Economic Impact of Laparoscopic Conversion to Open in Left Colon Resections

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ABSTRACT

Background and Objectives: Studies have shown economic and clinical advantages of laparoscopic left-colon resections. Laparoscopic conversion to open is an important surgical outcome. We estimated conversion incidence, identified risk factors, and measured the clinical and economic impact.

Methods: In this retrospective study, we used the Premier Perspective database to analyze left-sided colectomies from 2009 to 2014. Operating room time (ORT), length of stay (LOS), total hospital cost (2014 U.S. dollars); along with incidence of in-hospital clinical outcomes (anastomotic leak surrogate [Leak], transfusion, and mortality) were evaluated. Multivariable models accounting for hospital clustering were used to identify conversion risk factors and analyze the effect of conversion on economic and clinical outcomes.

Results: A total of 41,417 patients: 8,468 left hemicolectomy and 32,949 sigmoidectomy were identified. Lap-Conversion incidence was 13.3% (95% CI, 12.9–13.7). Adjusted mean LOS (±SE) days was significantly lower for the Lap-Successful group (4.9 compared with Lap-Conversion 6.8 and Open-Planned 7.0), but Lap-Conversion and Open-Planned had similar LOS. Adjusted mean cost was higher for Lap-Conversion $20,165 compared to Open-Planned $18,797; but this difference was smaller than the cost savings for Lap-Successful $16,206 ± $219. Open-Planned had lower odds of Leak compared to Lap-Conversion. Open-Planned and Lap-Conversion had similar odds of transfusion and mortality. Conversion risk factors included inflammatory bowel disease and left-hemicolectomy. Colorectal specialists were associated with 38% decreased odds of conversion.

Conclusions: Successful laparoscopic surgery was the most cost effective, with decreased LOS and odds of blood transfusion, leak surrogate, and mortality. Conversion was the most expensive and had increased odds of leak surrogate, but similar LOS compared to Open-Planned. The beneficial effect size of successful laparoscopic surgery was larger than the negative effect of conversion compared to Open-Planned.

Key Words: Colectomy, Conversion, Hospital costs, Laparoscopy, Length of stay, Operating time.

INTRODUCTION

In the United States, diseases of the colon are common with more than 600,000 operative procedures being performed each year.[1] Colon resections (colectomies) involve 2 types of approaches: laparoscopic and open. Rates of laparoscopic colectomy have varied between 29% and 41% and have been increasing over the past few years.[2–5] Studies have shown clinical and economic benefits of the laparoscopic approach. In various randomized clinical trials, the laparoscopic approach has been shown to be superior to open approach in oncologic outcomes, while also offering improved short-term and longer term outcomes, including shorter length of stay (LOS), reduced postoperative pain and mortality, and lower costs. Additional benefits of laparoscopy include earlier return to work and decreased complications.[6–12]

Conversion from a laparoscopic to an open approach is an important surgical outcome, as patients who undergo conversion do not derive the same benefits as those who have successful laparoscopic surgery.[13] However, conversion from a laparoscopic to an open resection may be necessary for a variety of reasons ranging from pre-emptive early conversion due to patient anatomy or procedural

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nonprogression, to reactive conversion due to intraoperative complications, such as bleeding, bowel injury, ureter damage, or splenic organ injury.[14] The possibility of a reactive conversion and its associated outcomes may be a barrier preventing some surgeons from attempting a laparoscopic approach. Conversion rates have been reported to vary from 10% to 17%, depending on patient selection, factors related to the procedure, and the experience.[14–19]

Most previous research focused on outcomes related to conversion had a limited number of patients, conducted in single-center studies, and analyzed multiple colon resection anatomies (right and left) or rectal resections together. Given the benefits of laparoscopy and the potential underutilization in left colon resection surgery, research using recent real world data is needed to better understand the impact of conversion on healthcare utilization and clinical outcomes associated with these approaches. There is a lack of quality research using large administrative databases estimating the incidence and economic impact of laparoscopic conversion to an open approach. The objective of this study was to estimate the incidence of Lap-Conversion in left-sided colon resections, identify risk factors, and analyze differences in LOS, total hospital costs, and ORT for colon resection approaches.

MATERIALS AND METHODS

Study Design and Data Source

This retrospective study used the Premier Perspective hospital database from 2009 through 2014, inclusive. This database contains complete clinical coding, hospital cost, and patient billing data from more than 600 hospitals throughout the United States representing about 20% of all acute care inpatient hospitalizations. The database contains a date-stamped log of all billed items including medications; laboratory, diagnostic, and therapeutic services; primary and secondary diagnoses and procedures for each patient's hospitalization; and demographic and payer information.

Study Population

Patients were included if they were ≥21 years of age and underwent an elective primary left-sided colon resection procedure identified using the International Classification of Diseases, ninth revision (ICD-9) procedure codes: left-hemicolectomy (17.35, 45.75) or sigmoidectomy (17.36, 45.76). Additional inclusion criteria included having at least one of the following diagnoses: diverticulitis, colon cancer, diverticulosis, benign neoplasm, and inflammatory bowel disease (IBD) either Crohn's or ulcerative colitis. Colon resection approaches were classified as Open-Planned (open code only: 45.75 or 45.76) or Lap-Attempted, which was further characterized as either Lap-Successful (laparoscopic code: 17.35 or 17.36, without conversion or an open code) or Lap-Conversion (ICD-9 diagnosis conversion code [V64.41] or simultaneous open and laparoscopic codes occurring on the same day of surgery). Robotic assistance was included as a laparoscopy based upon the ICD-9 laparoscopic procedure code. Patients were excluded from the study if there was a concomitant right-side colon or anterior resection procedure. Patients were additionally excluded if key demographic information was missing.

Study Variables

The primary dependent variables assessed in this study were hospital LOS (in days), total hospital costs (measured in 2014 U.S. dollars), operating room time (ORT, in minutes). All patients had LOS and total hospital costs, but only a subset of patients had ORT. Additional secondary outcome variables included postoperative computed tomographic scans (CT), and select complications (mortality, blood transfusion, and anastomotic leak surrogate [LEAK]). Mortality was identified through the discharge status variable, LEAK surrogate was identified with a composite of ICD-9 diagnosis codes representing intra-abdominal infection and fistula, blood transfusion was identified with Current Procedural Terminology (CPT-4), ICD-9 diagnosis codes, Healthcare Common Procedure Coding System (HCPCS) or charge descriptions. CT was identified through standard charge descriptions for postoperative imaging of the abdomen or pelvis. See Appendix for listing of all ICD-9, CPT-4, and HCPCS codes used in the study.

