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Robotic surgery trends in general surgical oncology from the National Inpatient Sample

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Abstract

Background Robotic surgery is offered at most major medical institutions. The extent of its use within general surgical oncology, however, is poorly understood. We hypothesized that robotic surgery adoption in surgical oncology is increasing annually, that is occurring in all surgical sites, and all regions of the US.

Study design We identified patients with site-specific malignancies treated with surgical resection from the National Inpatient Sample 2010–2014 databases. Operations were considered robotic if any ICD-9-CM robotic procedure code was used.

Results We identified 147,259 patients representing the following sites: esophageal (3%), stomach (5%), small bowel (5%), pancreas (7%), liver (5%), and colorectal (75%). Most operations were open (71%), followed by laparoscopic (26%), and robotic (3%). In 2010, only 1.1% of operations were robotic; over the 5-year study period, there was a 5.0-fold increase in robotic surgery, compared to 1.1-fold increase in laparoscopy and 1.2-fold decrease in open surgery (< 0.001). These trends were observed for all surgical sites and in all regions of the US, they were strongest for esophageal and colorectal operations, and in the Northeast. Adjusting for age and comorbidities, odds of having a robotic operation increased annually (5.6 times more likely by 2014), with similar length of stay (6.9 ± 6.5 vs 7.0 ± 6.5, $p = 0.52$) and rate of complications (OR 0.91, 95% CI 0.83–1.01, $p = 0.08$) compared to laparoscopy.

Conclusions Robotic surgery as a platform for minimally invasive surgery is increasing over time for oncologic operations. The growing use of robotic surgery will affect surgical oncology practice in the future, warranting further study of its impact on cost, outcomes, and surgical training.

Keywords Robotic surgery · Minimally invasive surgery · National Inpatient Sample

In the year 2000, the first robotic-assisted surgery platform was approved by the United States (US) Food and Drug Administration [1]. Since then, its role has continued to expand and robotic surgery is now offered at most major medical institutions. While robotic surgery has become standard of care in surgical fields like urology, the frequency of robotic use within general surgical oncology is less consistent and is sparsely studied. The robotic platform offers technologically sophisticated equipment to facilitate minimally invasive operations, but there are few conclusive clinical studies showing its superiority over traditional laparoscopy for surgical oncology operations [2]. Robotic surgery is also more expensive compared to traditional laparoscopy and open surgery. For these reasons, there is skepticism and controversy related to its use [3]. Understanding the level of use is important for directing future health care resources, and also guiding education and training in surgical oncology procedures.

The National Inpatient Sample (NIS) Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Healthcare Research and Quality, is the largest all-payer inpatient care database in the US [4, 5]. It is a database of hospital inpatient discharges representing 97% of the US population [4, 5]. We sought to characterize the use of robotic surgery in general surgical oncology operations, specifically its frequency of use overall, and trends

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in its use over several years. We hypothesized that the use of robotic surgery would increase with each successive year, and that this increase would be found across cancer sites. We also sought to compare changes in robotic surgery use to changes in the use of laparoscopy and open surgery.

Materials and methods

We queried the NIS databases from 2010 to 2014 for patients diagnosed with malignancies of the esophagus, stomach, small bowel, pancreas, liver, colon, and rectum. Malignancies of these sites are commonly treated by general surgeons and surgical oncologists. Cases were selected if the principal diagnosis for each site-specific malignant neoplasm matched the site of the principal procedure code. When patients had multiple organ-specific malignancies and/or organ-specific operations, the first listed organ-specific malignancy diagnosis was used for categorization. International Classification of Diseases (ICD)-9-Clinical Modification codes for diagnoses and procedures are listed in "Appendix." Procedures were coded as "open only" if procedure descriptions omitted laparoscopy, and if laparoscopic or robotic codes were absent from all secondary procedures. Procedures were coded as "laparoscopic" if the principal procedure description was laparoscopic, and if robotic codes were absent from all secondary procedures. Procedures were coded as "robotic" if a robotic code ever appeared as a secondary procedure. Comorbidities were quantified using the Deyo modification of the Charlson Comorbidity Index, excluding the diagnoses of cancer and metastatic cancer [6]. Complications were queried from the NIS database using established methods [7, 8]. Surgical complications included bleeding, abdominal infections, anastomotic leaks, wound complications, fistulas, gastrointestinal obstructions, incisional hernias, delayed gastric emptying, acute respiratory insufficiency and respiratory infections, iatrogenic peri-operative coronary, and cerebral infarctions.

