Nonprescription
	IV solutions
	Other

(Continued)

**Appendix 1.** Continued

<b>Department</b>	<b>Services</b>
IV therapy	Infusion pump
	IV therapy/drug/supply/delivery
	Other IV therapy
Restricted drug	Multiple source drug
	Medication under 10,000 units
	Medication over 10,000 units
	Self administered drugs (insulin)
<b>3. Operating Room Cost Center</b>	
Operating room	General care
	Minor surgery
	Nonkidney organ transplant
	Kidney transplant
	Other
Recovery room	General care
	Other
<b>4. Laboratory Cost Center</b>	
Laboratory	Clinical diagnostic
	Clinical diagnostic: Chemistry
	Clinical diagnostic: Immunology
	Clinical diagnostic: Renal patient (home)
	Clinical diagnostic: Non-routine dialysis
	Clinical diagnostic: Hematology
	Clinical diagnostic: Bacteriology/microbiology
	Clinical diagnostic: Urology
	Clinical diagnostic: Other laboratory
	Pathology
	Pathology: Cytology
	Pathology: Histology
	Pathology: Biopsy
	Pathology: Other
Gastroenterology	Intestinal services general classification
	Intestinal services other
<b>5. Supply Cost Center</b>	
Medical/surgical supplies	General classification
	Nonsterile supply
	Sterile supply
	Take-home supplies
	Prosthetic/orthotic devices
	Pacemaker
	Intraocular lens
	Oxygen take home
	Other implants
	Other
	Incident to radiology
	Incident to other diagnostic services
	Surgical dressings
	Investigational device

(Continued)

**Appendix 1.** Continued

<b>Department</b>	<b>Services</b>
Durable medical equipment	General classification
	Rental
	Purchase of new durable medical equipment
	Purchase of old durable medical equipment
	Supplies/drugs
	Other
6. Radiology	
Oncology	280 Oncology general classification
	289 Oncology other
Diagnostic radiology	320 Radiology diagnostic general classification
	321 Radiology diagnostic angiocardiology
	322 Radiology diagnostic arthrography
	323 Radiology diagnostic arteriography
	324 Radiology diagnostic chest x-ray
	329 Radiology diagnostic other
Therapeutic radiology	330 Radiology therapeutic general classification
	331 Radiology therapeutic chemotherapy injected
	332 Radiology therapeutic chemotherapy oral
	333 Radiology therapeutic radiation therapy
	335 Radiology therapeutic chemotherapy IV
Nuclear medicine	339 Radiology therapeutic other
	340 Nuclear medicine general classification
	341 Nuclear medicine diagnostic
	342 Nuclear medicine therapeutic
CT scan	349 Nuclear medicine other
	350 CT scan general classification
	351 CT scan head scan
	352 CT scan body scan
Other imaging	359 CT scan other
	0400 Other imaging services
	0401 Other imaging services: Diagnostic mammography
	0402 Other imaging services: Ultrasound
	0403 Other imaging services: Screening mammography
	0404 Other imaging services: PET scan
Magnetic resonance imaging	0409 Other imaging services: Other imaging services
	610 MRI general classification
	611 MRI brain (including brain stem)
	612 MRI spinal cord (including spine)
7. Anesthesia	619 MRI other
	370 Anesthesia general classification
	371 Anesthesia incident radiology
	372 Anesthesia incident to other diagnostic services
	374 Anesthesia acupuncture
Anesthesia	379 Anesthesia other

(Continued)



**Appendix 1.** Continued

<b>Department</b>	<b>Services</b>
8. Intensive Care Unit	
Intensive Care Unit	200 Intensive care general classification
	201 Intensive care surgical
	202 Intensive care medical
	203 Intensive care pediatric
	204 Intensive care psychiatric
	206 Intensive care intermediate ICU
	207 Intensive care burn care
	208 Intensive care trauma
	209 Intensive care other
Coronary Care Unit	210 Coronary care general classification
	2100 Alternative therapy services
	2101 Acupuncture
	2102 Acupressure
	2103 Massage
	2104 Reflexology
	2105 Biofeedback
	2106 Hypnosis
	2109 Another alternative therapy services
	213 Coronary care heart transplant
	214 Coronary care intermediate CCU
	219 Coronary care other
	213 Coronary care heart transplant
9. Respiratory	
Respiratory services	0410 Respiratory services
	0412 Respiratory services: Inhalation services
	0413 Respiratory services: Hyperbaric oxygen therapy
	0419 Respiratory services: Other respiratory services
	0410 Respiratory services
	0412 Respiratory services: Inhalation services
	0413 Respiratory services: Hyperbaric oxygen therapy
	0419 Respiratory services: Other respiratory services
Pulmonary function testing	046 Reserved for national assignment
	0460 Pulmonary function
	0469 Pulmonary function: Other
10. Cardiology	
Cardiology	048 Reserved for national assignment
	0480 Cardiology
	0481 Cardiology: Cardiac catheter lab
	0482 Cardiology: Stress test
	0483 Cardiology: Echocardiology
	0489 Cardiology: Other cardiology
Electrocardiogram/electroencephalogram	730 EKG/ECG general classification
	731 EKG/ECG holter monitor
	732 EKG/ECG telemetry
	739 EKG/ECG other
	740 EEG general classification
	749 EEG other