Covariates included in the study were patient characteristics such as age, gender, race, marital status, year of discharge, indication (diverticulitis, colon cancer, diverticulosis, benign neoplasm, and IBD), the number of different indications, and specific patient comorbidities from the Elixhauser Comorbidity group descriptions (cardiac arrhythmia, congestive heart failure, valvular disease, peripheral vascular disease, myocardial infarction, cerebrovascular disease, pulmonary circulation disorder, obesity, diabetes, hypothyroidism, hypertension, depression, alcohol abuse, and drug abuse).[20]

Procedure characteristics included in the study and models were type of payer (Commercial, Medicare, Medicaid, other), robotic technology use (ICD-9 procedure code 17.4), and resection type (left-hemicolectomy vs sigmoidectomy). Provider characteristics included hospital location (urban/rural), teaching status (teaching/nonteaching), geographical location (Midwest, South, Northeast, West), provider bed count (1–200 beds, 201–400 beds, 401–600 beds, > 600 beds), hospital bed size based on Centers for Medicare and Medicaid Services (CMS) definition (small, medium, large), costing procedure [procedural/ Ratio of Cost to Charges (RCC)],[21] hospital procedure volume of left-hemicolectomy and sigmoid from 2009 to 2014 (1–100, 101–300, 301–500, >500 procedures), and physician specialty (colorectal surgeon, general surgeon, and other).

Statistical Analysis

Descriptive analyses including means (standard deviations) for continuous variables and frequency distributions for categorical variables were performed to describe all the study variables. Lap-Conversion incidence was calculated for all procedures with evidence of a laparoscopic approach (Lap-Attempted). For Lap-Attempted procedures, patient, provider, and procedure factors associated with Lap-Conversion were explored in a multivariable logistic model which accounted for clustering within hospitals. Generalized estimating equations (GEEs) were used to evaluate the effect of surgical approach (Lap-Attempted, Open-Planned, or Lap-conversion) on LOS, total hospital costs, and ORT after accounting for clustering within hospitals and controlling for patient, provider, and procedure characteristics. Only the subset of patients that had ORT data available were evaluated for this outcome. All GEE models had a log link function. A negative binomial distribution was used for LOS and ORT and a gamma distribution was used for total hospital costs. Binary outcome variables (mortality, blood transfusion, postoperative CT, and LEAK surrogate) were analyzed with logistic regression that accounted for hospital clustering. All analyses were conducted using SAS for Windows, Version 9.4 (SAS Institute Inc., Cary, North Carolina, USA); and $P < 0.05$ (2-sided) were considered significant.

RESULTS

Descriptive Patient and Provider Characteristics

A total of 41,417 patients who underwent 8,468 left hemicolectomy and 32,949 sigmoidectomy procedures were identified. Mean ± SD age was 60 ± 13 years old, most the patients were female (52.4%) and Caucasian (76.0%). Over half of the patients had a diagnosis for diverticulitis (59.1%), followed by colon cancer (29.6%), diverticulosis (11.9%), colonic polyps (10.8%), and IBD (1.2%), and 9.4% of patients had more than one of the diagnostic classes. Diabetes (15.2%), chronic pulmonary diseases (14.7%), hypothyroidism (10.3%), and obesity (9.5%) were the most prevalent comorbidities. General surgeons (75.1%) and colorectal specialists (18.1%) performed most resections. **Tables 1–3** present the patient and provider characteristics of the study population. There were 15,150 Open-Planned procedures and 26,267 Lap-Attempted procedures. The breakdown of the procedural approaches is provided in **Figure 1**. The incidence of Lap-Conversion was 13.3% (95% CI, 12.9–13.7) and stratified by resection type: sigmoid 12.1% (95% CI, 11.7–12.6) and left hemicolectomy 18.4% (95% CI, 17.4–19.6). Almost all lap-conversions were identified via the V-code (95.4%).

Risk Factors Associated With Lap-Conversion

A total of 26,267 patients with Lap-Attempted procedures were included in the Multivariable regression models. Patient, procedure, and provider variables from **Tables 1–3** were included in these models as covariates. **Figure 2** represents a subset of significant risk factors associated with Lap-Conversion. Left-hemicolectomy had 63% increased odds for conversion compared to sigmoidectomy (OR = 1.63; 95% CI, 1.44–1.85). Inflammatory colon pathology also increased the odds for conversion: diverticulitis (OR = 1.44, 95% CI, 1.11– 1.86) and IBD (OR = 2.04; 95% CI, 1.42–2.93) compared with other indications. Patient comorbidities of pulmonary circulation disorders (OR = 1.71; 95% CI, 1.11–2.65), obesity (OR = 1.59; 95% CI, 1.43–1.76), diabetes (OR = 1.22; 95% CI, 1.11–1.33), and hypertension (OR = 1.10; 95% CI, 1.02–1.19), along with male gender (OR = 1.10; 95% CI, 1.02–1.20) were also found to significantly increase the odds of conversion.

Patient socioeconomic factors such as commercial insurance coverage, compared to other (OR = 0.72; 95% CI, 0.58–0.98), and being married (OR = 0.86; 95% CI, 0.78–0.94) were found to significantly reduce the odds of Lap-Conversion. Further, younger patients had decreased odds of Lap-Conversion as compared to older patients (OR, [95% CI] (ref: age 75 years and above): age, 18–44 years = 0.54, [0.44–0.67]; age, 45–54 years = 0.73 [0.61–0.86]; age, 55–64 years = 0.77 [0.66–0.91]; age, 65–74 = 0.81, [0.72–0.92]. Robotic-assistance had 57% decreased odds of needing to convert a procedure as compared to nonrobotic assistance surgeries (OR = 0.43; 95% CI, 0.31–0.59). Colorectal specialists had 38% decreased odds of