ICD-9 procedure codes specific to robotic-assisted surgeries were not available until late 2008. We used NIS 2010 data as the starting point for trend analysis assuming that the knowledge and application of these codes would be completely disseminated by the end of 2009. The 5-year period studied also overlaps with major changes to the NIS survey methodology. Prior to 2012, NIS data represented all records from each hospital selected, but starting in 2012, NIS used a random sample of discharges from all hospitals participating in HCUP. According HCUP, these changes to the sampling strategy produce more precise estimates of US population-level trends. The HCUP data use agreement was followed as per HCUP requirements.

Statistical analysis

NIS data were trend weighted so that results would be representative of national trends. As instructed by HCUP, updated trend weights were added to NIS data for the years 2010 and 2011 in order to produce estimates of frequencies comparable to estimates based on the re-designed sampling strategy enacted in 2012. Changes in use of open, laparoscopic, or robotic procedures were measured as percent change for years 2011 to 2014 using 2010 frequency of all procedures as the baseline (denominator).

For each cancer site, multivariable logistic regression was applied to determine likelihood of receiving a robotic procedure (yes/no) for each year, accounting for patient age and number of comorbid conditions. All analyses were performed using Stata/MP 14.0 (StataCorp LP, College Station, TX).

Results

The survey-weighted results represented a total of 716,993 patients including 17,966 esophageal (3%), 34,594 stomach (5%), 37,497 small bowel (5%), 53,745 pancreas (7%), 32,950 liver (5%), and 540,241 colorectal (75%) cases. The majority of procedures were open (505,961, 71%), followed by 188,572 (26%) laparoscopic, and 22,459 (3%) robotic.

In 2010, 1.1% of these operations used a robotic approach, compared to 23.5% laparoscopic and 75.3% open. There was a consistent increase in the number of robotic and laparoscopic cases for each year (Table 1). By 2014, the percent of robotic cases increased to 5.9%, and the percent of laparoscopic cases increased to 27.6%, whereas the percent of open cases decreased to 66.5%. Over the 5-year study period, there was a 5.0-fold increase in robotic surgery, compared to 1.1-fold increase in laparoscopy and 1.2-fold decrease in open surgery ($p < 0.001$, Table 1). Increased use of robotic surgery was observed for all surgical sites over the study period (Fig. 1), and was most notable for an increase from 3 to 9% for esophageal cancer operations, and an increase from 1 to 7% for colorectal cancer operations. Increased use of robotic surgery in surgical oncology was also observed in all regions of the US (Fig. 2). This increase was greatest in the Northeastern region of the US. This region had the lowest use of robotic surgery (1.0%) in 2010, but consistently had increasing use over the study period. By 2014, 7.7% of operations were robotic, representing a 697% increase in use over the study period.

Patient characteristics

The average age for the study cohort was 66 ± 13 years. Patients in the open group (average 66 ± 13 years) and

Table 1 Survey-weighted frequency of open, laparoscopic, and robotic procedures by year and surgical site

