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Original article

National trends and disparities of minimally invasive surgery for localized renal cancer, 2010 to 2015

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Abstract

Purpose: To investigate national utilization trends of minimally-invasive partial nephrectomy (PN) and minimally-invasive radical nephrectomy (RN), and to identify disparities in the usage of these techniques across different sociodemographic subgroups.

Materials and Methods: A retrospective cohort study was conducted using the National Cancer Database to identify patients undergoing partial or RN for cT1N0M0 renal cancer diagnosed between 2010 and 2015. Main outcomes of interest were the utilizations of minimally-invasive (robotic and laparoscopic) PN and RN.

Results: A total of 46,346 and 37,712 subjects who underwent PN and RN, respectively, were analyzed. During the study interval, increased utilization of robotic surgery paralleled the decreased utilization of open surgery. Robotic PN increased from 35.2% to 63.7% and robotic RN increased from 10.3% to 26.3%. The utilization of laparoscopic surgery was decreasing for PN but stable for RN through the study period. In the PN cohort, multivariable logistic regression showed non-Hispanic black (odds ratio [OR] = 0.90 [95% CI, 0.84−0.96]) and Hispanic (OR = 0.91 [0.84−0.99]) subjects were associated with less utilization of minimally invasive surgery (MIS) (vs. non-Hispanic white). Younger (18−64 years) Medicare (OR = 0.83 [0.77−0.90]), Medicaid (OR = 0.80 [0.74−0.87]), and uninsured (OR = 0.55 [0.49−0.62]) were also associated with less utilization of MIS (vs. private insurance). Compared with low socioeconomic status (SES), upper middle (OR = 1.14 [1.07−1.21]) and high (OR = 1.24 [1.16−1.33]) SES were associated with higher utilization of MIS. Similar demographic, insurance, and SES-related disparities were identified in the RN cohort.

Conclusions: Utilization of MIS for localized renal cancer has increased significantly and was mainly attributed to increased usage of robotic surgery. Racial/ethnic, insurance, and SES related disparities in MIS utilization were identified. Our findings demonstrate a targetable subgroup of patients who do not have the same access to advances in surgical technology. © 2018 Published by Elsevier Inc.

Keywords: Renal cancer; Robotics; Laparoscopy; Minimally invasive; Nephrectomy

1. Introduction

In the US, the incidence of kidney cancer (mostly renal cell carcinoma or renal cancer) continues to rise and it is projected that 65,340 new cases will be diagnosed in 2018 [1]. Due to increased use of cross-sectional imaging, there has also been a stage migration to lower-stage renal cancers

Disclaimer: The National Cancer Database is a joint project of the Commission on Cancer of the American College of Surgeons and the American Cancer Society. The data used in this study are derived from a deidentified National Cancer Database file. The American College of Surgeons and the Commission on Cancer have not verified and are not responsible for the analytic or statistical methodology employed, or the conclusions drawn from these data by the investigators.

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[2]. Among all diagnoses, 60% to 65% are localized T1 cancers and partial nephrectomy (PN) or radical nephrectomy (RN) is the standard of care [1–4].

Since the first report of laparoscopic nephrectomy in 1991, the interest in advancing minimally-invasive renal cancer surgery has been high in the field [5]. Consensus guidelines state that a minimally invasive approach is suitable in any case where clinical outcomes would not be compromised [4]. Laparoscopic radical nephrectomy (LRN) is now considered by many to be the gold standard and it is well established that LRN can achieve similar oncologic control with lower surgical morbidity compared with open radical nephrectomy [6]. Compared with its RN counterpart, laparoscopic partial nephrectomy (LPN) is a more technically challenging procedure with a steeper learning curve, which likely accounts for its limited adoption relative to LRN [7]. Despite these issues, LPN can provide oncologic results comparable to open partial nephrectomy (OPN) [8,9].

Robotic surgery, which has been rapidly adopted for radical prostatectomy over the last 10 to 15 years in the US, may have also influenced the treatment of renal cancer [10]. There is a paucity of data addressing the trends in surgical approaches for renal cancer and identifying which patients are more inclined to receive minimally invasive surgery (MIS). Previous studies did not control for or restrict the cancer stage, which is one of the main factors that drive decision making regarding MIS [11–13]. Like the prostatectomy literature, it is important to identify disparities in the receipt of new technology among certain sociodemographic subgroups in the robotic surgery era [14,15]. Therefore, to better address these unanswered questions, we analyzed a contemporary cancer registry database to comprehensively investigate the national trends and disparities of MIS utilization for the treatment of localized renal cancer.

2. Methods

2.1. Data source

A retrospective cohort study was performed using the National Cancer Database (NCDB), a joint project of the Commission on Cancer (CoC) of the American College of Surgeons and the American Cancer Society. The NCDB captures about 70% of newly diagnosed cancers in the US annually and contains data items depicting rich patient, facility, tumor, treatment, and follow-up information [16]. Data in the NCDB is fully deidentified and the study was deemed exempt from review by our Institutional Review Board.

2.2. Study cohort

Our study cohort selection process is depicted as a flowchart (Supplementary Fig. 1). Renal cancers were identified based on International Classification of Diseases for Oncology, third edition (ICD-O-3) topography code C64.9 and histology codes 8000 to 8980 [17]. Surgical approach was only available starting from 2010 [18,19].

We restricted our cohort to patients with clinical nonmetastatic (cN0M0) cT1 (unspecified), cT1a, or cT1b disease. Patients with missing/unknown clinical stage were included and reclassified only if the pathologic stage was confirmed to be T1. Only patients who underwent PN (code 30) or RN (codes 40 and 50) at the reporting facility were included. Lastly, we sequentially excluded cases with missing or unknown data on key variables.