Table 1.
Patient Demographics

Characteristics	All Patients (N = 41,417) (%)	Surgical Approach			
		Open Planned (n = 15,150) (%)	Lap Attempted		
			All-Lap (n = 26,267) (%)	Successful (n = 22,779) (%)	Conversion (n = 3,488) (%)
Gender					
Male	47.6	46.2	48.4	48.3	48.5
Female	52.4	53.8	51.7	51.7	51.5
Age, years					
21–44	12.3	10.0	13.7	14.2	10.2
45–54	22.5	19.6	24.2	24.5	22.1
55–64	27.5	26.7	27.9	28.0	27.3
65–74	23.4	25.1	22.4	22.1	24.8
75 plus	14.3	18.7	11.8	11.2	15.7
Race					
Caucasian	76.0	74.9	76.7	77.1	74.3
African American	6.9	8.0	6.2	5.9	8.3
Other	17.1	17.1	17.1	17.0	17.4
Marital status					
Married	57.6	54.2	59.6	60.3	55.1
Single	33.2	35.5	31.9	31.2	36.4
Other	9.2	10.3	8.5	8.5	8.6
Payer					
Medicare	37.7	44.1	34.0	33.0	40.5
Medicaid	4.6	5.7	4.0	3.8	5.0
Commercial	51.8	43.6	56.5	57.8	47.9
Other	5.9	6.6	5.5	5.4	6.5
Specific conditions (Elixhauser Comorbidity Group)					
Diabetes	15.2	17.9	13.7	13.0	18.2
Chronic pulmonary disease	14.7	16.6	13.6	13.2	15.7
Hypothyroidism	10.3	10.6	10.2	10.1	10.7
Obesity	9.5	9.5	9.6	9.1	12.7
Depression	8.9	9.9	8.8	8.7	9.1
Arrhythmia	6.3	8.0	5.4	5.1	6.8
Congestive heart failure	2.9	4.2	2.2	2.1	3.0
Valvular disease	2.6	2.9	2.5	2.5	2.4
Peripheral vascular disease	2.5	3.3	2.0	1.9	2.8
Alcohol abuse	1.4	1.7	1.2	1.2	1.5
Pulmonary circulatory disorder	0.7	1.1	0.5	0.4	1.0
Drug Abuse	0.6	0.7	0.5	0.5	0.5

Table 2.
Procedural Characteristics

Characteristics	All Patients (N = 41,417) (%)	Surgical Approach			
		Open Planned (n = 15,150) (%)	Lap Attempted		
			All-Lap (n = 26,267) (%)	Successful (n = 22,779) (%)	Conversion (n = 3,488) (%)
Left colon surgical anatomy					
Sigmoidectomy	79.5	34.5	65.5	57.6	7.9
Hemicolectomy	20.5	44.3	55.7	45.4	10.3
Indication					
Diverticulitis	59.1	51.5	63.5	63.6	62.6
Neoplasm cancer	29.6	36.3	25.7	25.4	27.6
Diverticulosis	11.9	13.4	11.0	10.9	11.4
Neoplasm polyp	10.8	10.9	10.7	10.7	10.7
IBD	1.2	1.6	1.0	0.9	1.6
2+ Indications	9.4	10.2	8.9	8.7	10.6
Physician specialty					
General	75.1	79.4	72.7	72.0	77.0
Colorectal	18.1	12.9	21.2	22.1	15.5
Other	6.7	6.2	5.9	7.6	7.8
Robotic Assisted	3.4	0.8	4.9	5.3	2.2
Year of surgery					
2009	17.0	19.9	15.4	15.3	15.8
2010	14.9	15.2	14.8	14.7	15.0
2011	16.3	16.0	16.5	16.6	16.0
2012	18.4	17.7	18.8	19.0	18.1
2013	16.9	15.5	17.8	17.7	18.2
2014	16.4	15.7	16.8	16.7	17.0

conversion compared to general surgeons (OR = 0.62; 95% CI, 0.44–0.88).

Resource Utilization: Hospital LOS, Costs, and ORT

Unadjusted mean LOS (SD) was 7.0 (4.8) days for Lap-Conversion and 7.4 (5.4) for Open-Planned as compared to 4.8 (3.4) for Lap-Successful. Unadjusted mean cost (SD) followed a similar trend: $20,957 ($15,315) for Lap-Conversion, $19,531 ($21,825) and $16,215 ($10,909) for Open-Planned and Lap-Successful approach. A subset of 38,680 patients had ORT available. The unadjusted mean ORT (SD) for Lap-Conversion was 268 (349) minutes compared to 204 (240) and 228 (312) for Open-Planned and Lap-Successful approaches, respectively.

Adjusted results (**Figures 3–5**) followed a similar pattern with Lap-Successful having significantly lower mean LOS (SE) of 4.9 (0.1) days and mean total hospital costs $16,206 ($219) compared to both Open-Planned (7.0 (0.1) days and $18,797 ($293)) and Lap-converted (6.8 (0.1) days and $20,165 ($354)), for both $P < .0001$. Open-Planned had statistically significantly shorter adjusted mean ORT (SE) of 205 (4) minutes compared to Lap-Successful (226 (5) minutes) and Lap-Conversion (255 (6) minutes), (both $P < .0001$). The adjusted mean LOS was not significantly different between Lap-Conversion and Open-Planned (p = .09). Although the mean total hospital costs were significantly different between Lap-Conversion and Open-Planned ($P < .0001$), the mean difference was relatively small ($1,368)

Table 3.
Hospital Characteristics

Characteristics	All Patients (N = 41,417) (%)	Surgical Approach			
		Open Planned (n = 15,150) (%)	Lap Attempted		
			All-Lap (n = 26,267) (%)	Successful (n = 22,779) (%)	Conversion (n = 3,488) (%)
Location					
Rural	10.0	13.3	8.1	7.8	10.2
Urban	90.0	86.7	91.9	92.2	89.9
Teaching Hospital	41.6	40.3	42.4	42.3	42.9
Geography					
Midwest	20.8	23.3	19.4	19.2	20.7
Northeast	20.2	16.3	22.5	22.6	22.0
South	40.6	41.9	39.9	40.2	38.1
West	18.3	18.6	18.2	18.0	19.2
Number of beds					
0–200	18.2	19.6	17.4	17.3	17.7
201–400	38.0	40.5	36.6	36.6	37.1
401–600	24.2	24.2	24.1	24.1	24.6
>600	19.6	15.7	21.9	22.1	20.7
CMS hospital size					
Small	7.2	7.9	6.8	6.9	6.1
Medium	16.9	15.9	17.4	17.6	16.3
Large	76.0	76.2	75.8	75.5	77.6
Hospital surgery volume*					
1–100	12.7	16.7	10.4	10.1	12.2
101–300	35.6	38.7	33.8	33.6	34.9
301–500	28.4	28.3	28.5	28.4	28.7
>500	23.4	16.4	27.4	27.9	24.2
Cost type					
Procedural	71.0	68.8	72.2	72.3	71.6
RCC	29.0	31.2	27.8	27.7	28.4

*Left colon surgery hospital volume from 2009–2014. CMS, Centers for Medicare and Medicaid Services; RCC, ratio of cost to charge

when compared to the cost savings of Lap-Successful compared with Open-Planned ($2,591).