Modality	Open					Laparoscopic					Robotic				
	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014
Esophageal	3523 (88%)	3344 (91%)	2890 (86%)	2920 (85%)	2935 (84%)	377 (9%)	308 (8%)	280 (8%)	310 (9%)	245 (7%)	116 (3%)	18 (1%)	190 (6%)	205 (6%)	305 (9%)
Stomach	6790 (90%)	6559 (90%)	6115 (90%)	6045 (89%)	5420 (86%)	627 (8%)	550 (8%)	465 (7%)	435 (7%)	505 (8%)	117 (2%)	132 (2%)	180 (3%)	290 (4%)	365 (6%)
Small bowel	8142 (94%)	6864 (93%)	6950 (92%)	6350 (92%)	6310 (91%)	543 (6%)	505 (7%)	575 (8%)	455 (7%)	565 (8%)	10 (<1%)	23 (<1%)	65 (1%)	80(1%)	60 (1%)
Pancreas	10294 (89%)	9507 (86%)	8960 (87%)	9050 (86)	8835 (84%)	1174 (10%)	1377 (12%)	1135 (11%)	1075 (10%)	1380 (13%)	34 (<1%)	159 (1%)	135 (1%)	305 (3%)	325 (3%)
Liver	5481 (83%)	5243 (78%)	5210 (80%)	5135 (80%)	5340 (79%)	1131 (17%)	1380 (21%)	1215 (19%)	1195 (19%)	1265 (19%)	4 (<1%)	55 (1%)	90 (1%)	75 (1%)	130 (2%)
Colorectal	76,377 (70%)	75,093 (66%)	70,035 (65%)	66,525 (63%)	63,720 (65%)	30,852 (29%)	36,079 (32%)	33,925 (32%)	34,235 (32%)	34,410 (31%)	1355 (1%)	2325 (2%)	3230 (3%)	5040 (5%)	7040 (7%)
Total	110,607 (75%)	106,610 (71%)	100,160 (71%)	96,025 (69%)	92,560 (66%)	34,704 (24%)	40,199 (27%)	37,595 (27%)	37,705 (27%)	38,370 (28%)	1636 (1%)	2712 (2%)	3890 (3%)	5995 (4%)	8,225 (6%)

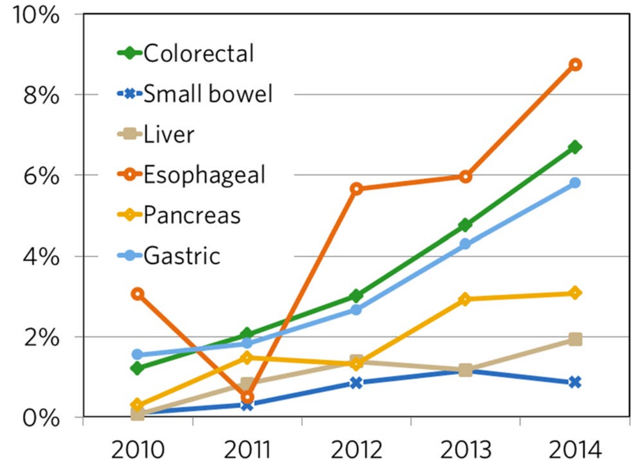

Fig. 1 Frequency of robotic surgical oncology procedures by surgical site over time. All surgical sites included in this analysis (colorectal, small bowel, liver, esophagus, pancreas, and gastric), had increasing frequency of robotic procedures over the study period

robotic group (average 64 ± 13 years) were significantly younger than those in the laparoscopic (67 ± 13) group, with similar findings each year. The odds of receiving a robotic operation decreased with increasing age (Odds ratio (OR) 0.98, 95% CI 0.984–0.989, $p < 0.001$).

The majority of patients had one or two comorbidities (98%). Adjusting for age and comorbidities, the odds of having a robotic operation increased with each year ($p < 0.001$, Table 2). Comparing 2010 to 2014, patients were 5.6 times more likely to have robotic operations compared to open or laparoscopic operations (95% Confidence interval (CI) 3.82–8.07, $p < 0.001$). Patients were 4.6 times more likely to have robotic operations compared with laparoscopic operations alone (95% CI 3.13–6.61, $p < 0.001$). Similar trends were observed when stratifying by disease site. When compared with laparoscopic surgery alone, the odds having of robotic surgery significantly increased for small bowel, pancreas, liver, and colorectal cancer starting in 2012, for gastric cancer starting 2013, and for esophageal cancer starting in 2014 (Table 2).

Patient outcomes

The overall post-operative complication rate was 31%. The highest rate was for open procedures (36%), and was lower among laparoscopic or robotic procedures (21% and 22% respectively). Surgical complication rates by surgical site, surgical approach, and year are presented in Table 3. A decline in robotic surgical complication rates from the beginning to the end of study period was observed for all sites, with the exception of esophagus. By 2014, complications were statistically lower for patients with gastric