2.3. Race/ethnicity, insurance, and socioeconomic status

One of our main objectives was to evaluate the impact of race/ethnicity, insurance, and socioeconomic status (SES) on MIS utilization. Race/ethnicity was categorized as non-Hispanic white (NHW), non-Hispanic black (NHB), non-Hispanic other, and Hispanic [20]. Insurance was categorized as private insurance, younger (aged 18–64 years) Medicare, older (aged 65+ years) Medicare, Medicaid, other government, and not insured [21].

SES was defined to account for education and income levels that are available in the NCDB [22,23]. These 2 variables are derived from the 2012 American Community Survey. Education was measured by number of adults in the patient's zip code who did not graduate from high school and was categorized as equally proportioned quartiles among all US zip codes (1, ≥21%; 2, 13–20.9%; 3, 7–12.9%, and 4, <7%). Income was measured by median household income for each patient's area of residence (zip code) and was categorized as equally proportioned quartiles based on income ranges among all US zip codes (1, <$38,000; 2, $38,000–$47,999; 3, $48,000–$62,999; and 4, ≥$63,000). The quartile assignments (1, 2, 3, and 4) of the 2 measures were added and new SES categories were generated based on a composite "score" of 2 to 3 (low), 4 to 5 (lower middle), 6 to 7 (upper middle), and 8 (high) [22].

2.4. Covariables

We included the following covariables: age, sex, Charlson–Deyo (comorbidity) score, county type of patient's residence, travel distance between patient's residence and reporting facility, clinical T stage, histologic grade, histology (clear cell vs. other), facility type, facility location, and year of diagnosis. Travel distance >250 miles was excluded to decrease bias from patients who were not close to their residence when they sought surgical care [24]. Histologic grade was determined using the Collaborative Stage Data Collection System Site-Specific Factor 6. Clear cell renal cell carcinoma (RCC) was determined using ICD-O to 3 histology codes 8,000, 8,005, 8,310, 8,312 to 8,316, and 8,359 [17]. Facility type (cancer program) in the NCDB is mainly

based on the number of newly diagnosed analytic cancer cases submitted and is categorized as community, comprehensive community, academic/research, and integrated network (https://www.facs.org/quality-programs/cancer/coc/apply/categories). Facility location categories in the NCDB are in accordance with the US Census division classifications. Year of surgery is not collected by the NCDB, so we used year of diagnosis as an alternative.

2.5. Outcomes of interest

The outcomes of interest were utilization of minimally-invasive partial nephrectomy (MIPN) and minimally-invasive radical nephrectomy (MIRN) in the overall PN and RN cohorts, respectively. MIPN was defined as robot-assisted partial nephrectomy (RAPN) and LPN. MIRN was defined as robot-assisted radical nephrectomy (RARN) and LRN. Cases converted from robotic or laparoscopic approach to open were still assigned as MIPN/MIRN given our study objective.

2.6. Statistical analysis

Patient, tumor, and facility characteristics were reported. Medians with interquartile ranges were used to describe continuous variables, whereas frequencies and percentages were used for categorical variables. Chi-squared (χ^2) and Wilcoxon rank-sum tests were used for comparison when appropriate. Multivariable logistic regressions were used to assess the factors associated with the utilization of MIPN and MIRN. Considering that race/ethnicity, insurance, and SES were likely to be correlated with each other, we alternatively included only 1 of the 3 variable in the first 3 models, and then included all 3 variables in the final model [20,25]. We repeated all logistic regression models in the subgroups of patients from the most recent diagnosis year (2015) as a sensitivity analysis. A 2-sided significance level of 0.05 was used for all statistical tests, and all analyses were performed using STATA 15 (StataCorp LP, College Station, TX).

3. Results

3.1. Baseline characteristics

We included a total of 84,058 patients who underwent either PN ($n = 46,346$, 55.1%) or RN ($n = 37,712$, 44.9%) at 1,229 hospitals for cT1N0M0 renal cancer diagnosed between 2010 and 2015. Table 1 presents patient, tumor, and facility characteristics of the PN and RN cohorts stratified by surgical approach.

3.2. Trends in MIS utilization

During the study interval, there was a trend of increased utilization of MIPN and MIRN, both of which were mainly attributed to increased usage of the robotic approach (Fig. 1). In the PN cohort, RAPN increased from 35.2% in 2010 to 63.7% in 2015 and there was a decreasing trend of LPN utilization. In the RN cohort, RARN increased from 10.3% in 2010 to 26.3% in 2015 and there were no major changes in percentage of LRN cases.

3.3. MIS utilization by clinical T stages and facilities

Supplementary Fig. 2 shows the distribution of MIS vs. open cases by clinical T stage. In the PN cohort, MIPN ratio was higher in the cT1a group (68.2%) compared with cT1b group (57.6%). In the RN cohort, MIRN ratio was slightly lower in the cT1a group (66.7%) compared with cT1b group (68.8%).

Distributions of MIS vs. open cases by facility type and facility location are shown in Fig. 2. Comprehensive Community cancer program had the highest MIPN ratio (68.1%) and Academic/Research cancer program had the highest MIRN ratio (70.3%). Community cancer program had both the lowest MIPN ratio (52.2%) and the lowest MIRN ratio (53.7%). Some variations of MIS utilizations were seen across the 9 geographic regions though the absolute differences were only approximately 15% between the lowest and highest regions. MIPN ratio was highest in the Mountain region (72.7%) and lowest in West South Central region (59.4%). MIRN ratio was also highest in the Mountain region (74.6%) and lowest in West South Central region (60.0%).