Secondary Outcomes

The overall incidence of unadjusted secondary outcomes was as follows: in-patient mortality (0.5%), transfusion (6.4%), CT (6.4%), and LEAK surrogate (12.4%). Lap-Successful had the lowest unadjusted incidence of all four outcomes. Unadjusted incidence of LEAK surrogate was lowest for Lap-Successful (OR; 95% CI) 8.9%; 8.5–9.3%), followed by Lap-Conversion (19.4%; 18.0–20.7%) and highest for Open-Planned (16.1%; 15.5–16.6%). Transfusion and CT rates were again lowest for Lap-Successful (3.6%; 3.4–3.9%) and 4.4% (4.2–4.7%) respectively; while

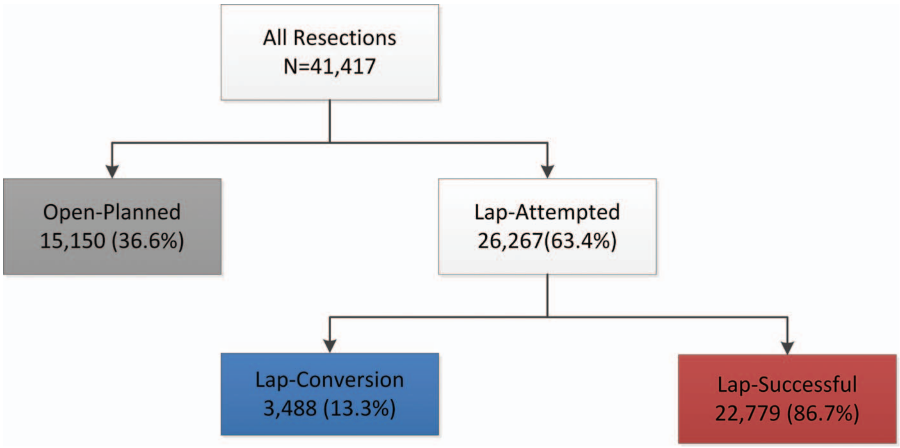

Figure 1. Classification of surgical approach.

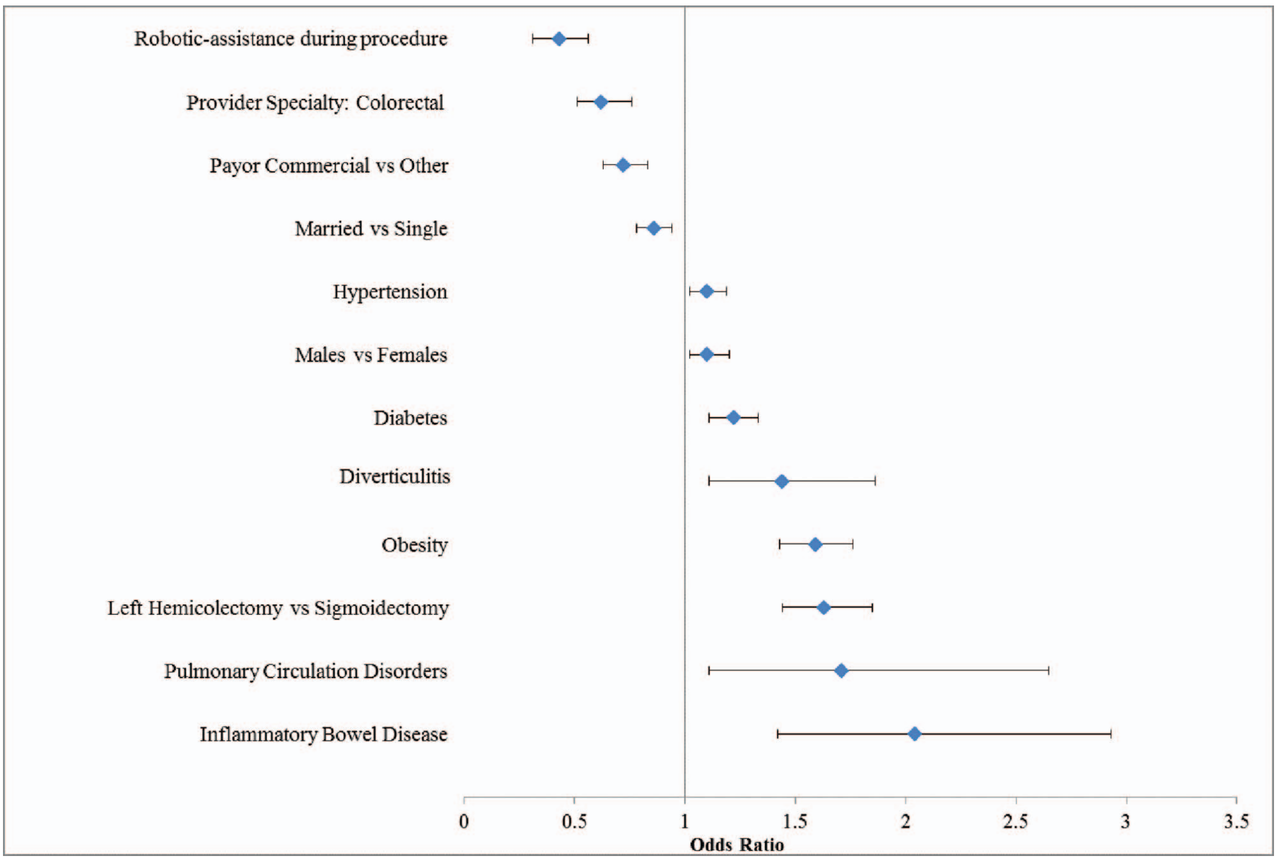

Figure 2. Selected clinically significant risk factors associated with lap-conversion.

Lap-Conversion (Transfusion: 8.7%; 7.8–9.6% and CT: 10.0%; 7.8–9.6%) and Open-Planned (Transfusion: 9.9%; 9.4–10.4% and CT: 8.7%; 8.2–9.1%)) had overlapping 95% CIs. The incidence of mortality was below 1% for all approaches. **Table 4** shows all unadjusted secondary outcomes.

