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ORIGINAL ARTICLE

Laparoscopic versus robotic adrenalectomy: a review of the national inpatient sample

Sarah Samreen[1] · Marcus Fluck[1] · Marie Hunsinger[1] · Jeffrey Wild[1] · Mohsen Shabahang[1] · Joseph A. Blansfield[1]

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Abstract

Background Laparoscopic adrenalectomy (LA) has become the standard treatment of adrenal lesions. Recently, robotic-assisted adrenalectomy (RA) has become an option, however, short-term outcomes for RA have not been well studied and benefits over LA are debatable. The aim of this study was to explore differences in short-term outcomes between LA and RA using the national inpatient sample (NIS) database.
Methods Patient data were collected from the NIS. All patients undergoing LA or RA from January 2009 to December 2012 were included. Univariate analysis and propensity matching were performed to look for differences between the groups.
Results A total of 1006 patients (66.4% in LA group and 33.6% in RA group) were identified. Patient age group, gender, race, risk of mortality, severity of illness or indication for adrenalectomy did not differ significantly between the LA or RA cohorts. Insurance type predicted procedure type (45% of medicare patients underwent RA versus 29% of patients with private insurance, $p < 0.0001$). Patients living in the highest income areas were more likely to receive the laparoscopic approach (31.7 versus 17.4%, $p < 0.0001$). Hospital volume, bed size and teaching status of the hospital were not significant factors in the decision of RA versus LA. There was no difference in complication and conversion rates between RA versus LA. The mean length of stay was shorter in the RA group (2.2 versus 1.9 days, $p = 0.03$). Total charges were higher in the RA group ($42,659 versus $33,748, $p < 0.0001$). There was a significant trend towards more adrenalectomies being performed robotic assisted by year. Only 22% of adrenalectomies were performed robotic-assisted in 2009 compared with 48% in 2012.
Conclusions The overall benefit for RA remains small and higher total charges for RA may currently outweigh the benefits. These findings may change as more cases are performed robotically assisted and robotic technology improves.

Keywords Robotic surgery · Laparoscopic surgery · Adrenalectomy · Endocrine surgery · National inpatient sample

Introduction

Adrenalectomy is a technically complex operation which requires careful dissection around major vessels and organs with removal of a small gland in a narrow space [1]. Laparoscopic adrenalectomy (LA) has become the standard treatment of adrenal lesions since first being performed in 1992 by Gagner et al. [2] It has proven to have less blood loss, earlier ambulation, shorter hospital stay, and faster return to normal activity compared with an open operation [3]. Although widely accepted, laparoscopy has certain limitations, such as the two-dimensional view, rigid instrumentation and an unstable camera platform.

To overcome these limitations, in 1999 Piazza et al. [4] and Hubens et al. [5] from Europe described the first robotic-assisted adrenalectomy (RA). In the United States, Cleveland Clinic was first to report robotic-assisted adrenalectomies on pigs in the year 2000 [6]. After the approval of the da Vinci System (Intuitive Surgical, Sunnyvale, CA) by the Food and Drug Administration, Horgan and Vanuno [7]. reported the first human robotic-assisted adrenalectomy series from the United States. Since then, RA has been added to the surgical armamentarium for the management of adrenal masses but LA still remains the gold standard. Advantages of robotic-assisted surgery for adrenalectomy are stereoscopic vision, improved magnification, and greater range of motion within a limited working space. Robotic techniques may also be useful for surgeons without substantial laparoscopic

✉ Sarah Samreen
ssamreen@geisinger.edu

[1] Geisinger Medical Center, 100 N. Academy Avenue, MC 21-69, Danville, PA 17822, USA

experience who wish to perform minimally invasive adrenalectomy [8]. However, short-term outcomes for RA have not been well studied and benefits over LA are debatable. The aim of this study was to explore differences in short-term outcomes between LA and RA using the national inpatient sample (NIS) database.

Methods

A retrospective analysis of the Nationwide Inpatient Sample (NIS) database from 2009 to 2012 was performed comparing laparoscopic to robotic-assisted adrenalectomy surgeries performed on adult patients. The first full year when the International Classification of Diseases (ICD) 9-PR code for distinguishing robotic procedures is reported in the NIS was 2009.