3.4. MIS utilization by race/ethnicity, insurance, and SES

Fig. 3 shows the distribution of MIS vs. open cases by race/ethnicity, insurance, and SES. Table 2 summarizes the multivariable logistic regression analyses showing the associations between the race/ethnicity, insurance, and SES and MIS utilization in the overall PN cohort. In the full model, NHB (odds ratio [OR] = 0.90; 95% CI = 0.84–0.96; $P = 0.001$) and Hispanic (OR = 0.91; 95% CI = 0.84–0.99; $P = 0.035$) were associated with lower odds of MIPN usage compared with NHW. Younger Medicare (OR = 0.83; 95% CI = 0.77–0.90; $P < 0.001$), Medicaid (OR = 0.80; 95% CI = 0.74–0.87; $P < 0.001$), and not insured (OR = 0.55; 95% CI = 0.49–0.62; $P < 0.001$) were associated with lower odds of MIPN usage compared with private insurance. Compared with low SES, upper middle SES (OR = 1.14; 95% CI = 1.07–1.21; $P < 0.001$) and high SES (OR = 1.24; 95% CI = 1.16–1.33; $P < 0.001$) were associated with higher odds of MIPN usage. The effect sizes were larger in the models that included these variables separately.

Table 3 summarizes the multivariable logistic regression results in the overall RN cohort. In the full model, NHB (OR = 0.92; 95% CI = 0.85–0.98; $P = 0.016$]) and non-Hispanic other (OR = 0.86; 95% CI = 0.75–0.99; $P = 0.032$) were associated with lower odds of MIRN usage compared with NHW group. Younger Medicare (OR = 0.80; 95% CI = 0.73–0.86; $P < 0.001$), Medicaid (OR = 0.85; 95%

Table 1
Patient, tumor, and facility characteristics of the cohorts stratified by surgical approach.

	Partial nephrectomy			Radical nephrectomy		
	MIPN (n = 30,384)	OPN (n = 15,962)	P value	MIRN (n = 25,457)	ORN (n = 12,255)	P value
Age, median (IQR), y[a]	61 (53−68)	61 (53−69)	0.118	64 (55−71)	63 (55−71)	0.523
Female sex	11,614 (38.2)	6,218 (39.0)	0.124	9,968 (39.2)	4,887 (39.9)	0.179
Charlson−Deyo score			<0.001			0.046
0	20,773 (68.4)	10,524 (65.9)		16,417 (64.5)	7,824 (63.8)	
1	7,424 (24.4)	4,016 (25.2)		6,231 (24.5)	3,118 (25.4)	
2	1,623 (5.3)	1,055 (6.6)		1,839 (7.2)	899 (7.3)	
≥3	564 (1.9)	367 (2.3)		970 (3.8)	414 (3.4)	
Race/ethnicity			<0.001			<0.001
Non-Hispanic white	24,279 (79.9)	12,281 (76.9)		19,841 (77.9)	9,221 (75.2)	
Non-Hispanic black	3,450 (11.4)	2,084 (13.1)		3,256 (12.8)	1,811 (14.8)	
Non-Hispanic other	885 (2.9)	489 (3.1)		726 (2.9)	353 (2.9)	
Hispanic	1,770 (5.8)	1,108 (6.9)		1,634 (6.4)	870 (7.1)	
Insurance			<0.001			<0.001
Private insurance	15,874 (52.2)	7,698 (48.2)		10,514 (41.3)	4,760 (38.8)	
Younger Medicare (18−64 y)	2,073 (6.8)	1,270 (8.0)		2,339 (9.2)	1,360 (11.1)	
Older Medicare (≥65 y)	9,638 (31.7)	5,097 (31.9)		10,248 (40.3)	4,771 (38.9)	
Medicaid	1,693 (5.6)	1,058 (6.6)		1,369 (5.4)	721 (5.9)	
Other government	485 (1.6)	215 (1.4)		353 (1.4)	153 (1.3)	
Not insured	621 (2.0)	624 (3.9)		634 (2.5)	490 (4.0)	
Socioeconomic status			<0.001			<0.001
Low (2−3)	5,605 (18.5)	3,514 (22.0)		5,432 (21.3)	3,163 (25.8)	
Lower middle (4−5)	8,625 (28.4)	4,782 (30.0)		7,629 (30.0)	3,864 (31.5)	
Upper middle (6−7)	9,921 (32.7)	4,910 (30.8)		8,084 (31.8)	3,453 (28.2)	
High (8)	6,233 (20.5)	2,756 (17.3)		4,312 (16.9)	1,775 (14.5)	
County type			0.018			0.033
Metro	25,572 (84.2)	13,279 (83.2)		20,888 (82.1)	9,924 (81.0)	
Urban	4,339 (14.3)	2,403 (15.1)		4,010 (15.8)	2,059 (16.8)	
Rural	473 (1.6)	280 (1.8)		559 (2.2)	272 (2.2)	
Travel distance, median (IQR), miles[a]	13.9 (6.3−33.7)	13.5 (5.8-33.1)	0.001	11.6 (5.2−28)	10.6 (4.7−25.5)	<0.001
Clinical T stage			<0.001			<0.001
T1a	22,386 (73.7)	10,438 (65.4)		9,441 (37.1)	4,708 (38.4)	
T1b	4,904 (16.1)	3,609 (22.6)		12,667 (49.8)	5,744 (46.9)	
T1 unspecified	3,094 (10.2)	1,915 (12.0)		3,349 (13.2)	1,803 (14.7)	
Histologic grade			<0.001			0.363
1−2	22,931 (75.5)	11,784 (73.8)		17,097 (67.2)	8,288 (67.6)	
3−4	7,453 (24.5)	4,178 (26.2)		8,360 (32.8)	3,967 (32.4)	
Histology			<0.001			0.761
Clear cell	22,614 (74.4)	12,381 (77.6)		20,394 (80.1)	9,834 (80.2)	
Other	7,770 (25.6)	3,581 (22.4)		5,063 (19.9)	2.421 (19.8)	
Facility type (cancer program)			<0.001			<0.001
Community	1,117 (3.7)	1,022 (6.4)		1,690 (6.6)	1,458 (11.9)	
Comprehensive community	11,052 (36.4)	5,181 (32.5)		11,926 (46.9)	5,731 (46.8)	
Academic/research	14,838 (48.8)	7,911 (49.6)		8,784 (34.5)	3,714 (30.3)	
Integrated network	3,377 (11.1)	1,848 (11.6)		3,057 (12.0)	1,352 (11.0)	
Facility location			<0.001			<0.001
New England	1,516 (5.0)	898 (5.6)		1,239 (4.9)	453 (3.7)	
Middle Atlantic	5,828 (19.2)	3,178 (19.9)		3,466 (13.6)	1,521 (12.4)	
South Atlantic	5,677 (18.7)	3,286 (20.6)		5,445 (21.4)	2,804 (22.9)	
East North Central	6,519 (21.5)	2,744 (17.2)		4,496 (17.7)	2,259 (18.4)	
East South Central	2,459 (8.1)	1,451 (9.1)		2,196 (8.6)	1,213 (9.9)	
West North Central	2,105 (6.9)	1,037 (6.5)		2,314 (9.1)	932 (7.6)	
West South Central	2,264 (7.5)	1,546 (9.7)		2,335 (9.2)	1,551 (12.7)	
Mountain	1,221 (4.0)	458 (2.9)		1,133 (4.5)	386 (3.2)	
Pacific	2,795 (9.2)	1,364 (8.6)		2,833 (11.1)	1,136 (9.3)	