The multivariable logistic regression models adjusting for hospital clustering demonstrate that Lap-Successful

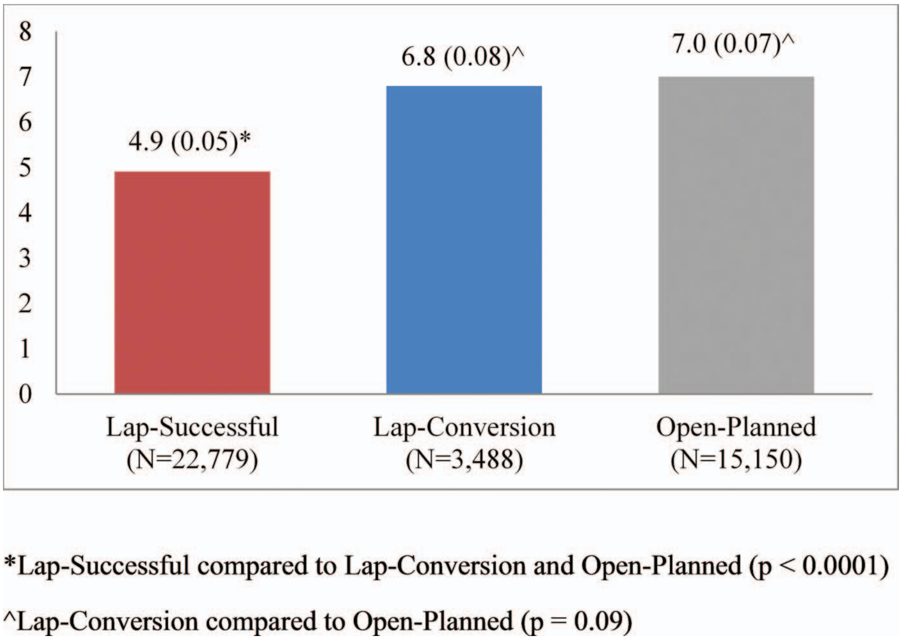

Figure 3. Adjusted mean hospital LOS in days (±SE).

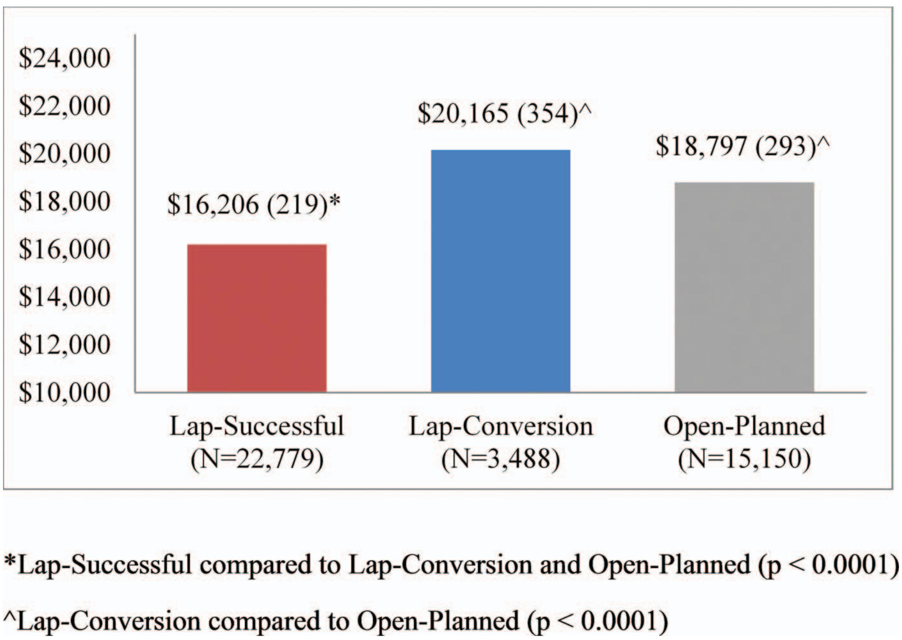

Figure 4. Adjusted mean total hospital costs in 2014 U.S. dollars (±SE).

was associated with significantly lower odds of blood transfusion compared to Open-Planned and Lap-Conversion respectively: (OR = 0.46 and 0.45; $P < 0.0001$), LEAK surrogate (OR = 0.59 and 0.46; $P < 0.0001$), CT (OR = 0.55 and 0.46; $P < 0.0001$), and mortality (OR = 0.51; $P = 0.0002$ and 0.41, $P = 0.0003$). Open-Planned had significantly lower odds for LEAK surrogate (OR = 0.78; $P < .0001$) and CT (0.84, $P = .0057$) compared to Lap-Conversion. There was no difference in association between Open-Planned and Lap-Conversion for blood transfusion or mortality. **Table 5** provides all adjusted ORs.

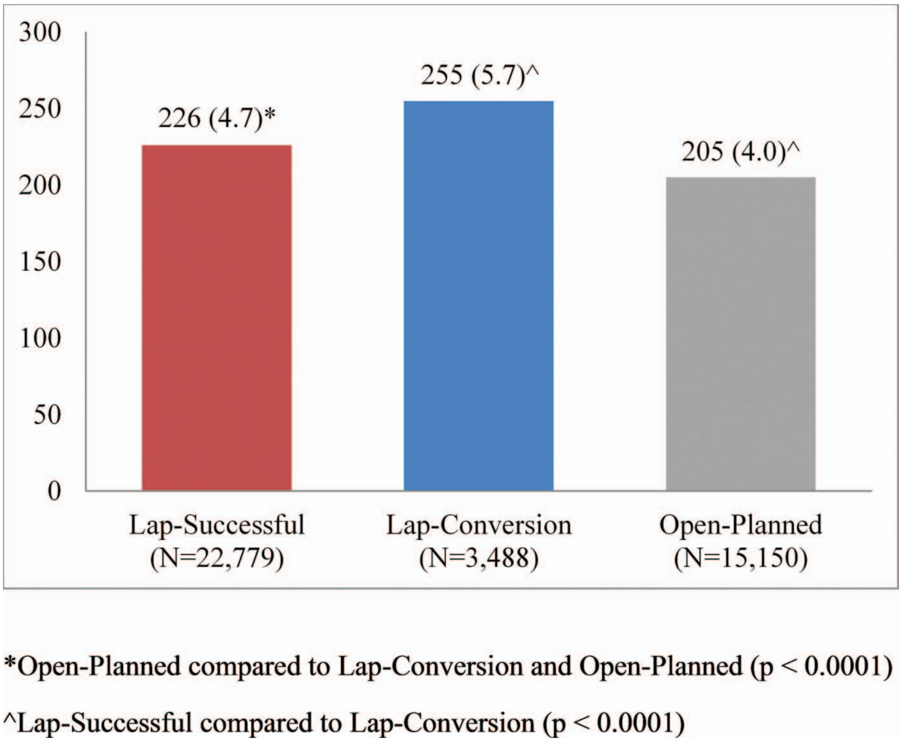

Figure 5. Adjusted mean operating room time in minutes (±SE).