(Continued)

**Appendix 1.** Continued

<b>Department</b>	<b>Services</b>
11. Therapy	
Physical Therapy	042 Reserved for national assignment
	0420 Physical therapy
	0421 Physical therapy: Visit charge
	0422 Physical therapy: Hourly charge
	0423 Physical therapy: Group rate
	0424 Physical therapy: Evaluation/re-evaluation
	0429 Physical therapy: Other physical therapy
Occupational therapy	043 Reserved for national assignment
	0430 Occupational therapy
	0431 Occupational therapy: Visit charge
	0432 Occupational therapy: Hourly charge
	0433 Occupational therapy: Group rate
	0434 Occupational therapy: Evaluation/re-evaluation
	0439 Occupational therapy: Other occupational therapy
Speech – language therapy	044 Reserved for national assignment
	0440 Speech-language pathology
	0441 Speech-language pathology: Visit charge
	0442 Speech-language pathology: Hourly charge
	0443 Speech-language pathology: Group rate
	0444 Speech-language pathology: Evaluation/re-evaluation
	0449 Speech-language pathology: Other speech language pathology
Audiology	047 Reserved for national assignment
	0470 Audiology
	0471 Audiology: Diagnostic
	0472 Audiology: Treatment
	0479 Audiology: Other audiology
12. Other Ancillary	
Blood products	380 Blood general classification
	381 Blood packed red cells
	382 Blood whole blood
	383 Blood plasma
	384 Blood platelets
	385 Blood Leucocytes
	386 Blood other components
	387 Blood other derivatives (cyoprecipitates)
	389 Blood other
Emergency room care	450 Emergency room general classification
	451 Emergency room Emergency Medical Treatment and Active Labor Act (EMTALA) emergency medical screening services
	452 Emergency room beyond Emergency Medical Treatment and Active Labor Act EMTALA screening
	456 Emergency room urgent care
	459 Emergency room other

(Continued)

**Appendix 1.** Continued

<b>Department</b>	<b>Services</b>
Clinic care	490 Ambulatory surgical care general classification
	499 Ambulatory other
	500 Outpatient services general classification
	509 Outpatient services other
	510 Clinic general classification
	511 Clinic chronic pain center
	512 Clinic dental
	513 Clinic psychiatric
	514 Clinic OB/GYN
	515 Clinic pediatric
	516 Clinic urgent care
	517 Clinic family practice
	519 Clinic other
Ambulance	540 Ambulance general classification
	541 Ambulance supplies
	542 Ambulance medical transport
	543 Ambulance heart mobile
	544 Ambulance oxygen
	545 Ambulance air
	546 Ambulance neonatal
	547 Ambulance pharmacy
	548 Ambulance telephone transmission EKG
549 Ambulance other	
Skilled nursing	550 Skilled nursing general classification
	551 Skilled nursing visit charge
	552 Skilled nursing hourly charge
	559 Skilled nursing other
Social services	560 Medical social services general classification
	561 Medical social services visit charge
	562 Medical social services hourly charge
	569 Medical social services other
Home health aide	570 Home health aide general classification
	571 Home health aide visit charge
	572 Home health aide hourly charge
	579 Home health aide other
Other visits	580 Other visits general classification (home health)
	581 Other visits visit charge (home health)
	582 Other visits hourly charge (home health)
	589 Other visits other
Units of service	590 Units of services general classification (home health)
	599 Units of services other
Oxygen therapy	600 Oxygen general classification (home health)
	601 Oxygen state/equip/supply/or cont (home health)
	602 Oxygen state/equip/supply under 1LPM (home health)
	603 Oxygen state/equip/supply over 4 LPM (home health)
	604 Oxygen portable add-on (home health)