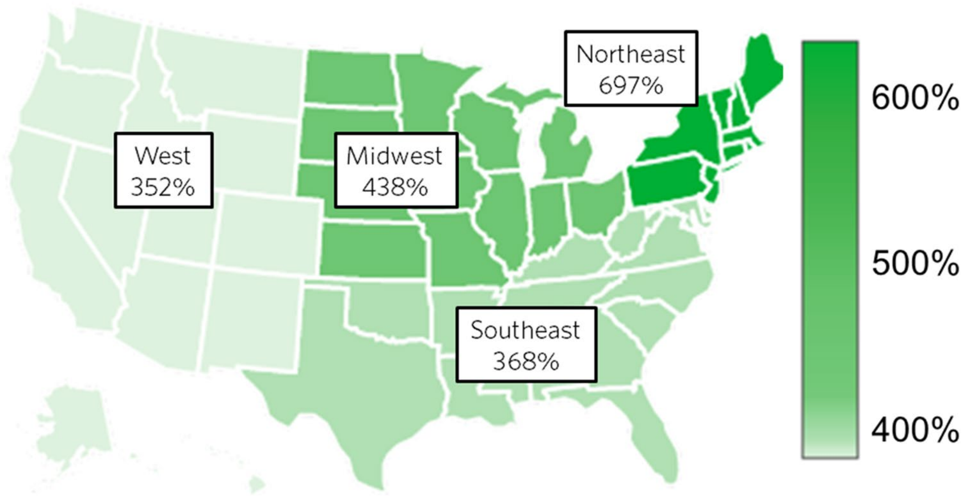

Fig. 2 Change in the frequency of robotic surgical oncology procedures over time by region of the US. Change was measured as percent change from 2010 to 2014

Table 2 Odds of having a robotic operation adjusting for age and number of comorbidities, stratified by surgical site and year

	2011	2012	2013	2014
Esophageal (robot vs lap)	0.19 (0.42–0.88)	2.24 (0.68–7.40)	2.12 (0.65–6.98)	**4.00 (1.22–13.09)**
Stomach (robot vs lap)	1.28 (0.47–3.50)	1.77 (0.68–4.58)	**3.63 (1.44–9.11)**	**3.89 (1.60–9.48)**
Small Bowel (robot vs lap)	2.40 (0.46–12.62)	**5.89 (1.37–25.33)**	**9.15 (2.25–37.20)**	**5.54 (1.30-23.55)**
Pancreas (robot vs lap)	3.95 (0.85–18.24)	**3.52 (1.18–10.47)**	**9.62 (3.87–23.95)**	**7.94 (3.53–17.85)**
Liver (robot vs lap)	9.71 (0.95–99.57)	**15.31 (1.87–125.14)**	**15.46 (1.91–125.11)**	**25.37 (3.25–197.88)**
Colorectal (robot vs lap)	1.48 (0.95–2.31)	**2.13 (1.46–3.11)**	**3.37 (2.32–4.91)**	**4.66 (3.22–6.76)**
All sites (robotic vs lap)	1.44 (0.93–2.24)	**2.16 (1.48–3.15)**	**3.39 (2.33–4.93)**	**4.55 (3.13–6.61)**
All sites (robotic vs lap/open)	**1.64 (1.05–2.57)**	**2.17 (1.48–3.17)**	**3.99 (2.74–5.80)**	**5.56 (3.82–8.07)**

Data from 2010 were used as reference. Values presented are the odds ratio (95% confidence interval). Values in bold are statistically significant ($p < 0.05$)

($p = 0.04$), small bowel ($p < 0.001$), liver ($p < 0.001$), and colorectal cancers ($p < 0.001$) who underwent robotic surgery, compared to patients who underwent laparoscopic or open surgery. The association of lower surgical complications in the robotic group compared to the laparoscopic group was lost, however, after adjusting for age, comorbidities, year, and surgical site (OR 0.91, 95% CI 0.83–1.01, $p = 0.08$). Similar multivariable analyses were conducted for medical complications, and each disease site individually, also showing similar complication rates between robotic and laparoscopic groups.

Length of stay (LOS) was similar between robotic (6.9 ± 6.5 days) and laparoscopic cases (7.0 ± 6.5 days, $p = 0.52$); which were shorter compared with open cases (10.6 ± 9.3 days, $p = < 0.001$), with similar findings each year. This was generally true when broken down by disease site. By 2014, patients with colorectal cancer who received a robotic surgery had shorter LOS by 0.4 days when compared to the laparoscopic group (6.1 vs 6.5 days, $p = 0.03$), and patients with pancreatic cancer who received a robotic surgery had shorter LOS by 3.0 days when compared to the laparoscopic group (8.7 vs 11.7 days, $p = 0.03$). The remaining surgical sites had similar LOS for robotic and laparoscopic groups the final year studied.