Table 4.
Incidence of In-Hospital Secondary Clinical Outcomes

Outcome	All Patients (N = 41,417)			Surgical Approach: Lap-Successful (n = 22,779)			Lap-Conversion (n = 3,488)			Open-Planned (n = 15,150)		
Secondary Outcomes	Rate (%)	95% CI		Rate (%)	95% CI		Rate (%)	95% CI		Rate (%)	95% CI	
LEAK Surrogate	12.4	12.1	12.7	8.9	8.5	9.3	19.4	18.0	20.7	16.1	15.5	16.6
Blood Transfusion	6.4	6.1	6.6	3.6	3.4	3.9	8.7	7.8	9.6	9.9	9.4	10.4
Postoperative CT	6.4	6.2	6.7	4.4	4.2	4.7	10.0	9.0	11.0	8.7	8.2	9.1
Mortality	0.5	0.4	0.5	0.2	0.2	0.3	0.7	0.4	1.0	0.8	0.6	0.9

DISCUSSION

Multiple studies including several high-quality clinical trials and meta-analyses have demonstrated the benefits of laparoscopy compared to open surgery in elective colon resections with shorter LOS, earlier return to work, and decreased complications. Consistent with the literature,[5–10,15] our analysis found that the LOS and total hospital costs were lower and operating room times were longer for laparoscopic surgery, as compared with the planned open approach. Keller et al[22] analyzed the Premier Perspective database and demonstrated similar advantages in the use of laparoscopy for emergent colon resection with decreased hospitalization for both laparoscopic right and left colectomies compared to open surgery. Although laparoscopy was associated with a lower postoperative LOS (7.4 vs 9.4 days), there was no significant difference in mean total hospital costs ($29,651 vs $30,326, inflation adjustment not stated). This study did not consider laparoscopic conversion or adjust for the colon resection anatomy.

Table 5.
Adjusted Odds Ratios (OR): Effect of Surgical Approach on In-Hospital Secondary Clinical Outcomes

Secondary Outcomes*	Lap-Successful vs Open-Planned	Lap-Successful vs Lap-Conversion	Open-Planned vs Lap-Conversion
Blood Transfusion	0.46	0.45	0.98
	$P < .0001$	$P < .0001$	$P = 0.78$
LEAK Surrogate	0.59	0.46	0.78
	$P < .0001$	$P < .0001$	$P < .0001$
Postoperative CT	0.55	0.46	0.84
	$P < .0001$	$P < .0001$	$P = .0057$
Mortality	0.51	0.41	0.81
	$P = .0002$	$P = .0003$	$P = .31$

The incidence of laparoscopic conversion in colon resections in our study was 13%. Delaney et al[15] reported an incidence of conversion using the Premier Perspective database of 10.1% that included both right- and left-sided colectomies from 2004 to 2006. Their study found that laparoscopic attempted procedures had shorter LOS (7.0 vs 8.1 days; $P < .0001$), but higher mean total costs ($8,076 vs $7,678; $P = .0002$) compared to planned open after adjusting for patient age, gender, diagnosis, teaching hospital status, APR-DRG, and hospital colectomy volume. Of note, the type of colectomy was not included in the model. Fox et al[16] analyzed all colectomies in the National Inpatient Sample from 2008 to 2009 and estimated the rate of conversions to be 10.3% out of a sample of 9,075 colectomies and a more recent analysis by Moghadamyeghaneh et al[17] estimated conversion at approximately12.5%. This study also did not differentiate the type of colectomy being performed.[16,17] Yerokun et al[18] analyzed patients undergoing segmental, total, and proctocolectomies for nonmetastatic colon cancer from 2010–2012 in the United States National Cancer Data Base. The incidence of conversion was 13.2% (n = 6,144). After adjusting for multiple confounders conversion patients actually had shorter hospital LOS (4% decrease; $P < .0001$), lower odds of 30-day mortality (OR = 0.77; 95% CI, 0.64–0.94), and similar overall survival compared to planned open surgery.

A recent review and meta-analysis comparing laparoscopic conversion and planned open surgery, analyzed 20 clinical studies with 30,656 patients including both right- and left-sided colectomies and rectal resections.[19] The mean conversion rate was 17% (range, 7–46%). Fourteen studies included LOS which was not significantly different between conversion and planned open surgeries. There was no difference in the incidence of other complications, except for wound infection (OR = 1.43, 95% CI, 1.12, 1.83). Allaix et al[14] published a review of clinical studies analyzing the long-term effects of laparoscopic conversion compared to successful laparoscopic colon resections for cancer. The median conversion rate for colectomies was 10.0% and included right- and left-sided resections. The most common reasons for conversion were related to tumor location or size. The authors concluded that conversion in colon resections did not significantly increase the postoperative morbidity compared to successfully completed laparoscopy. They also found that due to inclusion of both colon and rectal resections and heterogeneity in reporting that it was difficult to conclude that conversion patients had poorer oncologic outcomes.

The risk factors identified in this study include obesity, diverticulitis, IBD, and left hemicolectomy, and protective factors included procedures performed by colorectal specialists, younger age, patients with commercial insurance, and robotic assistance. Hospital left-sided colectomy surgical volume over the study period was not predictive of conversion. This result may be due to the limitation that this was not specific to individual surgeons. Our study found that robotic-assisted laparoscopy reduced the odds for conversion by 57% compared to traditional laparoscopy. This finding should be interpreted in context with prior studies and with the limitation that a small proportion of procedures used this technology (4.9%) and may reflect unmeasured cofounding: patient selection bias or a nonrepresentative set of surgeons. The published literature is mixed on the effect of robotic assistance and conversion. A recent meta-analysis analyzed 11 studies reporting robotic (n = 584) and laparoscopic (n = 981) colon resections.[23] The weighted rate of conversion was

4.3% for robotic assisted compared to 7.1% for traditional laparoscopy and the risk difference was significant (OR= −0.02, 95% CI, −0.04 to 0.00). There was no significant difference in the subset of patients undergoing resection for cancer. This analysis included both right and left sided anatomies. An analysis of the Michigan Surgical Quality Collaborative registry focused on laparoscopic versus robotic assisted laparoscopic colectomies which included both partial and total colectomies.[24] A total of 2006 partial colectomy procedures were analyzed of which 244 were robotic assisted procedures. After propensity score matching, the incidence of conversion in colon resections was not significantly different, 16.9% for laparoscopic compared to 9.0% for robotic ($P = .06$). A limitation of this study was that differentiation and adjustment between right-side and left-side anatomic resections was not performed.