Abbreviations: IQR = interquartile range; MIPN = minimally-invasive partial nephrectomy; MIRN = minimally-invasive radical nephrectomy; OPN = open partial nephrectomy; ORN = open radical nephrectomy.

[a] Age and travel distance are expressed as median (IQR) but all other variables in this table are expressed as number (percentage).

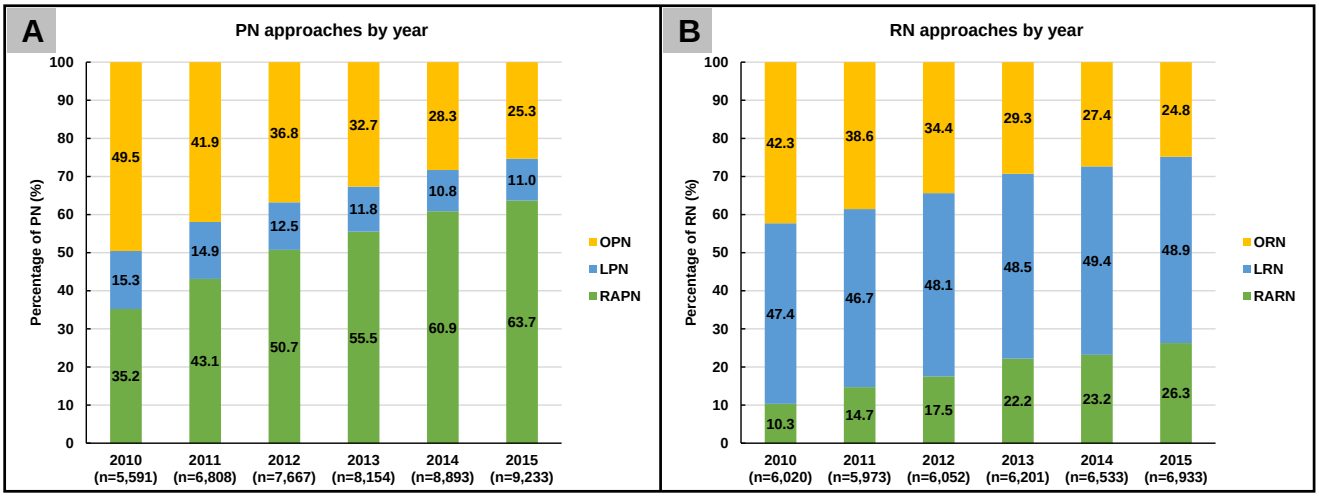

Fig. 1. Partial nephrectomy (A) and radical nephrectomy (B) stratified by surgical approach and year of diagnosis.

Abbreviations: PN = partial nephrectomy; OPN = open partial nephrectomy; LPN = laparoscopic partial nephrectomy; RAPN = robot-assisted partial nephrectomy; RN = radical nephrectomy; ORN = open radical nephrectomy; LRN = laparoscopic radical nephrectomy; RARN = robot-assisted radical nephrectomy.