The NIS is maintained by the Healthcare Cost and Utilization Project (HCUP) of the Agency for Healthcare Research and Quality. Admissions are from a 20% stratified sample of non-Federal hospitals within the United States, including university, specialty, and community hospital, excluding long-term facilities. This research was deemed exempt from institutional review board approval due to the de-identified nature of the NIS database. When the patient number of an observation is less than ten, the exact proportion is not reportable (NR) to maintain patient confidentiality, although the reported p value is calculated with the exact number of observations in the analysis.

The aim of the study was to explore differences in short-term outcomes between LA and RA. The primary outcomes of the study were conversion rate to open adrenalectomy, post-operative complications, length of inpatient stay, discharge disposition and total inpatient charges.

All analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary NC). Univariate analysis of categorical variables was performed using the Chi-square test and analysis of continuous variables was performed using the Student's *t* test. Propensity scores were developed to control for confounding in surgical approach, defined as the conditional probability of robotic surgery. Variables included in the propensity matching were: indication for adrenalectomy, age group, gender, race, insurance status, income quartile, Mortality Risk Index, Comorbidity Severity Index, hospital ownership, hospital bed size and volume. Hospital bed size is collected and defined by the NIS variable "hosp_bedsize"[9]. Patients were matched using an 8:1 greedy match algorithm using a 1:1 patient to patient ratio. All tests were two-sided and p values < 0.05 were considered significant.

As required by the NIS data use agreement, table cell values less than 11 were suppressed from reporting, however, exact values were used to calculate reported p values. The complications included are mechanical wound, infectious wound, pulmonary, gastrointestinal, cardiovascular, sepsis, or operative complications.

Inclusion and exclusion criteria

All patients 18 years or older with the ICD-9-PR codes 72.x and 73.0 for adrenalectomy were included. Patients were excluded from analysis if their inpatient stay contained coding of major cardiovascular (30–39.x), urologic (55–64.x), obstetric and gynecologic (65–75.x), or orthopedic surgeries (76–84.x).

Robotic-assisted procedures were identified using ICD-9-PR codes 17.41–17.45 and 17.49, laparoscopic procedures were identified by procedure code 54.21. Conversions to open procedures were identified using ICD-9 code V64.4x. Cohorts were defined by the surgical approach intended-to-treat the adrenal gland.

Benign adrenal disease was identified by ICD-9 diagnosis codes 227.0 or 237.2, malignant adrenal disease was identified by 194.0, and other adrenal disorders were classified as 255.x. Complications were identified by ICD-9 diagnosis codes and grouped into mechanical wound complications (998.83, 998.12,998.13,998.3, and 998.6), infectious wound complications (998.5, 998.59, 998.51, and 997.5), pulmonary complications (997.3, 518.4, 518.5, 512.1), gastrointestinal complications (997.4), cardiovascular complications (997.79, 415.11, 997.02, 997.2, 997.1), sepsis (998.0 and 998.89), other operative complications (998.2, 998.4, 998.11) and blood transfusions (990.2, 990.3, 990.4, 990.9).

Inpatient total charges were adjusted for inflation in terms of 2012 US dollars as specified by the United States department of Labor's Consumer Price Index Inflation calculator (2009*1.070, 2010*1.053, and 2011*1.021).

For each year, the median volume of procedures for all hospitals was calculated and compared with each individual hospital's weighted volume (based on the NIS weighting strategy). High volume hospitals were defined as performing more than the median number of procedures in the same year, and vice versa for low volume hospitals. The NIS weighting strategy was not used to report final procedure volume.

Results

From January 2009 through December 2012, there were 668 (66.4%) laparoscopic and 338 (33.6%) robotic-assisted adrenalectomies identified for analysis, a total of 1006 procedures. Table 1 shows the patient and facility factors associated with surgical approach. Patient age group, gender, race, risk of mortality, severity of illness, or indication for adrenalectomy did not differ significantly between the laparoscopic or robotic-assisted

