Robotic versus laparoscopic radical nephrectomy: comparative analysis and cost considerations

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Introduction: *Robotic-assisted laparoscopic radical nephrectomy (RRN) is an increasing utilized alternative to laparoscopic radical nephrectomy (LRN); however, there is a little data on comparative effectiveness and cost of these procedures. We analyzed perioperative outcomes and hospital charge difference among patients undergoing laparoscopic radical nephrectomy (LRN) and robotic radical nephrectomy (RRN).*

Materials and methods: *Our institutional renal mass registry was queried for patients who underwent either LRN or RRN from 2010 to 2014. Demographic, perioperative outcomes and hospital charge data were compared between surgical approaches.*

Results: *Overall, 319 minimally invasive radical nephrectomies were performed during the study period. Of these, 243 were LRN and 76 were RRN. Patient demographic and tumor characteristics were similar between groups. Among operative characteristics, operative time (136 min versus 139 min, p = 0.531), intraoperative complications (2.8% versus 2.0%, p = 0.650), and length of stay (2 days versus 2 days, p = 0.745) were similar for LRN and RRN, respectively. Estimated blood loss (50 mL versus 100 mL, p = 0.041) and rate of conversion to an alternative surgical approach (1.0% versus 11.1%, p < 0.001) were higher in RRN. RRN cases were also more likely to include lymph node dissection (12.6% versus 24.2%, p = 0.031). Total charges trended higher for RRN but did not meet traditional levels of significance ($14,913 versus $16,265, p = 0.171).*

Conclusions: *RRN appears to be a clinically equivalent alternative to LRN with similar perioperative outcomes, albeit at greater hospital charges.*

Key Words: radical nephrectomy, laparoscopy, robotics, cost, outcomes

Introduction

Radical nephrectomy (RN) remains the mainstay of treatment for renal tumors larger than 7 cm as well as those technically unamenable partial nephrectomy.[1-3] Over the past two decades, the use of minimally invasive approaches for RN has drastically increased[4] as estimated blood loss (EBL), length of stay (LOS), and recovery time can be significantly decreased while maintaining oncologic outcomes and complication rates similar to open RN.[5-8]

Within the last decade, robotic technology has been applied to minimally invasive RN. A handful of studies have compared robotic-assisted laparoscopic radical nephrectomy (RRN) to laparoscopic radical nephrectomy (LRN).[9-11] These studies have primarily focused on the feasibility of RRN and have been limited by small sample size (15 cases of RRN or less). One study found significantly decreased LOS and narcotic requirement among patients who underwent RRN compared to LRN.[9]

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The robotic-assisted laparoscopic approach has been more extensively studied in its application to partial nephrectomy (PN). Robotic-assisted laparoscopic PN has been shown to have a shorter learning curve[12,13] and has led to increased use of PN.[14] Robotic-assisted laparoscopic PN is also associated with decreased EBL and warm ischemia time[13,15] as well as operative time[15] and LOS[13] when compared to laparoscopic PN. These benefits, however, come at a small to moderate cost premium.[16]

We sought to expand upon the existing literature by examining perioperative outcomes and hospital charge data in a large single institution series of RRN and LRN cases, with the hypothesis that RRN may offer surgical advantages over LRN, albeit at a higher charge.

Materials and methods

Study design and statistical analysis

Our institutional review board approved renal mass registry was queried for patients who underwent either LRN or RRN from 2010 to 2014. A total of 319 consecutive patients were identified. Hand-assist laparoscopic nephrectomy is not utilized at our institution and no cases were included in this analysis.

Following dichotomization by surgical approach (LRN versus RRN), demographic; perioperative outcomes, including operative time, lymph node dissection (LND), EBL, conversion to alternative approach, intraoperative and postoperative complications, and LOS; and charge data were compared between groups using appropriate comparative tests (Fisher's exact test for categorical variables, Mann-Whitney U test for continuous variables, and Pearson Chi-square test for categorical variables with multiple levels). Operative time was calculated from the time of incision to closure of all surgical wounds.

All charge data were collected as part of the Maryland Health Services Cost Review Commission (HSCRC). The HSCRC is a Maryland state legislature mandate that has collected clinical, demographic, and billing data from all inpatient discharges in 51 Maryland hospitals in an attempt to regulate cost.[17] The data are deidentified and available to the public and have been used previously by our group and others to analyze surgical charges and outcomes.[14,18,19]

Charge data were adjusted for inflation using Bureau of Labor and Statistics data (http://www.bls.gov/data/inflation_calculator.htm) and are reported in year 2014 equivalents. Statistical analysis was performed using STATA version12 software (College Station, TX, USA). A two-tailed $p < 0.05$ was defined as statistical significance.