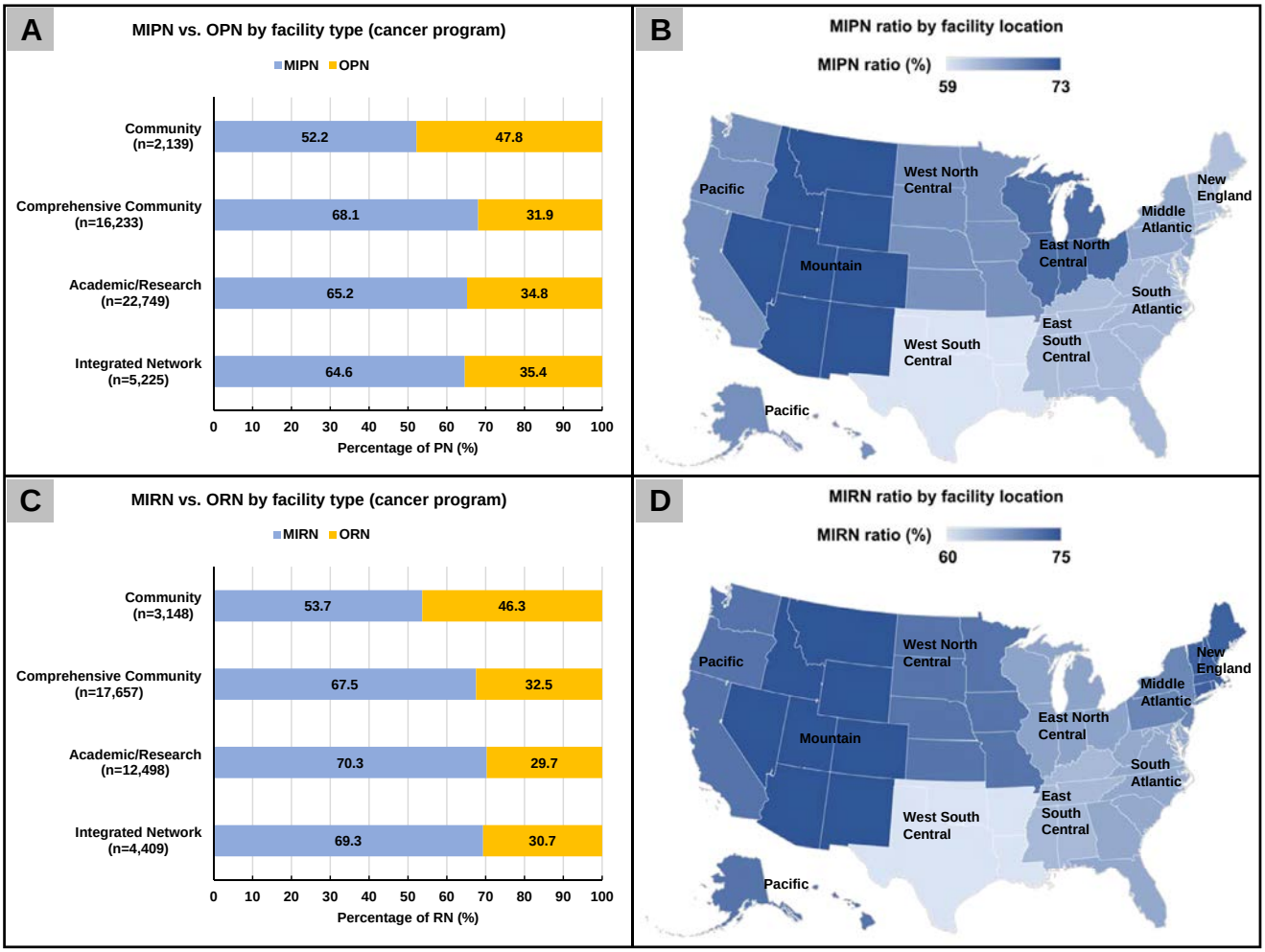

Fig. 2. Distributions of minimally-invasive vs. open surgery stratified by facility type and facility location.

Abbreviations: PN = partial nephrectomy; OPN = open partial nephrectomy; MIPN = minimally-invasive partial nephrectomy; RN = radical nephrectomy; ORN = open radical nephrectomy; MIRN = minimally-invasive radical nephrectomy.