Discussion

We investigated the implementation of robotic surgery for general surgical oncology operations over a 5-year period, from 2010 to 2014 and found that robotic use sharply increased during this period. The increase in

Table 3 Complication rates year of surgery, surgical approach, and disease site

	2010			2011			2012			2013			2014		
	Open (%)	Lap (%)	Robot (%)	Open (%)	Lap (%)	Robot (%)	Open (%)	Lap (%)	Robot (%)	Open (%)	Lap (%)	Robot (%)	Open (%)	Lap (%)	Robot (%)
Esophageal	44	38	28	51	46	50	58	52	50	52	52	49	52	41	56
Stomach	25	22	25	29	29	14	43	41	28	34	29	38	32	30	19
Small bowel	34	20	N/A	39	23	20	56	30	15	45	23	19	45	30	17
Pancreas	29	21	14	31	31	14	44	39	33	39	32	33	36	34	26
Liver	26	13	N/A	27	18	33	38	24	17	33	20	27	34	18	15
Colorectal	23	12	17	27	14	13	40	24	22	35	21	20	35	21	17
Total	26	13	18	29	15	14	42	25	24	37	22	23	36	22	19

N/A no applicable operations were performed to be evaluated for complications

robotic operations was observed for all examined disease sites: esophagus, stomach, liver, pancreas, small bowel, colon, and rectum. This increase was also observed in all regions of the country, and persisted when controlling for age and comorbidities. Length of stay was generally similar for patients undergoing robotic and laparoscopic surgeries. Surgical complications with robotic cases declined throughout the study period, and were statistically lower than laparoscopic and open operations for most surgical sites by 2014. After adjusting for confounding variables, however, complication rates between robotic and laparoscopic procedures were also similar. These results lend themselves to a discussion regarding the controversies related to use of the robotic platform, namely, the issues of data to support its use, expense related to its use, and how resources should be allocated in the future.

Novel surgical technology is disruptive to standard surgical practices, and adoption of robotic surgery has been met with opposition and skepticism in the past, particularly for oncologic operations. There is an accepted pathway to demonstrate effectiveness of new drugs; however, new procedures and technologies in surgery develop out of clinical need and then become incorporated into practice [9, 10]. Reports tend to emphasize feasibility rather than efficacy, and results are affected by surgeon experience and variations in peri-operative care [9]. In spite of these challenges, there are many studies demonstrating safety, improved short-term outcomes, and oncologic equivalence for cancer operations performed with minimally invasive techniques compared to open surgery. Randomized controlled trials of laparoscopic vs open surgery have been performed in colon cancer [11], rectal cancer [12–14], esophageal cancer [15], and gastric cancer [16, 17]. Ejaz et al. performed a similar study examining the use of minimally invasive surgery for hepatic and pancreatic resections in the Nationwide Inpatient Sample from 2000 to 2011. They also found that laparoscopy was increasing over time, from 2.3 to 7.5% over that time period [18].

Significant improvements in outcome have not, however, been easily identified when comparing robotic surgery to traditional laparoscopy. Robotic surgery is a technological advancement intended to improve precision in minimally invasive surgery. Thus, outcomes using different minimally invasive platforms should be similar in the hands of experts. Prospective randomized studies in rectal cancer surgery showed few positive differences between robotics and traditional laparoscopy, with longer robotic operative times [19, 20]. High-quality studies in gastric cancer echo these findings [21]. There is a paucity of prospective studies evaluating robotics in liver and pancreatic cancer surgeries, likely due to longer learning curves for these procedures [22]. Several studies have also described the feasibility of robotic pancreaticoduodenectomy and distal pancreatectomy but they are largely retrospective and affected by selection bias [23].

In an economic climate of cost-conscious medical consumerism, the additional cost of robotic surgery also cannot be ignored. Robotic surgery has been associated with an increased cost of 13% compared to laparoscopy [24], in part due to higher purchase and maintenance costs [25], as well as more costly consumable surgical supplies [26]. This fact hampers randomization in studies. Kim et al. matched patients since the study was not funded to pay the additional $7,326 US dollars charge with robotic surgery [21].