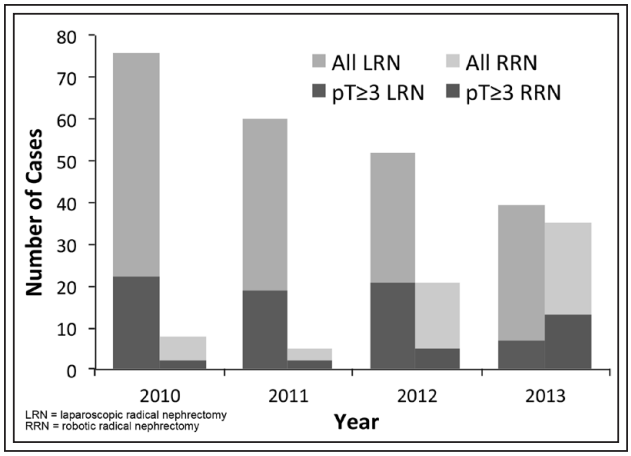

Figure 1. The proportion of radical nephrectomies performed via a robotic approach increased over the study for all patients and for patients with advanced tumor stage.

Results

Overall, 319 minimally invasive RNs were performed during the 5 year study period. Of these, 243 (76%) were LRN and 76 (24%) were RRN. Fourteen surgeons had performed LRN and five had performed RRN. Selection was based on surgeon preference and given the widespread availability of robotic technology at our institution after 2009, many surgeons opted to perform this procedure by the robotic approach. Figure 1 shows the number of LRN and RRN cases performed per year as well as the number of high clinical stage surgeries (pT3a or greater clinical pathology). Use of RRN at our institution increased significantly from 2010 to 2013 for all tumor types ($p < 0.000$) as well as for advanced tumors pathological stage T3a or greater ($p < 0.000$).

Table 1 details the patient demographics of each group. Between groups, we observed no differences in patient age, gender, body mass index, or American Society of Anesthesiologists score. Table 1 also details the tumor characteristics of each group. The percentage of patients with renal cell carcinoma (RCC), distribution of RCC subtype, clinical stage, pathologic tumor stage, and surgical indication were similar between groups (all $p > 0.075$).

Table 2 details perioperative outcomes. Operative time (136 min versus 139 min, $p = 0.531$), intraoperative complications (2.8% versus 2.0%, $p = 0.650$), and LOS (2 days versus 2 days, $p = 0.745$) were similar for LRN and RRN, respectively. EBL (50 mL versus 100 mL, $p = 0.041$) and rate of conversion to laparoscopic or open approach (1.0% versus 10.3%, $p = 0.001$) were higher in RRN. The majority of conversions happened

TABLE 1. **Patient demographics and tumor characteristics of patients undergoing total nephrectomy**

	Overall	Laparoscopic	Robotic assisted	p value
Number	319	243 (76%)	76 (24%)	
Age	63.0 (52.9-70.3)	63.0 (52.9-70.4)	62.1 (54.4-69.6)	0.93
Male, n (%)	206 (64.6)	154 (63.3)	52 (68.4)	0.493
BMI	28.3 (24.9-32.7)	28.3 (25.6-32.8)	27.3 (23.9-32.3)	0.247
ASA	3 (2-3)	3 (2-3)	3 (2-3)	0.078
Tumor diameter (cm)	5.5 (4-8)	5.9 (4-8)	5.1 (3.9-7.7)	0.154
RCC, n (%)	255 (80.0)	189 (77.8)	66 (86.8)	0.101
RCC subtype				0.847
Clear cell	163 (64.4)	119 (63.6)	44 (66.7)	
Papillary	33 (13.0)	24 (12.8)	9 (13.6)	
Chromophobe	25 (9.9)	17 (9.1)	8 (12.1)	
Other	98 (30.7)	83 (34.2)	15 (19.7)	
Clinical stage, n (%)				0.207
cT1a	65 (23.2)	47 (22.6)	18 (25.0)	
cT1b	115 (41.1)	85 (40.9)	30 (41.7)	
cT2a	53 (18.9)	44 (21.1)	9 (12.5)	
cT2b	25 (8.9)	19 (9.1)	6 (8.3)	
cT3a	14 (5)	9 (4.3)	5 (6.9)	
cT3b	2 (0.7)	0 (0.0)	2 (2.8)	
cT4	0 (0.0)	0 (0.0)	0 (0.0)	
Pathologic T stage, n (%)				0.250
pT1a	56 (22.0)	39 (20.6)	17 (25.8)	
pT1b	72 (28.2)	53 (28.0)	19 (28.8)	
pT2a	25 (9.8)	20 (10.6)	5 (7.6)	
pT2b	10 (3.9)	8 (4.2)	2 (3.0)	
pT3a	88 (34.5)	67 (35.5)	21 (31.8)	
pT3b	2 (0.8)	0 (0.0)	2 (3.0)	
pT4	2 (0.8)	2 (1.1)	0 (0.0)	
Pathologic N stage, n (%)				0.075
pN0	34 (13.3)	20 (10.5)	14 (21.2)	
pN1	6 (2.3)	4 (2.1)	2 (3.0)	
pNX	216 (84.4)	166 (87.3)	50 (75.8)	
Surgical indication				0.758
Cytoreduction	15 (5.3)	12 (5.6)	3 (4.2)	
Primary treatment	268 (94.4)	200 (93.9)	68 (95.8)	