Laparoscopic adoption in colon resections has been increasing ranging from earlier estimates by Blimoria et al.[25] analysis of the American College of Surgeons National Surgical Quality Improvement Project from 2005 to 2006 of 27.4%[22] and Delaney et al[15] 33.2% from the Perspective Rx database from 2004 to 2006. An analysis of the National Inpatient Sample from 2008–2009 estimated 44.8% for all colectomies were performed laparoscopically[16] and a more recent analysis of this data set from 2009–2012 estimated that 59.3% of all colectomies performed in 2012 were attempted with laparoscopy. The rate varied according to the anatomic type: sigmoidectomy (62.7%), cecectomy (59.7%), right colectomy (52%), and left colectomy (49.5%). Type of hospitals were also associated with increased laparoscopy utilization (e.g., urban, teaching, and larger hospitals).[17] Laparoscopic conversion to open surgery remains an important outcome and the incidence in left-sided colon resections and subsequent impact on hospital cost and LOS has not been as extensively studied. As laparoscopic attempted left colectomies continue to increase, understanding the risk factors and implications of laparoscopic conversions becomes more important. Several studies have analyzed the timing and reason for conversion and the effect on postoperative outcomes. Yang et al[26] evaluated reactive conversions (due to an intraoperative complication such as bleeding or bowel injury) compared to preemptive conversion (due to lack of progression or unclear anatomy). Patients with reactive conversion had increased postoperative complications (50% vs 27%; $P = .028$) and longer hospitalization (6 vs 5 days; $P = .08$). Ayatac et al[27] also compared the timing and reason for conversion and the impact on patient outcomes. They found that reactive conversion patients were not associated with increased hospitalization (8 vs 7 days; Chi-square test; $P = .148$) and that shorter operating times were not associated with decreased morbidity or LOS.

More research is showing laparoscopic conversions have similar reported outcomes as planned open surgery. In this study, conversion to open surgery had similar length of hospitalization and was associated with a mean total hospital cost increase of $1,368 compared with planned open surgery. This increase, while statistically significant, was substantially smaller than the $2,591 cost savings and decrease of 2 hospital days for successful laparoscopic surgery compared to planned open. Successful laparoscopic surgery was associated with decreased odds of all secondary clinical outcomes: mortality, blood transfusion, LEAK surrogate, and CT scans compared to open surgery and conversion. Conversion and planned open surgery had similar odds of blood transfusion and mortality; but conversion had significantly higher odds for anastomotic leak surrogate and postoperative CT imaging compared to planned open. These negative effects of conversion compared to planned open approach must be viewed in the context of the benefit of successful laparoscopic surgery where the beneficial effects of laparoscopic surgery on healthcare utilization and secondary clinical outcomes were larger than the negative effects of conversion compared to planned open.

The results of this study continue to add to the body of evidence that demonstrates the increasing desirability of attempting laparoscopic left-sided colon resections where successful laparoscopic surgery has clear resource utilization benefits and laparoscopic conversion to open on average has a smaller increase in resource utilization compared to planned open surgery. The results of this study may help surgeons better contextualize the healthcare utilization benefits of successful laparoscopic surgery and the potential risks of laparoscopic conversion against traditional open surgery.

Limitations of this study are related to the use of a hospital billing database for purposes of clinical outcomes research. There may be misclassification of surgical approach that would affect identification of conversion related effects. In addition, limits to identification of conversion risk factors include lack of clinical details related to the complexity of the resection including the bulkiness or location of the lesion or if the splenic flexure needed to be mobilized. This study evaluated a small subset of clinical outcomes (LEAK surrogate, mortality, and blood transfusion) but other important complications such as surgical site infection (SSI) were not evaluated for lack of specific codes. Also, because the Premier Perspective database is cross sectional in nature, the study lacks information related to prior patient medical history or post discharge events. Prior patient therapies such as neoadjuvant therapy or prior abdominal surgeries may be important unmeasured risk factors for laparoscopic conversion or for more complex patients being channeled to planned open approaches or other unmeasured confounding. Robotic-assisted surgery was associated with decreased odds of conversion, but this result should be interpreted with caution. Only a small proportion of the laparoscopic attempted procedures used robotic assistance. Clinically important variables such as previous operations and patient anatomy were not available in the database and could result in unmeasured confounding due to patient selection bias and a nongeneralizable set of highly skilled surgeons disproportionately performing robotic-assisted surgery.

Despite these limitations, the strengths of this study include a large cohort evaluating the incidence and risk factors for laparoscopic conversion with adjustment for hospital level clustering. The effect of conversion on resource utilization specific to left-sided colon resections was contextualized to both successful laparoscopic and planned open surgery in a real-world setting. To our knowledge this is the first large hospital database study of this type.

CONCLUSION

Surgeons must balance both the benefits of successful laparoscopic resections along with the risks of laparoscopic conversion for their patients when deciding whether to attempt laparoscopic left-sided colon resections. The results of this study point to a low incidence of conversion and an overall benefit of attempting laparoscopic surgery. Successful laparoscopic surgery was the most cost effective and had significantly lower odds of mortality, blood transfusion, and LEAK surrogate compared to either planned open or conversion. While conversion had the highest cost and increased odds of LEAK surrogate compared to planned open, there was no difference in LOS, mortality, or blood transfusions. The beneficial effect size for all outcomes evaluated was larger for successful laparoscopic surgery compared to the negative effects of conversion compared to planned open surgery. Additional future research focusing on the clinical impact of conversion and decision modeling is needed.

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Appendix:
Identification of Surgical Approach

Code Type	Code	Definition	Approach
ICD-9	17.35	Laparoscopic left hemicolectomy	Lap
ICD-9	17.36	Laparoscopic sigmoidectomy	Lap
ICD-9	45.75	Open left hemicolectomy	Open
ICD-9	45.76	Open sigmoidectomy	Open
ICD-9	V64.41	Laparoscopic conversion	Conversion
		Identification of Robotic Assistance	
ICD-9	17.41	Open robotic-assisted procedure	Robotic
ICD-9	17.42	Laparoscopic robotic-assisted procedure	Robotic

Indication for Surgery

Code Type	Code	Definition	Indication
ICD-9	562.11	Diverticulitis of colon without mention of hemorrhage	Diverticulitis
ICD-9	562.13	Diverticulitis of colon with hemorrhage	Diverticulitis
ICD-9	562.10	Diverticulosis of colon without mention of hemorrhage	Diverticulosis
ICD-9	562.12	Diverticulosis of colon with mention of hemorrhage	Diverticulosis
ICD-9	555	Regional enteritis	IBD
ICD-9	556	Ulcerative colitis	IBD
ICD-9	152.1	Malignant neoplasm of jejunum	Neoplasm (cancer)
ICD-9	153	Malignant neoplasm of colon	Neoplasm (cancer)
ICD-9	154	Malignant neoplasm of rectum, rectosigmoid junction, and anus	Neoplasm (cancer)
ICD-9	158.0	Malignant neoplasm of retroperitoneum	Neoplasm (cancer)
ICD-9	158.8	Malignant neoplasm of specified parts of peritoneum	Neoplasm (cancer)
ICD-9	158.9	Malignant neoplasm of peritoneum, unspecified	Neoplasm (cancer)
ICD-9	171.5	Malignant neoplasm of connective and other soft tissue of abdomen	Neoplasm (cancer)
ICD-9	199.1	Other malignant neoplasm without specification of site	Neoplasm (cancer)
ICD-9	202.80	Other malignant lymphomas, unspecified site, extranodal and solid organ sites	Neoplasm (cancer)
ICD-9	202.83	Other malignant lymphomas, intra-abdominal lymph nodes	Neoplasm (cancer)
ICD-9	209.00	Malignant carcinoid tumor of the small intestine, unspecified portion	Neoplasm (cancer)
ICD-9	209.03	Malignant carcinoid tumor of the ileum	Neoplasm (cancer)
ICD-9	209.15	Malignant carcinoid tumor of the descending colon	Neoplasm (cancer)
ICD-9	209.17	Malignant carcinoid tumor of the rectum	Neoplasm (cancer)
ICD-9	209.30	Malignant poorly differentiated neuroendocrine carcinoma, any site	Neoplasm (cancer)
ICD-9	215.5	Other benign neoplasm of connective and other soft tissue of abdomen	Neoplasm (polyp)