Table 1 Demographics for robotic and laparoscopic cohorts

Variable	Laparoscopic *n* = 668	Robotic *n* = 338	*p* value
Age group			0.07
< 60	429 (64.2%)	192 (56.8%)	
60–69	137 (20.5%)	82 (24.3%)	
70–79	89 (13.3%)	51 (15.1%)	
80 +	13 (2.0%)	13 (3.9%)	
Male	258 (38.6%)	135 (39.9%)	0.69
Race			0.16
White	400 (59.9%)	208 (61.5%)	
Black	90 (13.5%)	30 (8.9%)	
Hispanic	47 (7.0%)	30 (8.9%)	
Other/unknown	131 (19.6%)	70 (20.7%)	
Obesity (> 30 BMI)	96 (14.4%)	50 (14.8%)	0.86
Primary Payor			< 0.0001
Medicare	156 (23.4%)	126 (37.3%)	
Medicaid	50 (7.5%)	30 (8.9%)	
Private insurance	409 (61.3%)	164 (48.5%)	
Self-pay	26 (3.9%)	12 (3.6%)	
No charge	NR	NR	
Other	NR	NR	
Elective	595 (89.1%)	317 (94.1%)	0.02
Patient ZIP Income Quartile			< 0.0001
First	145 (21.7%)	81 (2.0%)	
Second	145 (21.7%)	96 (28.4%)	
Third	149 (22.3%)	93 (27.5%)	
Fourth	212 (31.7%)	57 (17.4%)	
Unknown	17 (2.5%)	11 (3.3%)	
Risk of mortality subclass			0.87
Minor likelihood of dying	507 (75.9%)	261 (77.2%)	
Moderate likelihood of dying	140 (21.0%)	66 (19.5%)	
Major likelihood of dying	NR	NR	
Extreme likelihood of dying	NR	NR	
Severity of illness subclass			0.09
Minor loss of function	581 (87.0%)	311 (92.0%)	
Moderate loss of function	NR	NR	
Major loss of function	46 (6.9%)	17 (5.0%)	
Extreme loss of function	NR	NR	
Hospital bed size			0.27
Small	58 (8.7%)	NR	
Medium	108 (16.2%)	67 (19.8%)	
Large	491 (73.5%)	242 (71.6%)	
Unknown	11 (1.7%)	NR	
Location/teaching status of Hospital			0.06
Rural	NR	NR	
Urban nonteaching	119 (17.8%)	68 (20.1%)	
Urban teaching	533 (81.1%)	260 (77.4%)	
Unknown	NR	NR	
Hospital ownership			0.40
Government	109 (16.3%)	48 (14.2%)	
Private, not-profit	509 (76.2%)	266 (78.7%)	
Private, investor-owned	39 (5.8%)	NR	

Table 1 (continued)

Variable	Laparoscopic $n=668$	Robotic $n=338$	p value
Unknown	11 (1.7%)	NR	
Hospital volume			0.16
High volume	129 (19.3%)	53 (15.7%)	
Low volume	539 (80.7%)	285 (84.3%)	
Indication for adrenalectomy			0.33
Adrenal disorder	378 (56.6%)	195 (57.7%)	
Benign	213 (31.9%)	106 (31.4%)	
Malignant	17 (2.5%)	NR	
Other/unknown	60 (9.0%)	NR	
Laterality			0.98
Bilateral	11 (1.7%)	NR	
Partial	53 (7.9%)	NR	
Unilateral	604 (90.4%)	306 (90.5%)	

adrenalectomy cohorts. There was also no significant statistical difference in hospital characteristics such as bedsize, teaching status, ownership, or procedure volume. More robotic-assisted adrenalectomies were done as elective procedures (94.1 versus 89.1%, $p=0.015$), while patients living in the highest income areas were more likely to receive the laparoscopic approach (31.7 versus 17.4%, $p<0.0001$). Primary payor did predict which patients would undergo robotic-assisted adrenalectomy. Only 29% of patients with private insurance underwent RA compared with 45% and 37.5% of patients with medicare and medicaid, respectively, $p<0.0001$.

Propensity matching was performed to create two uniform groups of patients for comparing peri-operative outcomes. Following propensity matching there were 328 robotic-assisted and 328 laparoscopic records and there were no significant differences in any patient or hospital variables. Table 2 shows propensity-matched outcomes between the two approaches. Total inpatient charges were significantly lower in the laparoscopic group ($33,749 versus $42,659, $p<0.0001$). This was present even though length of hospital stay was significantly shorter for the robotic patients (1.9 versus 2.2 days, $p=0.03$). There was no significant difference in discharge disposition or inpatient complications between the groups. Additionally, the conversion-to-open rate was less than 2% for both groups and was not statistically different (p 0.70).

There was a significant trend towards more adrenalectomies being performed robotic-assisted by year. Only 22% of adrenalectomies were performed robotic-assisted in 2009 compared with 48% in 2012. This trend is seen on Table 3 and Fig. 1.