Values are expressed as medians ± interquartile range unless otherwise specified
BMI = body mass index; ASA = American Society of Anesthesiologists; RCC = renal cell carcinoma

earlier in the surgeon's robotic surgery learning curve. Interestingly, RRN cases were more likely to include lymph node dissection (12.6% versus 24.2%, p = 0.031).

Table 3 contains an itemized comparison of perioperative and hospital charges. Total charges trended higher for RRN but did not meet traditional levels of significance ($14,913 versus $16,265, p = 0.171). This trend was primarily driven by operating room ($5,122 versus $5,470 p = 0.084) and supply charges ($3,351 versus $3,660 p = 0.073).

Discussion

Given the increase in costs associated with robotic technology, we sought to determine if RRN offered any advantages compared to LRN in terms of measurable

TABLE 2. **Perioperative outcomes of patients undergoing total nephrectomy**

	Overall	Laparoscopic	Robotic assisted	p value
Number	319	243 (76%)	76 (24%)	
Operative time (min)	139 (109-167)	136 (108-167)	139 (112-167)	0.513
Lymph node dissection, n (%)	40 (15.6)	24 (12.6)	16 (24.2)	0.031
EBL (mL)	50 (50-100)	50 (50-100)	100 (50-150)	0.041
Conversion, n (%)	9 (3.4)	2 (1.0)	7 (10.3)	0.000
Intraoperative complications, n (%)	6 (2.1)	2 (2.8)	4 (2.0)	0.650
Postoperative complications, n (%)	12 (15.8)	11 (19.0)	1 (5.6)	0.273
LOS (days)	2 (2-3)	2 (2-3)	2 (2-3)	0.745

Values are expressed as medians ± interquartile range unless otherwise specified
EBL = estimated blood loss; LOS = length of stay

perioperative outcomes. In this study we demonstrate that RRN is clinically equivalent to LRN with similar perioperative outcomes, albeit at a marginally higher hospital charge.

A handful of other studies have examined the outcomes of RRN and LRN with similar results. In a retrospective review of 10 RRN cases and matched LRN controls, White and coworkers found that patients who underwent RRN had a significantly shorter LOS as well as a lower median narcotic requirement during hospital, suggesting a potentially improved postoperative course.[9] However, this was primarily a preliminary study and was limited by the methodology and small numbers of cases.

Nazemi and colleagues[10] performed a prospective cohort study comparing 57 cases of RN performed using either open, robotic, or laparoscopy with or without hand assistance (6 cases were robotic). They reported a significantly shorter LOS and lower EBL in the robotic compared to the open group, but did not observe a significant difference when compared to either of the laparoscopic groups. Furthermore, the robotic group had the longest operative times of all of the groups and was the only group which was significantly longer than open RN. Conversely, we observed no significant difference in LOS and a mild, yet significant, increases in EBL in the RRN group. The lack of difference in LOS may be explained by standardized postoperative pathways for RN at our institution.

An additional prospective study performed by Hemal and Kumar[11] compared 15 cases of RCC stage T1-2N0M0 treated with RRN to a similar cohort of 15 LRN cases. They found no significant differences in the two cohorts, with the exception of a significantly increased operative time in the RRN group. Contrary to the findings by Nazemi et al and Hemal and Kumar,

TABLE 3. **Health care costs of patients undergoing total nephrectomy**

	Overall	Laparoscopic	Robotic assisted	p value
Number	319	243 (76%)	76 (24%)	
Charge type (2014 USD)				
Total charges	15,312 (12,124-18,669)	14,913 (12,107-18,486)	16,265 (12,482-19,034)	0.171
OR charges	5,180 (4,042-6,820)	5,122 (3,984-6,703)	5,470 (4,383-7,533)	0.084
Room charges	4,117 (2,691-6,201)	4,117 (2,657-6,201)	4,215 (3,426-6,146)	0.943
Drug charges	158 (87-298)	145 (82-287)	214 (123-316)	0.017
Radiology charges	0 (0-121)	0 (0-112)	0 (0-187)	0.378
Lab charges	537 (390-919)	531 (385-911)	539 (407-1,087)	0.700
Supply charges	3,450 (2,786-4,608)	3,351 (2,639-4,528)	3,660 (2,961-4,792)	0.073
Therapy charges	0 (0-0)	0 (0-0)	0 (0-0)	0.738
Other charges	0 (0-141)	0 (0-141)	0 (0-201)	0.275

we found that RRN and LRN cases had similar operative times. This may be explained by the fact that these preliminary studies investigated very early RRN cases and may have been influenced by the learning curve. Our data set includes several cases from the past 5 years, performed by surgeons experienced in robotic surgery. Therefore, as surgeons become more experienced with robotics, RRN can be performed at a similar speed to LRN.