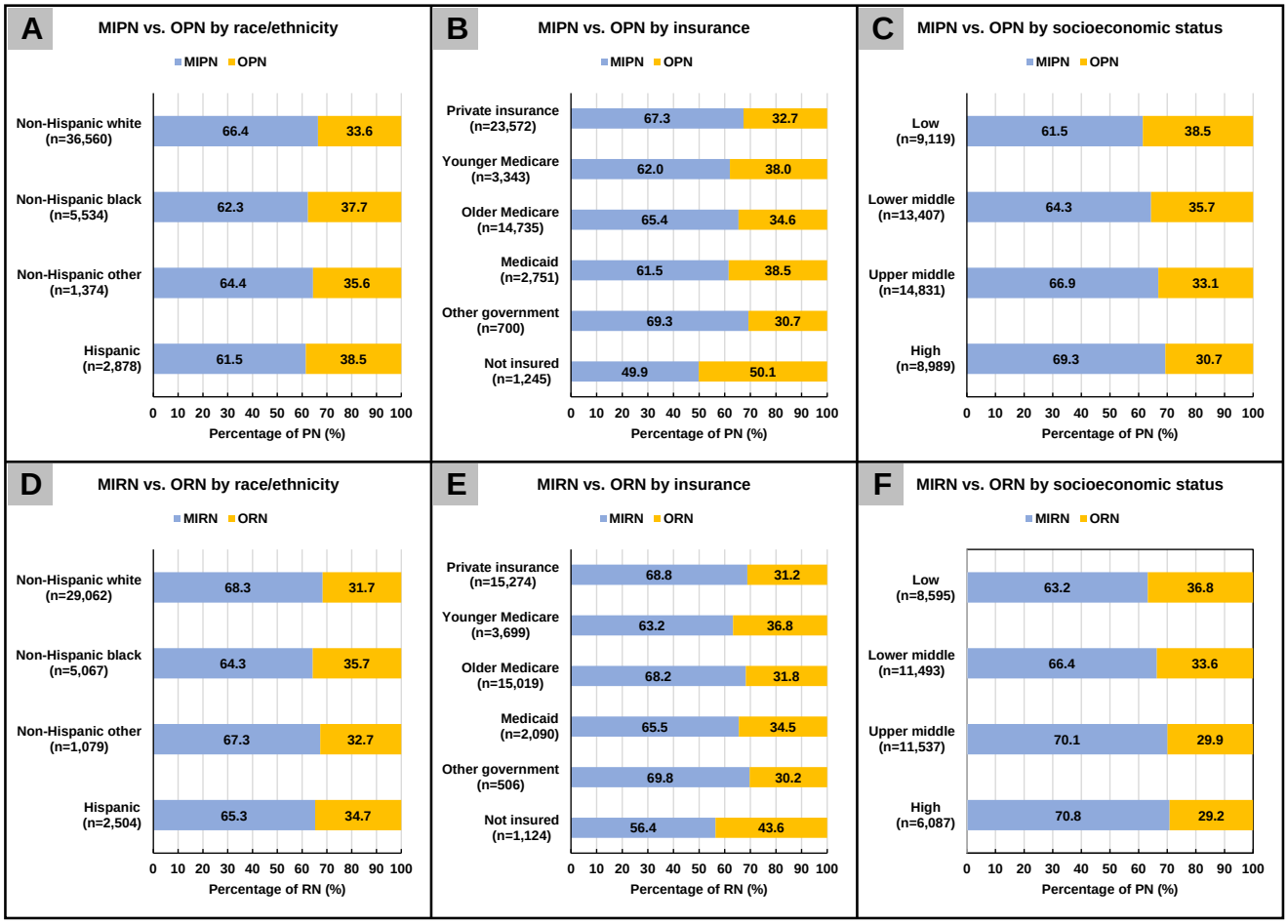

Fig. 3. Distributions of minimally-invasive vs. open surgery stratified by race/ethnicity, insurance, and socioeconomic status.
A, B, and C, partial nephrectomy; D, E, and F, radical nephrectomy.
Abbreviations: PN = partial nephrectomy; OPN = open partial nephrectomy; MIPN = minimally-invasive partial nephrectomy; RN = radical nephrectomy; ORN = open radical nephrectomy; MIRN = minimally-invasive radical nephrectomy.

CI = 0.77−0.94; $P = 0.002$), and not insured (OR = 0.65; 95% CI = 0.58−0.74; $P < 0.001$) were associated with lower odds of MIRN usage compared with private insurance. Compared with low SES, lower middle SES (OR = 1.07; 95% CI = 1.01−1.14; $P = 0.028$), upper middle SES (OR = 1.23; 95% CI = 1.15−1.31; $P < 0.001$), and high SES (OR = 1.23; 95% CI = 1.13−1.33; $P < 0.001$) were associated with higher odds of MIPN usage. The effect sizes were also larger in the models that separately included these variables.

3.5. Sensitivity analysis

Given the increased MIS usage and increased number of cases included throughout the study interval, we repeated the multivariable logistic regressions in the subgroups of cases ($n = 9,233$ for PN and $n = 6,933$ for RN) diagnosed in 2015 (Supplementary Tables 1 and 2). In the PN cohort full model (Supplementary Table 1), none of the race/ethnicity groups were found to be associated with MIPN usage compared with NHW. Not insured (OR = 0.61; 95% CI = 0.44−0.83; $P = 0.002$) was still associated with lower odds of MIPN usage compared with private insurance. Upper middle SES (OR = 1.25; 95% CI = 1.08−1.44; $P = 0.003$) and high SES (OR = 1.41; 95% CI = 1.19−1.68; $P < 0.001$) were still associated with higher odds of MIPN usage compared with low SES. The ORs for upper middle SES (1.25 vs. 1.07) and high SES (1.41 vs. 1.23) groups were higher than the ORs in the primary analysis.

In the RN cohort full model (Supplementary Tables 2), none of the race/ethnicity groups were found to be associated with MIRN usage compared with NHW. Younger Medicare (OR = 0.78; 95% CI = 0.64−0.96; $P = 0.017$) and not insured (OR = 0.61; 95% CI = 0.42−0.88; $P = 0.008$) were still associated with lower odds of MIRN usage compared with private insurance. Upper middle SES (OR = 1.31; 95% CI = 1.11−1.55; $P = 0.002$) and high SES (OR = 1.46; 95% CI = 1.20−1.79; $P < 0.001$) were still associated with higher odds of MIRN usage compared with low SES. The ORs for upper middle SES (1.31 vs. 1.23) and high SES (1.46 vs. 1.23) groups were higher than the ORs in the primary analysis.

Table 2
Multivariable logistic regression analysis in the overall partial nephrectomy cohort ($n = 46,346$).

	Race/ethnicity only[a]		Insurance only[a]		Socioeconomic status only[a]		Full model (all 3 variables)[a]	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Race/ethnicity								
Non-Hispanic white	Ref.						Ref.	
Non-Hispanic black	0.83 (0.78−0.88)	<0.001					0.90 (0.84−0.96)	0.001
Non-Hispanic other	0.88 (0.78−0.99)	0.029					0.89 (0.79−1.00)	0.060
Hispanic	0.82 (0.76−0.89)	0.010					0.91 (0.84−0.99)	0.035
Insurance								
Private insurance			Ref.				Ref.	
Younger Medicare			0.80 (0.74−0.87)	<0.001			0.83 (0.77−0.90)	<0.001
Older Medicare			0.96 (0.90−1.02)	0.215			0.97 (0.91−1.03)	0.360
Medicaid			0.75 (0.69−0.82)	<0.001			0.80 (0.74−0.87)	<0.001
Other government			1.11 (0.94−1.31)	0.362			1.12 (0.95−1.33)	0.174
Not insured			0.52 (0.46−0.59)	<0.001		-	0.55 (0.49−0.62)	<0.001
Socioeconomic status								
Low					Ref.		Ref.	
Lower middle					1.09 (1.03−1.16)	0.003	1.04 (0.98−1.11)	0.150
Upper middle					1.22 (1.15−1.29)	<0.001	1.14 (1.07−1.21)	<0.001
High					1.35 (1.27−1.45)	<0.001	1.24 (1.16−1.33)	<0.001

Abbreviation: OR = odds ratio; CI = confidence interval.
[a] Adjusted for age, sex, Charlson−Deyo (comorbidity) score, county type, travel distance, clinical T stage, histologic grade, histology, facility type, facility location, and year of diagnosis.