Table 2 Propensity-matched outcomes

Variable	Laparoscopic $n=328$	Robotic $n=328$	p value
Total charges*, $US 2012	$33,749 ($31,609, $36,029)	$42,659 ($40,163, $45,315)	<0.0001
Length of stay*	2.2 (2.1, 2.4)	1.9 (1.7, 2.2)	0.03
Any complication	19 (5.8%)	15 (4.8%)	0.48
Conversion to open	NR (<2%)	NR (<2%)	0.70
Need for transfusion	14 (4.3%)	NR	0.12
Disposition			0.22
Routine	302 (92.1%)	313 (95.4%)	
Transfer to SNF, ICF	NR	NR	
Home health care	22 (6.7%)	13 (4.0%)	
Died	NR	NR	

SNF skilled nursing facility, *ICF* intermediate care facility

*Reported as mean and 95% CI

Table 3 Yearly trends

Variable	Laparoscopic $n=668$	Robotic $n=338$	p value
Year			<0.0001*
2009	171 (25.6%)	48 (14.2%)	
2010	157 (23.5%)	61 (18.1%)	
2011	189 (28.3%)	87 (25.7%)	
2012	151 (22.6%)	142 (42.0%)	

*Cochran–Armitage trend test

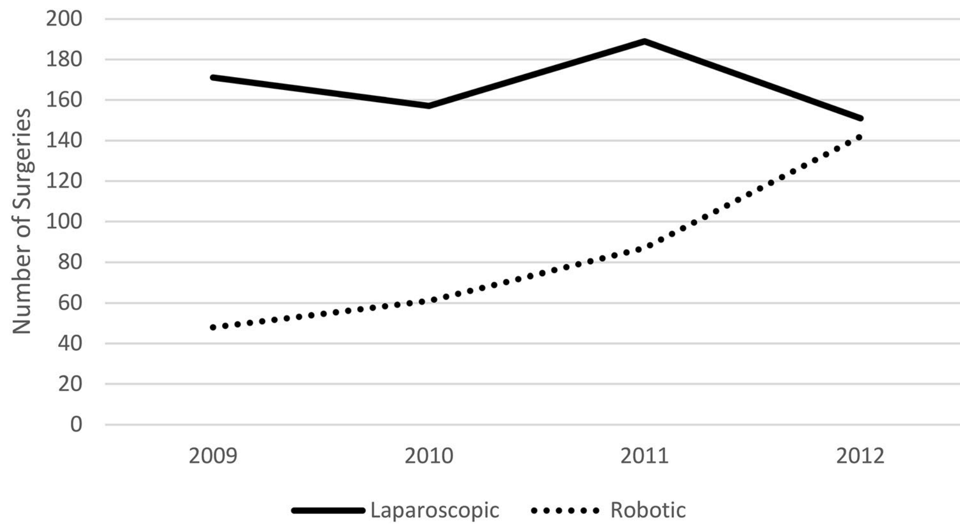

Fig. 1 Yearly trend of laparoscopic and robotic adrenalectomy procedures

Discussion

Robotic-assisted technique is reported to have several advantages over laparoscopy. The three-dimensional (3-D) optics provides depth perception, and excellent magnification with outstanding resolution that aids visualization. The robotic instruments allow precise movements and filter out tremors. The instrument wrists offer 7 degrees of movement allowing freedom in a small space. Additionally, surgeon comfort is enhanced by the ergonomically designed robotic station [10]. Finally, the robotic system allows virtual simulation, and a rapid learning curve [11–13]. Some favorable applications that have been adapted to robotic-assisted adrenalectomy are FireFly technology and tele-monitoring [14]. FireFly technology, utilized after injecting indocyanin green dye, allows partial adrenalectomy by delineating the tumor margins [15]. Telementoring allows remote monitoring of a procedure by a well-trained surgeon, and is a way to learn and perform a new surgical technique [16, 17]. In addition, single-port RA could potentially benefit patients [18, 19].

To our knowledge, this is the largest study to date that pools nationwide cases of all approach laparoscopic and robotic-assisted adrenalectomies, and compares short-term post-operative outcomes for these cases. Despite all the theoretical benefits of robotic surgery for adrenalectomy mentioned above, our study demonstrates that there are no clinical peri-operative advantages to performing robotic-assisted adrenalectomy. In addition, the total inpatient charges were significantly higher for the RA group compared to the LA group ($42,659 versus $33,749; $p < 0.0001$). The shorter length of stay with RA (1.9 versus 2.2; $p = 0.03$) translates into less than 1/4th of a day and is likely not clinically relevant.