Of note, we found that RRN cases were more likely to require conversion to alternative approaches than LRN. Two LRN cases in our registry were converted to an open approach for bleeding. Of the RRN cases converted to an open approach, 2 were for bleeding, 3 for dense adhesions and 1 for unamenable tumor characteristics. One RRN case was converted to a LRN for unamenable tumor characteristics. The increased frequency of conversion to alternative approaches may be suggestive of unique surgical challenges faced by RRN. Also, it may be secondary to the learning curve associated with RRN and the application of RRN to increasingly challenging cases, as the median tumor size of converted RRN cases was 9 cm.

Interestingly, we found that RRN cases were more likely to include LND. While this trend has also been observed in a retrospective comparison of robotic and laparoscopic nephrouterectomy,[20] the role of LND in the treatment of RCC is controversial.[21-23] The increased utilization of LND may be a function of surgeon practices or may reflect advantages of robotic assistance such as improved operative visualization, favorable ergonomics, tremor reduction, or improved dexterity.[24] Our data demonstrate that the use of RRN is increasing for high pathological stage cases. Robotic technology certainly facilitates the delicate dissection techniques required for retroperitoneal lymph node dissection and may indicate a role for RRN in locally-advanced RCC – a selection bias that may not be discoverable by traditional clinical and pathological staging criteria. Therefore, RRN may expand the role of minimally-invasive surgery in locally-advanced RCC (patients with tumor thrombi or regional lymphadenopathy) – a niche typically reserved for open surgery.[25]

We found an operative charge premium for RRN. This is consistent with data from Kates et al,[26] who using HSCRC data for all RN cases performed in Maryland between 2008 and 2012 found a total hospital charge premium of $5,111 for RRN compared to LRN. ($23,391 for RRN and $18,280 for LRN). Similarly, Yang et al[27] performed a retrospective cost analysis of 24,312 RN cases from the National Inpatient Sample. They reported total hospital costs for RRN were $15,149 compared to $11,735 for LARN or a charge premium of $3,414, and argued that lack of improved outcomes for RRN did not justify the cost. We report a lower charge premium of $1,352 for RRN. This lower charge premium is likely multifactorial and reflects both the thoughtful use of disposables in the operating room[28] and a mature clinical pathway for robotic cases.[16] Often, laparoscopic cases use a variety of disposable devices including staplers and advanced energy/tissue sealant devices that are not utilized during robotic cases and further decrease the charge premium between robotic and laparoscopic cases.

We did not include capital acquisition costs above, since these are not reflected in our hospital charge analysis. However, it is worth noting that our hospital has three robots that were acquired at a cost of $1,750,000 each. Over the 5 year study period, 4,459 robotic cases were performed, adding a $1,177 cost premium.

Additionally, the service contract cost for our hospital is $129,000/year, which amount to $645,000 over 5 years. Divided over the 4,459 robotic cases, this adds an additional $144/case cost premium. Combining acquisition and service contract costs, an additional $1,322 cost per case is incurred. However, it is also important to note that performing a similar analysis for laparoscopic equipment acquisition and service contracts is difficult to ascertain as this equipment is shared among laparoscopic and endoscopic procedures. Including robotic costs without laparoscopic would add an inaccurate cost premium to the robotic group. Again, these data reflect robot acquisition and service cost, not hospital charge as in the main analysis.

There are limitations of our study that deserve mention. The study was performed retrospectively and there is likely considerable selection bias as patients were not randomized to surgical approach. Additionally the cases included were performed by a variety of surgeons (5 different surgeons for RRN). There may be confounding effects resulting from surgeons being at different points on the learning curve and selection of patients for RRN. Additionally, the single-institution nature of our study may limit its generalization to other care settings.

Conclusions

RRN appears to be a clinically equivalent alternative to LRN with similar perioperative outcomes. Potential drawbacks of RRN include greater costs, which may be attenuated at high-volume centers, and slightly increased EBL and rate of conversion to an alternative surgical approach. Additional study is needed to determine the role of RRN in locally advanced tumors, a niche where the costs of RRN may offset expenditures. □

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