Table 3
Multivariable logistic regression analysis in the overall radical nephrectomy cohort (n = 37,712).

	Race/ethnicity only[a]		Insurance only[a]		Socioeconomic status only[a]		Full model (all 3 variables)[a]	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Race/ethnicity								
Non-Hispanic white	Ref.						Ref.	
Non-Hispanic black	0.84 (0.78−0.90)	<0.001					0.92 (0.85−0.98)	0.016
Non-Hispanic other	0.85 (0.74−0.97)	0.016					0.86 (0.75−0.99)	0.032
Hispanic	0.89 (0.81−0.97)	0.012					0.98 (0.89−1.08)	0.659
Insurance								
Private insurance			Ref.				Ref.	
Younger Medicare			0.76 (0.70−0.82)	<0.001			0.80 (0.73−0.86)	<0.001
Older Medicare			1.05 (0.98−1.13)	0.161			1.06 (0.99−1.13)	0.103
Medicaid			0.81 (0.73−0.89)	<0.001			0.85 (0.77−0.94)	0.002
Other government			1.10 (0.90−1.33)	0.366			1.11 (0.91−1.35)	0.297
Not insured			0.63 (0.56−0.71)	<0.001			0.65 (0.58−0.74)	<0.001
Socioeconomic status								
Low					Ref.		Ref.	
Lower middle					1.11 (1.04−1.18)	0.001	1.07 (1.01−1.14)	0.028
Upper middle					1.29 (1.21−1.37)	<0.001	1.23 (1.15−1.31)	<0.001
High					1.31 (1.21−1.41)	<0.001	1.23 (1.13−1.33)	<0.001

Abbreviation: OR = odds ratio; CI = confidence interval.
[a] Adjusted for age, sex, Charlson−Deyo (comorbidity) score, county type, travel distance, clinical T stage, histologic grade, histology, facility type, facility location, and year of diagnosis.

4. Discussion

In this retrospective cohort study based on a large, national cancer dataset, we evaluated patients undergoing nephrectomy for clinical stage T1 renal cancer diagnosed between 2010 and 2015 in the US. The usage of robotic surgery for PN and RN increased from 35.2% to 63.7% and 10.3% to 26.3%, respectively. Meanwhile, the use of open surgery for PN and RN decreased from 49.5% to 25.3% and 42.3% to 24.8%, respectively.

The utilization of laparoscopic surgery was decreasing for PN and stable for RN through the study period. Within

these trends, certain subgroups of patients were less likely to receive surgical treatment of their renal cancer with MIS.

Within our study population, RAPN became the predominant surgical approach for PN in 2012. By 2015, OPN accounted for only 25% of the total cases. We also found that 40.1% of all the RAPN cases were performed in comprehensive community or community cancer programs. Similar to the robotic prostatectomy literature, RAPN has become increasingly utilized at community hospitals [26]. The rapidly increased RAPN usage (35.2%–63.7%) is consistent with a recent study based on Premier Hospital Database [12]. The trend may be related to the growing evidence showing that RAPN provides better perioperative outcomes than LPN and OPN [27,28]. Considering the significant advantages of the robotic platform over conventional laparoscopy, it is not surprising that LPN cases were being replaced by RAPN. More encouragingly, OPN cases are also being replaced by RAPNs, which suggest robotics significantly expanded the indications of MIS for PN.

Although RARN usage also increased significantly throughout study interval (10.3%–26.3%), LRN was still the dominant surgical approach (~50%), and this remained stable through the study period. In addition, the decrease in open radical nephreopen paralleled the increase in RARNs, which suggests urologists may be performing RARN for more complex or difficult tumors. However, a previous study using Premier Hospital Database, showed a decrease in LRNs that paralleled the increase in RARNs from 2010 to 2015 [11]. The authors stated that the use of RARN has been steadily replacing LRN, which was met with skepticism [13,29]. There are several important differences between our studies. Their study, which included RNs at 416 US hospitals between 2003 and 2015, had 33% fewer patients than our RN cohort when comparing the 2010 to 2015 data. In addition, we included only histologically diagnosed T1 renal cancer while they did not specify tumor stage due to database limitations. Collectively, our study suggests that for T1 renal cancer, increased utilization of robotic surgery may have expanded the MIS for both PN and RN. These findings show that while MIS is often considered the gold standard for treatment of clinically localized RCC due to its association with reductions in perioperative complications and hospital length of stay, open surgery may be indicated in certain circumstances, and has been associated with similar cost and long-term oncological outcomes [30].

To our knowledge, this is the largest and the most contemporary study to date showing the national trends and differences in utilization of MIS for certain subgroups of patients with renal cancer. Alameddine et al. [31] recently reported their analysis on the utilization of RAPN in the NCDB (2010–2013). Unlike their study, we demonstrated different surgical management along the continuum of T1 disease since we included both PN and RN. Second, LPN was not accounted for in their study, and our results showed that 11.0% of PNs were still performed through laparoscopic approach in 2015. We believe it is necessary to combine LPN and RAPN together since they are both MIS options. Third, SES was not included in their analysis and no sensitivity analysis was performed to account for the increased usages of MIPNs.