(Continued)

**Appendix 1.** Continued

<b>Department</b>	<b>Services</b>
Home therapy training	640 Home IV therapy services general classification
	641 Home IV therapy services nonroutine nursing
	642 Home IV therapy services IV site care, central line
	643 Home IV therapy services IV start/change, peripheral line
	644 Home IV therapy services nonroutine nursing, peripheral line
	645 Home IV therapy services training patient caregiver, central line
	646 Home IV therapy services training disabled patient, central line
	647 Home IV therapy services training patient/caregiver, peripheral line
	648 Home IV therapy services training disabled patient, peripheral line
	649 Home IV therapy services other
Hospice care	650 Hospice services general classifications
	651 Hospice services routine home care
	652 Hospice services continuous home care2
	653 Reserved
	654 Reserved
	655 Hospice inpatient care
	656 Hospice general inpatient care (non-respite)
	657 Hospice physician services
659 Hospice other	
Respite care	660 Respite care general classification
	661 Respite care hourly charge/skilled nursing
	662 Respite care hourly charge/home health aide/homemaker
Special residence care	670 Outpatient special residence charges general classification
	671 Outpatient special residence charges hospital based
	672 Outpatient special residence charges contracted
	679 Outpatient special residence charges other
Casting	700 Cast room general classification
	709 Cast room other
Observation	760 Treatment or observation room general classification
	761 Treatment or observation room treatment
	762 Treatment or observation room observation
	769 Treatment or observation other
Preventative care	770 Preventative care services general classification
	771 Preventative care services vaccine administration
	779 Preventative care services other
Telemedicine	780 Telemedicine general classification
	789 Telemedicine other
Lithotripsy	79 Reserved for state use
	790 Extracorporeal shock wave therapy
	799 Extracorporeal shock wave therapy (ESWT): Other ESWT
Inpatient renal replacement therapy	800 Inpatient renal dialysis general classification
	801 Inpatient renal dialysis hemodialysis
	802 Inpatient renal dialysis peritoneal (non-CAPD)
	803 Inpatient renal dialysis continuous ambulatory peritoneal (CAPD)
	804 Inpatient renal dialysis continuous cycling peritoneal (CCPD)
	809 Inpatient renal dialysis other

(Continued)

**Appendix 1.** Continued

<b>Department</b>	<b>Services</b>
Organ acquisition	810 Organ acquisition general classification
	811 Organ acquisition living donor
	812 Organ acquisition cadaver donor
	813 Organ acquisition unknown donor
	814 Organ acquisition unsuccessful organ search donor bank charge
	819 Organ acquisition other
Hemodialysis	820 Hemodialysis general classification
	821 Hemodialysis composite or other rate
	822 Hemodialysis home supplies
	823 Hemodialysis home equipment
	824 Hemodialysis maintenance 100%
	825 Hemodialysis support services
Peritoneal dialysis	829 Hemodialysis other
	830 Peritoneal dialysis general classification
	831 Peritoneal composite or other rate
	832 Peritoneal home supplies
	833 Peritoneal home equipment
	834 Peritoneal maintenance 100%
Continuous ambulatory peritoneal dialysis	835 Peritoneal support services
	839 Peritoneal other
	840 CAPD outpatient general classification
	841 CAPD composite or other rate
	842 CAPD home supplies
	843 CAPD home equipment
Continuous cycling peritoneal dialysis	844 CAPD maintenance 100%
	845 CAPD support services
	849 CAPD other
	850 CCPD Outpatient general classification
	851 CCPD composite or other rate
	852 CCPD home supplies
	853 CCPD home equipment
	854 CCPD maintenance 100%
	855 CCPD support services
	859 CCPD other

(Continued)