Due to the inherent limitation of the NIS database, this study is unable to separate out the cost of the surgery itself from the total inpatient charges. However, there are typically no differences in the post-operative care of patients undergoing LA versus RA and the length of stay for patients undergoing RA was shorter. Therefore, it is most likely that the higher total inpatient charges in the RA group are in fact from the higher cost of robotic surgery.

Several elements can potentially lead to the inflated cost of robotic-assisted surgery. First, the purchase of the robot is costly. Maintenance of the unit, price of the robotic instruments and drapes further adds to the cost. These costs could be curtailed over time with increased frequency of use in high-volume centers. Second, the length of the procedure can be longer when performed robotically. This is especially true at the beginning of a surgeon's learning curve. Agcaoglu et al. [20] mentioned utilizing up to 20–25 min in the transport of the robotic unit to the operating room, system start-up, draping of the robotic arms and calibrating the robotic camera. Hospitals with dedicated robotic-operating rooms and dedicated ancillary staff for these tasks may be able to cut down on the additional set-up time. This additional time may also decrease as more procedures are performed [1, 21, 22]. Surgeon experience and first assist level also play a significant role in determining the operative time for RA. Prior studies have shown that operative times decrease with increasing experience with RA [22–25]. Brunaud et al. [24] demonstrated that a learning curve of 15 cases was necessary for a junior surgeon to have similar operative times to a senior surgeon. They also showed that previous experience with LA before using the robotic system was associated with shorter operative times. However, the NIS database does not provide information about surgeon experience or operative times and we are not able to tease out this factor in our study.

The complication rate for RA in our study was 4.8%, which is in accordance with 4–10% reported complication rate for RA in the literature [23, 26, 27]. The complication rate for LA in our study was 5.8%, which is in accordance to the reported complication rate for LA at 3–15% in the literature [22, 28, 29]. There was no statistically significant difference in inpatient complications between RA and LA. After examining the initial study results, a power analysis determined 15,756 patients would be required to demonstrate a significant difference given the reported rate of complications.

Regarding conversion rate, our study demonstrated that the conversion rate for both LA and RA was $< 2\%$ which was not statistically different for the two groups. Several robotic-assisted procedures get converted to traditional laparoscopy [30]. Reasons for conversion are usually related to malposition of trocars, difficulty to maintain hemostasis, and failure to progress robotically [31, 32]. The conversion rate may decrease with increasing experience [32]. Meta-analysis of previous studies concur with our findings and show that overall complication rates, and conversion rates are similar for RA and LA [14, 33].

There was no difference in the need for blood transfusion between the LA and RA groups ($p = 0.12$). Studies in the past have reported lower estimated blood loss (EBL) for adrenalectomies performed robotically [20, 22, 27, 34–36]. Recent meta-analysis [33] of these studies demonstrated that the difference in EBL was only 25 ml which is not clinically relevant in terms of need for transfusion or any other change in patient management.

Our study shows that while more adrenalectomies are being done laparoscopically (668 LA versus 338 RA), the rate of RA procedures is on a rise (Table 3; Fig. 1). This trend may continue as the cost of the robot becomes less prohibitive, and more institutions acquire robotic technology. There is still a pressing need for a well-designed prospective randomized control trial to determine the exact role and benefits of robotics in adrenal surgery.

Due to the inherent nature of NIS database, we are unable to differentiate the individual approaches (i.e., transperitoneal versus retroperitoneal) used for the LA or RA. We are also not able to tease out the specific patient-related factors that led to specific choice of technique by surgeons. For example, it is not well understood why more patients with medicare and medicaid underwent RA versus patients with private insurance underwent LA. It is unlikely that this finding will hold true in future studies with larger cohorts. Another limitation of our study is that secondary to accessibility of data at the time of analysis, our outcomes end at December 2012. In the recent past, more institutions acquiring robotic technology, more surgeons being trained in robotic techniques, previously trained surgeons acquiring more experience over time, and innovation in robotic surgery may affect outcomes.

Conclusion

In conclusion, overall benefit for RA remains small and total charges for RA may currently outweigh the benefits. Our study emphasizes that RA and LA have similar conversion rate, morbidity, and disposition. There is still need for a well-done randomized controlled trial to determine the exact role and benefit of robotics in adrenal surgery. But until then, laparoscopic surgery should stay the gold standard for adrenalectomies.

Compliance with ethical standards

Conflict of interest Sarah Samreen MD, Marcus Fluck BS, Marie Hunsinger RN BSHS, Jeffrey Wild MD, Mohsen Shabahang MD PhD, Joseph A. Blansfield MD have no conflicts of interest or financial ties to disclose.

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