Without conclusive clinical studies supporting the use of robotic surgery, combined with evidence that it increases costs, the reasons for increased robotic surgery in general surgical oncology may exist elsewhere. There are little data on recovery and quality of life related to robotics in surgical oncology. Further, there are a number of intangible elements related to robotic surgery that may never be captured by a randomized controlled trial. These include ergonomics with diminished surgeon fatigue [27, 28], issues related to hand dominance [29], learning curve and skill retention of trainees [30], and superior visualization with a three-dimensional view [10, 31, 32]. Proponents of robotic rectal surgery suggest that that the technical limitations of laparoscopy in the pelvis are overcome by the articulating instruments and tridimensional view. Robotic surgery has also been considered a valuable alternative to historically "incision dominant" surgeries, such as minor superior–posterior hepatectomies, given issues with access using straight instruments [2]. The learning curves for right hemicolectomy and rectal resection are reported to be lower for robotic compared to laparoscopic surgery [33–35]. Operative times may increase after the initial robotic surgical experience for colorectal and liver surgery, though presumably due to greater comfort with the platform leading to more complex cases [34, 36, 37]. This is contrasted with robotic pancreatic surgery, which has a dramatic decrease in operative time after only the first 10 procedures [38, 39]. Influences of non-clinical factors should also be considered: one study examining common urologic and gynecologic procedures showed a correlation between the use of robotic surgery and hospital market competition [40]. These unaccounted variables are at least part of the reason for the sharp increase in use of robotic surgery within surgical oncology.

Our study has several limitations, many which are inherent to its basis on an administrative database populated with ICD-9 codes. Detailed information about cancer and tumor characteristics is unavailable, which may impact surgical approach decisions. The NIS data also do not track individual patients, so an unknown number of records may represent the same patient with cancer diagnosed at more than one primary site. Follow-up information such as readmissions within 30 days, vital status, and survival time is also unavailable for NIS data, thereby limiting our ability to compare important clinical outcomes for robotic cases to other surgical approaches. Further, since it is retrospective, a selection bias will be present.

To conclude, the rate of use of robotic surgery is increasing annually in general surgical oncology. This is occurring in all cancer sites, and throughout the US. Increasing use of robotic surgery is likely due to a number of factors that are difficult to capture in patient data sets, related to ergonomics, learning curve, and other non-clinical factors. Further prospective research should focus on quantitative measurements of these factors to identify the best use of robotic surgery within surgical oncology procedures. Given its continued increasing use, the training of general surgeons and surgical oncologists should also include the robotic platform.

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Compliance with ethical standards

Disclosures Dr. Camille L. Stewart has received consulting fees from Verb Surgical. Dr. Kurt A. Melstrom has received consulting fees from Ethicon. Dr. Yuman Fong has received consulting fees from Ethicon. Dr. Yanghee Woo has received consulting fees from Verb Surgical, Ethicon, and Intuitive Surgical. Drs. Philip HG Ituarte, Susanne G. Warner, Laleh G. Melstrom, and Lily L. Lai have no conflicts of interest or financial ties to disclose.

Appendix

See Table 4.

Table 4 International Classification of Diseases (ICD)-9-Clinical Modification codes for diagnoses and procedures that were matched based on principal diagnosis for each site-specific malignant neoplasm