Despite increased usage of MIPN and MIRN, our study demonstrates that disparity differences in utilization of MIS exist among certain sociodemographic subgroups and geographic areas. Although NHB was not associated with the decreased MIS usage in the full models of our sensitivity analysis, the lower utilization was indicated in the race/ethnicity only models (Supplementary Tables 1–2).

Patients who had no insurance, younger Medicare, and Medicaid were also less likely to receive MIPN or MIRN compared with private insurance. The most consistent and significant disparity of MIS usage appeared to be in SES, which might account for the racial/ethnic, and insurance-related differences. These results indicate that socioeconomically disadvantaged patients have less access to MIS (surgeons) and similar patterns are seen in other cancer surgeries [19,32,33,34]. The mechanism behind this association cannot be determined in the current study, but several theories can be speculated. Ulmer et al. [35] reported that obtaining a second opinion from another urologist was the strongest factor associated with opting for minimally invasive radical prostatectomy. Patients with higher SES are also more likely to be influenced by marketing for robotic or MIS [36,37,38]. Multiple studies have demonstrated that access to or acquisition of a robotic system leads to increased usage of PN [39,40]. We did not test the association between utilization of radical vs. PN because the NCDB lacks information, such as RENAL score, on clinical indication for these procedures. However, minority patients have been shown to have decreased access to centers with robotic approaches for radical prostatectomy [14]. Similar issues to access may explain our results.

Geographic disparities, which may be related to insurance inequalities, were also found to be significant in our analysis and are consistent with findings from previous studies [19,41]. The South West Central region of the United States, in particular, was found to have the lowest ratio of MIS to open surgery for both PN and RN. In support of these findings, recent data shows that Texas, which is the second largest state by population and land area, is home to the largest number of uninsured adults in the nation [42]. Previous studies have suggested that those who are uninsured or on Medicaid are less likely to undergo MIPN compared to open surgery [14]. Given this large uninsured population, timely access to high-volume MIS centers may not be feasible. In addition, the geographic distribution of the urology workforce has resulted in disparities in access to care, and may influence surgical approach selection. In analyzing the American Board of Urology case log data set, Poon et al. [10] showed that initial board certification, higher surgical volume, and practicing in areas with a

population larger than 1,000,000 people was associated with higher usage of laparoscopic nephrectomy. In a more recent study analyzing practice patterns in the urology workforce, Halpen et al. [43] showed that while the proportion of urban urologists has increased significantly since 2003, the proportion of nonurban urologists has remained stable. Nonurban urologists also tended to be older, lack subspecialty fellowship training, and perform fewer major surgical cases. These findings highlight the notion that while regionalization of MIS to urban academic facilities may improve perioperative outcomes, an unintended consequence of such is decreased provider availability and significant travel burden and expenses for patients requiring complex MIS and multidisciplinary cancer care.

Understanding trends, as well as disparities for access to care, is important for healthcare policy and future research. The nephrectomy literature is sparse on this topic, and identifying underserved groups is important for achieving health equity. There is no simple solution to achieve health equity, but some propositions have been reported. Loehrer et al. [44] investigated the impact of 2006 Massachusetts health care reform on racial disparities in MIS and showed that increasing insurance coverage led to equal rates of MIS in white and non-white patients. Public reporting of MIS rates has also been proposed, which might both increase consumer insight and motivate hospitals to meet certain rates of MIS [45]. However, while public reporting has demonstrated an ability to change physician practice in the short term, its sustainability is questionable [46]. Finally, ensuring that reimbursements favor or equivalent MIS to open techniques where outcomes are comparable might play a role in equalizing the availability of MIS to all populations [47]. Kim et al. [14] reported differential usage in MIS techniques between those insured with Medicaid vs. other insurance. Considering that the initial investment and upkeep for a robotic platform is so large, hospitals and physicians with such resources might be incentivized to operate on a greater proportion of privately insured or Medicare patients.

Our study has several limitations. First, we could only control tumor stage in our study. Other patient factors such as body mass index and comorbidities, as well as tumor characteristics including tumor location, endophytic vs. exophytic components, and distance from the renal sinus are associated with the technical complexity of nephrectomy, and are not captured by the NCDB. However, we believe restricting our cohort to cT1N0M0 cancer is clinically relevant as there is less controversy about using MIS in localized renal cancer [4]. In addition, compared to other national databases such as Premier Hospital Database and Nationwide Inpatient Sample, NCDB has a larger sample size of patients and has more cancer characteristics available [11,48,49]. Second, as a cancer registry, NCDB does not collect data for benign tumors. However, since renal mass biopsy is not a common clinical practice and 80% to 85% of surgically resected T1 renal masses are malignant, adding additional benign tumors in our study may not change our results [4,50]. The NCDB collects approximately 70% of the new cancer cases in the United States from CoC-accredited hospitals. Though the database collects the majority of cancer cases, the CoC hospitals and the patients that present to them may not be representative of the general population. Specifically, CoC cancer hospitals have been shown to be larger and more likely teaching hospitals compared to nonaccredited hospitals [51]. Thus, they may have the surgical volume to justify the large initial investment required for robotic platforms. Lastly, SES in our study is based on the zip code level instead of true individual level. Since only income and education are available in the NCDB, we could not account for additional SES-related factors such as occupation.

5. Conclusions

Utilization of MIS for localized renal cancer has increased significantly and was mainly attributed to increased usage of robotic surgery. Racial/ethnic, insurance, and SES-related disparities in MIS utilization were identified. Our findings demonstrate a targetable subgroup of patients who do not have the same access to advances in surgical technology.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.urolonc.2018.10.028.

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