The First National Examination of Outcomes and Trends in Robotic Surgery in the United States

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BACKGROUND: There are few population-based data describing outcomes of robotic-assisted surgery. We compared outcomes of robotic-assisted, laparoscopic, and open surgery in a nationally representative population database.

STUDY DESIGN: A retrospective analysis of the Nationwide Inpatient Sample database from October 2008 to December 2009 was performed. We identified the most common robotic procedures by ICD-9 procedure codes and grouped them into categories by procedure type. Multivariate analyses examined mortality, length of stay (LOS), and total hospital charges, adjusting for age, race, sex, Charlson comorbidity index, and teaching hospital status.

RESULTS: A total of 368,239 patients were identified. On adjusted analysis, compared with open, robotic-assisted laparoscopic surgery was associated with decreased odds of mortality (odds ratio = 0.1; 95% CI, 0.0–0.2; $p < 0.001$), decreased mean LOS (−2.4 days; 95% CI, −2.5 to 2.3; $p < 0.001$), and increased mean total charges in all procedures (range $3,852 to $15,329) except coronary artery bypass grafting (−$17,318; 95% CI, −34,492 to −143; $p = 0.048$) and valvuloplasty (not statistically significant). Compared with laparoscopic, robotic-assisted laparoscopic surgery was associated with decreased odds of mortality (odds ratio = 0.1; 95% CI, 0.0−0.6; $p = 0.008$), decreased LOS overall (−0.6 days; 95% CI, −0.7 to −0.5; $p < 0.001$), but increased LOS in prostatectomy and other kidney/bladder procedures (0.3 days; 95% CI, 0.1–0.4; $p = 0.006$; 0.8 days; 95% CI, 0.0–1.6; $p = 0.049$), and increased total charges ($1,309; 95% CI, 519–2,099; $p = 0.001$).

CONCLUSIONS: Data suggest that, compared with open surgery, robotic-assisted surgery results in decreased LOS and diminished likelihood of death. However, these benefits are not as apparent when comparing robotic-assisted laparoscopic with nonrobotic laparoscopic procedures. (J Am Coll Surg 2012;215:107–116. © 2012 by the American College of Surgeons)

Although robotically assisted minimally invasive surgery was approved for clinical practice in the United States in July 2000,[1] distinct ICD-9 procedure codes for robotic surgery were not assigned until October 2008.[2]

Numerous studies have described the outcomes of specific procedures performed robotically, primarily in small trials.[3-11] However, to our knowledge, there has not yet been an analysis of robotic surgery outcomes across procedures or between fields of medicine.

Using a national cohort, we identified the most commonly performed robotic procedures; examined trends in the prevalence of these procedures over time; and compared mortality, length of stay (LOS), and total charges among robotic, open, and nonrobotic laparoscopic procedures.

METHODS

Retrospective analysis of the US Nationwide Inpatient Sample (NIS) database was performed from October 2008 to December 2009, the only currently available time period of the dataset that includes robotic procedure codes. The NIS is the largest all-payer inpatient database in the United States, sampling from approximately 20% of all US hospitals. In 2008, the NIS contained discharge data from 1,056 hospitals located in 42 states, and in 2009, the NIS con-

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Abbreviations and Acronyms

CABG = coronary artery bypass grafting
LOS = length of stay
NIS = Nationwide Inpatient Sample

tained data from 1,050 hospitals located in 44 states. It includes >100 clinical and nonclinical data variables from each hospital stay, including primary and secondary diagnoses, primary and secondary procedures, admission and discharge status, patient demographics, expected payment source, total charges, LOS, and hospital characteristics.[12]

The top robotic procedures by frequency were identified by ICD-9 procedure codes (ICD-9 codes 17.41, 17.42, 17.43, 17.44, 17.45, 17.49). The primary procedures of the top 90% of patients who had a code for robotic surgery were identified and included in this study (23 procedures; Table 1). All patients with these procedures as the primary procedure were identified and classified as to whether they had the procedure performed via robotic surgery, nonrobotic laparoscopic surgery, or open surgery. Laparoscopic procedures were identified by one of the following additional ICD-9 procedure codes (54.21, 54.51, or 65.63) or if the primary procedure itself was identified as laparoscopic (eg, laparoscopic total abdominal hysterectomy). Procedures were grouped into 10 categories based on the following procedure types: prostatectomy, hysterectomy, other kidney/bladder procedures, partial nephrectomy, other gynecological procedures, valvuloplasty, coronary artery bypass grafting (CABG), knee replacement, gastroenterostomy, and esophagogastric sphincter competence (Table 2).

The percent of procedures performed robotically over time was found for each category of procedure (Fig. 1). For outcomes analyses, only open robotic-assisted and laparoscopic robotic-assisted procedures were included (ICD-9 codes 17.41 and 17.42). The definition of the code open robotic-assisted procedures is not obvious, but the number of robotic procedures categorized as such was not trivial. Both procedure codes were used in our outcomes analyses. Patients were grouped according to category and method of procedure (Table 3). By procedure category, unadjusted analyses examined differences in total hospital charges, LOS, and mortality, comparing procedures performed open or laparoscopic with those performed with robotic assistance (Tables 4 and 5). Multivariate analyses examined total hospital charges, LOS, and mortality, controlling for age, race, sex, Charlson comorbidity index, and teaching hospital status (Figs. 2 to 6). The Charlson index is a measure of

Table 1. Top Procedures Performed Robotically

ICD-9 code	Procedure	Frequency	%	Cumulative %
60.5	Radical prostatectomy	12,207	48.62	48.62
68.41	Laparoscopic total abdominal hysterectomy	2,713	10.81	59.43
68.51	Laparoscopically assisted vaginal hysterectomy	1,703	6.78	66.21
55.4	Partial nephrectomy	852	3.39	69.60
60.69	Prostatectomy (other)	714	2.84	72.45
55.87	Correction of ureteropelvic junction	517	2.06	74.51
55.51	Nephroureterectomy	482	1.92	76.42
68.31	Laparoscopic supracervical hysterectomy	474	1.89	78.31
68.61	Laparoscopic radical abdominal hysterectomy	458	1.82	80.14
68.49	Total abdominal hysterectomy (other and unspecified)	416	1.66	81.79
35.12	Open heart valvuloplasty of mitral valve without replacement	284	1.13	82.93
57.71	Radical cystectomy	252	1.00	83.93
36.15	Single internal mammary–coronary artery bypass	244	0.97	84.90
65.63	Laparoscopic removal of both ovaries and tubes	212	0.84	85.75
70.78	Vaginal suspension and fixation with graft or prosthesis	210	0.84	86.58
68.29	Other excision or destruction of lesion of uterus	191	0.76	87.34
68.59	Other and unspecified vaginal hysterectomy	131	0.52	87.86
81.54	Total knee replacement	117	0.47	88.33
44.38	Laparoscopic gastroenterostomy	112	0.45	88.78
56.74	Ureteroneocystostomy	94	0.37	89.15
44.67	Laparoscopic procedures for creation of esophagogastric sphincteric competence	87	0.35	89.50
65.41	Laparoscopic unilateral salpingo-oophorectomy	81	0.32	89.82
68.71	Laparoscopic radical vaginal hysterectomy	80	0.32	90.14