General robot codes			
1741	Open robotic-assisted procedure		
1742	Laparoscopic robotic-assisted procedure		
1743	Percutaneous robotic-assisted procedure		
1744	Endoscopic robotic-assisted procedure		
1745	Thoracoscopic robotic-assisted procedure		
1749	Other and unspecified robotic-assisted procedure		
General laparoscopic codes			
5421	Laparoscopy		
Esophageal surgery		Esophageal cancer diagnoses	
4231	Local excision of esophageal diverticulum	1500	Malignant neoplasm of cervical esophagus
4232	Local excision of other lesion or tissue of esophagus	1501	Malignant neoplasm of thoracic esophagus
4239	other destruction of lesion or tissue of esophagus	1502	Malignant neoplasm of abdominal esophagus
424	Esophagectomy, not otherwise specified	1503	Malignant neoplasm of upper third of esophagus
4241	Partial esophagectomy	1504	Malignant neoplasm of middle third of esophagus
4242	Total esophagectomy	1505	Malignant neoplasm of lower third of esophagus
		1508	Malignant neoplasm of other specified part of esophagus
		1509	Malignant neoplasm of esophagus, unspecified site
		1510	Malignant neoplasm of cardia
		1590	Malignant neoplasm of intestinal tract, part unspecified
		2301	Carcinoma in situ of esophagus
Stomach surgery		Stomach cancer diagnoses	
435	Partial gastrectomy with anastomosis to esophagus	1510	Malignant neoplasm of cardia
436	Partial gastrectomy with anastomosis to duodenum	1511	Malignant neoplasm of pylorus
437	Partial gastrectomy with anastomosis to jejunum	1512	Malignant neoplasm of pyloric antrum
438	Other partial gastrectomy	1513	Malignant neoplasm of fundus of stomach
4381	Partial gastrectomy with jejunal transposition	1514	Malignant neoplasm of body of stomach
4389	Open and other partial gastrectomy	1515	Malignant neoplasm of lesser curvature of stomach, unspecified
4391	Total gastrectomy	1516	Malignant neoplasm of greater curvature of stomach, unspecified
4391	Total gastrectomy with intestinal interposition	1518	Malignant neoplasm of other specified sites of stomach
4399	Other total gastrectomy	1519	Malignant neoplasm of stomach, unspecified site
		1590	Malignant neoplasm of intestinal tract, part unspecified
		1952	Malignant neoplasm of abdomen
		2302	Carcinoma in situ of stomach

Table 4 (continued)

Stomach surgery		Stomach cancer diagnoses	
		2352	Neoplasm of uncertain behavior of stomach, intestines, and rectum
Small bowel surgery		**Small bowel cancer diagnoses**	
4531	Other local excision of lesion of duodenum	1520	Malignant neoplasm of duodenum
4532	Other destruction of lesion of duodenum	1521	Malignant neoplasm of jejunum
4533	Local excision of lesion or tissue of small intestine, except duodenum	1522	Malignant neoplasm of ileum
4561	Multiple segmental resections of small intestine	1528	Malignant neoplasm of other specified sites of small intestine
4562	Other partial resection of small intestine	1529	Malignant neoplasm of small intestine, unspecified site
4591	Small-to-small intestinal anastomosis	1561	Malignant neoplasm of extrahepatic bile ducts
4592	Anastomosis of small intestine to rectal stump	1562	Malignant neoplasm of ampulla of vater
4593	Other small-to-large intestinal anastomosis	1569	Malignant neoplasm of biliary tract, part unspecified site
		1590	Malignant neoplasm of intestinal tract, part unspecified
		1952	Malignant neoplasm of abdomen
		1974	Secondary malignant neoplasm of small intestine including duodenum
		2352	Neoplasm of uncertain behavior of stomach, intestines, and rectum
Pancreas surgery		**Pancreas cancer diagnoses**	
5209	Other pancreatotomy	1570	Malignant neoplasm of head of pancreas
5212	Open biopsy of pancreas	1571	Malignant neoplasm of body of pancreas
5222	Other excision or destruction of lesion or tissue of pancreas or pancreatic duct	1572	Malignant neoplasm of tail of pancreas
5251	Proximal pancreatectomy	1573	Malignant neoplasm of pancreatic duct
5252	Distal pancreatectomy	1574	Malignant neoplasm of islets of langerhans
5253	Radical subtotal pancreatectomy	1578	Malignant neoplasm of other specified sites of pancreas
5259	Other partial pancreatectomy	1579	Malignant neoplasm of pancreas, part unspecified
526	Total pancreatectomy	1520	Malignant neoplasm of duodenum
527	Radical pancreaticoduodenectomy	1528	Malignant neoplasm of other specified sites of small intestine
		1529	Malignant neoplasm of small intestine, unspecified site
		1561	Malignant neoplasm of extrahepatic bile ducts
		1562	Malignant neoplasm of ampulla of vater
		1569	Malignant neoplasm of biliary tract, part unspecified site
		1590	Malignant neoplasm of intestinal tract, part unspecified
		1952	Malignant neoplasm of abdomen
		1974	Secondary malignant neoplasm of small intestine including duodenum
		2308	Carcinoma in situ of liver and biliary system