**Appendix 1.** Continued

<b>Department</b>	<b>Services</b>
Reserved for dialysis	860 Reserved for dialysis (national assignment)
	861 Reserved for dialysis (national assignment)
	862 Reserved for dialysis (national assignment)
	863 Reserved for dialysis (national assignment)
	864 Reserved for dialysis (national assignment)
	865 Reserved for dialysis (national assignment)
	866 Reserved for dialysis (national assignment)
	867 Reserved for dialysis (national assignment)
	868 Reserved for dialysis (national assignment)
	869 Reserved for dialysis (national assignment)
	870 Reserved for dialysis (state assignment)
	871 Reserved for dialysis (state assignment)
	872 Reserved for dialysis (state assignment)
	873 Reserved for dialysis (state assignment)
	874 Reserved for dialysis (state assignment)
	875 Reserved for dialysis (state assignment)
	876 Reserved for dialysis (state assignment)
	877 Reserved for dialysis (state assignment)
	878 Reserved for dialysis (state assignment)
	879 Reserved for dialysis (state assignment)
	890 Reserved for national assignment
	891 Reserved for national assignment
	892 Reserved for national assignment
	893 Reserved for national assignment
	894 Reserved for national assignment
	895 Reserved for national assignment
	896 Reserved for national assignment
	897 Reserved for national assignment
	898 Reserved for national assignment
899 Reserved for national assignment	
Psychiatry	900 Psychiatric/psychological treatments general classification
	901 Psychiatric/psychological treatments electroshock treatment
	902 Psychiatric/psychological treatments milieu therapy
	903 Psychiatric/psychological treatments play therapy
	904 Psychiatric/psychological treatments activity therapy
	909 Psychiatric/psychological treatments other
	910 Psychiatric/psychological services general classification
	911 Psychiatric/psychological services rehabilitation
	912 Psychiatric/psychological svc partial hospitalization <intensive
	913 Psychiatric/psychological svc partial hospitalization intensive
	914 Psychiatric/psychological services individual therapy
	915 Psychiatric/psychological services group therapy
	916 Psychiatric/psychological services family therapy
	917 Psychiatric/psychological services bio feedback
	918 Psychiatric/psychological services testing
	919 Psychiatric/psychological other

(Continued)

**Appendix 1.** Continued

Department	Services	
Other diagnostic service	920 Other diagnostic services general classification	
	921 Other diagnostic services peripheral vascular lab	
	922 Other diagnostic services electromyogram	
	923 Other diagnostic services pap smear	
	924 Other diagnostic services allergy test	
	925 Other diagnostic services pregnancy test	
	929 Other diagnostic services other	
	Other therapeutic service	940 Other therapeutic services general classification
		941 Other therapeutic services recreational therapy
942 Other therapeutic services education/training		
943 Other therapeutic services cardiac rehabilitation		
944 Other therapeutic services drug rehabilitation		
945 Other therapeutic services alcohol rehabilitation		
946 Other therapeutic services complex medical equipment routine		
947 Other therapeutic services complex medical equipment ancillary		
949 Other therapeutic services		

Adapted from Maeda HSR; 2013. Labor and Delivery Cost Center not included as not applicable to these general surgery patients. Categorization and description of revenue codes further elaborated at: <http://www.resdac.org/cms-data/variables/revenue-center-code>.

**Appendix 2.** Current Procedure Terminology Codes of Operation Included in this Analysis

Procedure	Current procedure terminology code
Colectomy	
Colectomy, partial; with anastomosis	41440
Colectomy, partial; with skin level cecostomy or colostomy	44141
Colectomy, partial; with end colostomy and closure of distal segment (Hartmann type procedure)	44143
Colectomy, partial; with coloproctostomy (low pelvic anastomosis)	44145
Colectomy, partial; with coloproctostomy (low pelvic anastomosis), with colostomy	44146
Colectomy, total, abdominal without proctectomy; with ileostomy or ileoproctostomy	44150
Colectomy, partial, with removal of terminal ileum with ileocolostomy	44160
Laparoscopy, surgical; colectomy, partial, with anastomosis	44204
Laparoscopy, surgical; colectomy, partial, with removal of terminal ileum with ileocolostomy	44205
Laparoscopy, surgical; colectomy, partial, with anastomosis, with coloproctostomy (low pelvic anastomosis)	44207
Cholecystectomy	
Cholecystectomy	47600
Cholecystectomy; with cholangiography	47605
Laparoscopy, surgical; cholecystectomy	47562
Laparoscopy, surgical; cholecystectomy with cholangiography	47563
Pancreatectomy	
Pancreatectomy, distal subtotal, with or without splenectomy; without pancreaticojejunostomy	48140
Pancreatectomy, proximal subtotal with total duodenectomy, partial gastrectomy, choledochenterostomy and gastrojejunostomy (Whipple-type procedure)	48150
Pancreatectomy, proximal subtotal with near-total duodenectomy, choledochenterostomy and duodenojejunostomy (pylorus-sparing, Whipple-type procedure)	48153