Continued

Appendix:
Continued

Code Type	Code	Definition	Indication
ICD-9	211.3	Benign neoplasm of colon	Neoplasm (polyp)
ICD-9	211.4	Benign neoplasm of rectum and anal canal	Neoplasm (polyp)
ICD-9	230.3	Carcinoma in situ of colon	Neoplasm (polyp)
ICD-9	230.4	Carcinoma in situ of rectum	Neoplasm (polyp)
ICD-9	235.2	Neoplasm of uncertain behavior of stomach, intestines, and rectum	Neoplasm (polyp)
ICD-9	235.5	Neoplasm of uncertain behavior of other and unspecified digestive organs	Neoplasm (polyp)
ICD-9	238.1	Neoplasm of uncertain behavior of connective and other soft tissue	Neoplasm (polyp)
ICD-9	239.0	Neoplasm of unspecified nature of digestive system	Neoplasm (polyp)
ICD-9	569.0	Anal and rectal polyp	Neoplasm (polyp)
ICD-9	569.44	Dysplasia of anus	Neoplasm (polyp)
ICD-9	569.89	Other specified disorders of intestine	Neoplasm (polyp)

Identification of Clinical Outcomes

Code Type	Code	Definition	Clinical Outcome
ICD-9	99.00	Perioperative autologous transfusion whole blood	Transfusion
ICD-9	99.01	Exchange transfusion	Transfusion
ICD-9	99.02	Transfusion previously collected autologous blood	Transfusion
ICD-9	99.03	Whole blood transfusion NEC	Transfusion
ICD-9	99.04	Packed cell transfusion	Transfusion
ICD-9	99.05	Platelet transfusion	Transfusion
ICD-9	99.07	Serum transfusion	Transfusion
ICD-9	99.08	Blood expander transfusion	Transfusion
ICD-9	99.09	Transfusion of other substance	Transfusion
CPT-4	36430	Transfusion, blood or blood components	Transfusion
CPT-4	86890	Autologous blood/component; predeposit	Transfusion
CPT-4	86891	Autologous blood operative salvage	Transfusion
CPT-4	86985	Splitting blood/blood products each unit	Transfusion
HCPCS	P9010	Blood (whole), for Transfusion, per unit	Transfusion
HCPCS	P9011	Blood, split unit	Transfusion
HCPCS	P9012	Cryoprecipitate, each unit	Transfusion
HCPCS	P9016	Red blood cells, Leukocytes reduced, each unit	Transfusion
HCPCS	P9017	Fresh frozen plasma (single donor), frozen within 8 hours of collection, each unit	Transfusion
HCPCS	P9021	Red blood cells, each unit	Transfusion
HCPCS	P9022	Red blood cells, washed, each unit	Transfusion

Continued

Appendix:
Continued

Code Type	Code	Definition	Clinical Outcome
HCPCS	P9023	Plasma, pooled multiple donor, solvent/detergent treated, frozen, each unit	Transfusion
HCPCS	P9038	Red blood cells, irradiated, each unit	Transfusion
HCPCS	P9039	Red blood cells, deglycerolized, each unit	Transfusion
HCPCS	P9040	Red blood cells, leukocytes reduced, irradiated, each unit	Transfusion
HCPCS	P9043	Infusion, plasma protein fraction (human), 5%, 50 ml	Transfusion
HCPCS	P9044	Plasma, cryoprecipitate reduced, each unit	Transfusion
HCPCS	P9048	Infusion, plasma protein fraction (human), 5%, 250 ml	Transfusion
HCPCS	P9051	Whole blood or red blood cells, leukocytes reduced, CMV-negative, each unit	Transfusion
HCPCS	P9054	Whole blood or red blood cells, leukocytes reduced, frozen deglycerolized, washed, each unit	Transfusion
HCPCS	P9056	Whole blood, leukocytes reduced, irradiated, each unit	Transfusion
HCPCS	P9057	Red blood cells, frozen/deglycerolized/washed, leukocytes reduced, irradiated, each unit	Transfusion
HCPCS	P9058	Red blood cells, leukocytes reduced, CMV-negative, irradiated, each unit	Transfusion
HCPCS	P9059	Fresh frozen plasma between 8–24 hours of collection, each unit	Transfusion
HCPCS	P9060	Fresh frozen plasma, donor retested, each unit (fresh frozen plasma donor retested)	Transfusion
ICD-9	537.4	Fistula of stomach or duodenum	Anastomotic leak surrogate
ICD-9	567.21	Peritonitis (acute) generalized. Pelvic peritonitis, male	Anastomotic leak surrogate
ICD-9	567.22	Peritoneal abscess	Anastomotic leak surrogate
ICD-9	569.5	Abscess of intestine	Anastomotic leak surrogate
ICD-9	569.81	Fistula of intestine, excluding rectum and anus	Anastomotic leak surrogate
ICD-9	596.1	Intestinovesical fistula	Anastomotic leak surrogate
ICD-9	619.1	Digestive-genital tract fistula, female	Anastomotic leak surrogate
ICD-9	997.4	Digestive system complications Complications of: Intestinal (internal) anastomosis and bypass, not elsewhere classified, except that involving urinary tract	Anastomotic leak surrogate
ICD-9	998.59	Other postoperative infection	Anastomotic leak surrogate
ICD-9	998.6	Persistent postoperative fistula, not elsewhere classified	Anastomotic leak surrogate
ICD-9	E878.2	Surgical operation with anastomosis, bypass, or graft, with natural or artificial tissues used as implant causing abnormal patient reaction, or later complication, without mention of misadventure at time of operation	Anastomotic leak surrogate