Table 4 (continued)

Pancreas surgery		Pancreas cancer diagnoses	
		2353	Neoplasm of uncertain behavior of liver and biliary passages
Liver surgery		**Liver/Gallbladder cancer diagnoses**	
5022	Partial hepatectomy	1550	Malignant neoplasm of liver, primary
5023	Open ablation of liver lesion or tissue	1551	Malignant neoplasm of intrahepatic bile ducts
5024	Percutaneous ablation of liver lesion or tissue	1552	Malignant neoplasm of liver, not specified as primary or secondary
5025	Laparoscopic ablation of liver lesion or tissue	1560	Malignant neoplasm of gallbladder
5026	Other and unspecified ablation of liver lesion or tissue	1561	Malignant neoplasm of extrahepatic bile ducts
5029	Other destruction of lesion of liver	1562	Malignant neoplasm of ampulla of vater
503	Lobectomy of liver	1568	Malignant neoplasm of other specified sites of gallbladder and extrahepatic bile ducts
504	Total hepatectomy	1569	Malignant neoplasm of biliary tract, part unspecified site
5011	Closed (percutaneous) [needle] biopsy of liver	1952	Malignant neoplasm of abdomen
5012	Open biopsy of liver	2308	Carcinoma in situ of liver and biliary system
5014	Laparoscopic liver biopsy	2353	Neoplasm of uncertain behavior of liver and biliary passages
5136	Choledochoenterostomy		
5137	Anastomosis of hepatic duct to gastrointestinal tract		
Colorectal surgery		**Colorectal cancer diagnoses**	
4594	Large-to-large intestinal anastomosis	1530	Malignant neoplasm of hepatic flexure
4595	Anastomosis to anus	1531	Malignant neoplasm of transverse colon
4862	Anterior resection of rectum with synchronous colostomy	1532	Malignant neoplasm of descending colon
4863	Other anterior resection of rectum	1533	Malignant neoplasm of sigmoid colon
4869	Other resection of rectum—other	1534	Malignant neoplasm of cecum
4851	Abdominoperineal resection of rectum	1535	Malignant neoplasm of appendix vermiformis
485	Abdominoperineal resection of the rectum, not otherwise specified	1536	Malignant neoplasm of ascending colon
4851	Laparoscopic Abdominoperineal Resection Of The Rectum	1537	Malignant neoplasm of splenic flexure
4852	Open abdominoperineal resection of the rectum	1538	Malignant neoplasm of other specified sites of large intestine
4859	Other abdominoperineal resection of the rectum	1539	Malignant neoplasm of colon, unspecified site
1731	Laparoscopic multiple segmental resections of large intestine	1540	Malignant neoplasm of rectosigmoid junction
1732	Laparoscopic cecectomy	1541	Malignant neoplasm of rectum

Table 4 (continued)

Colorectal surgery		Colorectal cancer diagnoses	
1733	Laparoscopic right hemicolectomy	1542	Malignant neoplasm of anal canal
1734	Laparoscopic resection of transverse colon	1543	Malignant neoplasm of anus, unspecified site
1735	Laparoscopic left hemicolectomy	1548	Malignant neoplasm of other sites of rectum, rectosigmoid junction, and anus
1736	Laparoscopic sigmoidectomy	1590	Malignant neoplasm of intestinal tract, part unspecified
1739	Other laparoscopic partial excision of large intestine	1952	Malignant neoplasm of abdomen
4571	Open and other multiple segmental resections of large intestine	1953	Malignant neoplasm of pelvis
4572	Open and other cecectomy	1975	Secondary malignant neoplasm of large intestine and rectum
4573	Open and other right hemicolectomy	2303	Carcinoma in situ of colon
4574	Open and other resection of transverse colon	2304	Carcinoma in situ of rectum
4575	Open and other left hemicolectomy	2352	Neoplasm of uncertain behavior of stomach, intestines, and rectum
4576	Open and other sigmoidectomy		
4579	Other and unspecified partial excision of large intestine		
4581	Laparoscopic total intra-abdominal colectomy		
4582	Open total intra-abdominal colectomy		
4583	Other and unspecified total intra-abdominal colectomy		

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