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Safety of Minimally-Invasive Partial vs Radical Nephrectomy for cT1-T2 Renal Masses: An NSQIP Analysis

Jonathan Song
Boston University
Nancy Donohoo
ndonohoo@bu.edu

Boston University
Samuel Lee
Boston University
James Jones
Boston University
Daniel Chen
Boston University
Frank Meng
Boston University
Mark Katz
Boston University
David Wang
Boston University

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Abstract

Introduction

Minimally-invasive (**MIS**) management of cT1b-T2 renal masses with partial (**MIPN**) or radical (**MIRN**) nephrectomy varies based on tumor characteristics and surgeon experience. We reviewed post-operative complications for trends to guide surgical planning.

Methods

We reviewed the ACS NSQIP for all MIPN and MIRN with cT1-T2/N0/M0 for 30-day post-operative outcomes. Patients were excluded for pre-operative dialysis, eGFR < 15, sepsis, disseminated cancer, or ventilator-dependency. Univariate logistic regression modeling ($p < 0.10$) was used to select covariates and screen outcomes for inclusion in multivariate modeling.

Results

13,024 patients were included with 9,418 (72%) patients undergoing MIPN. 8496 (65%), 3584 (28%), 716 (5%), and 228 (2%) patients had cT1a, cT1b, cT2a, and cT2b tumors, respectively. There was no difference in transfusion (2.0 vs 2.4%), post-operative dialysis (0.2 vs 0.3%), related readmission (3.6 vs 3.3%), or related reoperation (1.0 vs 1.2%) rates. MIRN was associated with higher odds of AKI (OR 2.83; 95% CI 2.12–3.80), delayed return of bowel function (OR 2.23; 95% CI 1.51–3.28), and delayed discharge (OR 2.48; 95% CI 2.12–2.89). MIRN was not significantly associated with prolonged operation or death. cT1b-T2 tumors were independently associated with transfusion (OR 1.61; 95% CI 1.16–2.24) and delayed discharge (OR 1.14; 95% CI 1.00-1.31) vs cT1a tumors.

Conclusions

Complication rates for cT1-T2 renal masses after MIPN were favorable compared to MIRN. Larger cT1b-T2 tumors were associated with transfusion and delayed discharge, independent of approach. In properly selected patients, MIPN is safe and may reduce risk of AKI, ileus, and delayed discharge without impact on operative time, bleeding, reoperation, readmission, or death.

INTRODUCTION

There has long been a debate on the role of partial (**PN**) vs radical (**RN)** nephrectomy in managing clinically localized renal masses. American Urological Association (**AUA**) guidelines recommend PN over RN for cT1a renal tumors (≤ 4 cm), based on comparable oncological outcomes and better kidney function preservation [1, 2]. The role of PN is less clearly defined for cT1b (> 4, ≤ 7 cm) and cT2 (> 7 cm) renal masses – RN is recommended only in select situations where patient or tumor characteristics make PN technically infeasible or ineffective for oncologic control and where the patient does not have pre-existing chronic kidney disease (**CKD**) or proteinuria, solitary kidney, bilateral disease, or familial renal cell carcinoma [1]. In practice, identifying those select situations varies greatly among urologists.

When technically feasible and appropriate, increased preservation of renal function with PN may lower risk of cardiovascular events and future morbidity or mortality, with equivalent cancer control [1, 3, 4]. However, there is some question whether post-operative renal function is an adequate predictor for future CKD progression or comparable to medically induced CKD [5]. On the other hand, PN can be a more challenging operation, which can require more diligent post-operative care and which has been associated with higher rates of perioperative and post-operative complications, including higher risk of hemorrhage, operating time, urinary leak or fistula, reoperation, or readmission [3, 6].

As such, safety of PN for larger cT1b-T2 tumors is less clear and there is limited literature that evaluates outcomes by surgical approach for larger tumors. Therefore, we sought to compare functional and surgical outcomes for minimally-invasive partial nephrectomy (**MIPN**) and radical nephrectomy (**MIRN**) management of cT1-T2 renal masses using a well-annotated, prospectively collected national database.

METHODS

Data Source

We retrospectively reviewed the American College of Surgeons (**ACS**) National Surgical Quality Improvement Program (**NSQIP**) database for patients with cT1-T2/N0/M0 renal masses that underwent MIPN or MIRN from 2019–2023. All years with nephrectomy-specific data were queried. Inclusion or exclusion criteria corresponded to Current Procedural Terminology (**CPT**) codes. We used inclusion criteria of MIPN (CPT 50543) or MIRN (CPT 50545) as the principal procedure. We were unable to differentiate between laparoscopic and robotic-assisted approaches based on CPT code in the NSQIP database. Exclusion criteria included pre-operative dialysis, eGFR < 15, disseminated cancer, pre-operative sepsis or septic shock, and ventilator-dependency (Fig. 1). We limited analysis to variables that have been consistently reported in the NSQIP throughout the indicated time frame.

Outcomes

We studied numerous 30-day post-operative outcomes. Surgical complications included wound dehiscence, urinary leak or fistula, stent placement, drain placement, blood transfusion received within 72 hours, prolonged operative time (≥5 hours), ileus, delayed discharge (≥3 days), and unplanned related reoperation. Clinical complications included post-operative dialysis, post-operative renal insufficiency or acute kidney injury (**AKI**; Cr rise > 2 mg/dL), myocardial infarction **(MI**), cardiac arrest requiring cardiopulmonary resuscitation, cerebrovascular accident (**CVA**) with neurologic deficit, unplanned related readmission, and death. Major adverse cardiac events (**MACE**) were also analyzed, defined as any MI, cardiac arrest, CVA, or death.

Statistical Analysis

Only those post-operative outcomes that reached a statistically significant association with surgical approach ($p < 0.10$) in univariate logistic regression modeling were modeled in multivariate analysis. Multivariate logistic regression was used to analyze the association between surgical approach and outcomes, adjusting for various confounders. For a given outcome, covariate selection was determined using significance with the outcome in univariate logistic regression modeling ($p < 0.10$). No features were trimmed from multivariate modeling after incorporation. Confounding variables included tumor stage (cT1b-T2 vs cT1a), sex, age, body mass index (**BMI**), modified 5-item frailty index (**5-mFI**), American Society of Anesthesiology (**ASA**) Classification (high-risk defined as ≥3), diabetes mellitus (**DM**), smoking status, regular use of oral or parenteral corticosteroids or immunosuppressants, bleeding disorder, prior pelvic radiation, prior pelvic surgery, year of procedure, prolonged operating time, drain placement, pre-operative urinary tract infection (**UTI**), pre-operative white blood cell count (**WBC**), pre-operative hematocrit (**HCT**), pre-operative platelet count (**PLT**), pre-operative partial thromboplastin time (**PTT**), pre-operative international normalized ratio (**INR**), and pre-operative estimated glomerular filtration rate (**eGFR**) as defined by the 2021 CKD-EPI equation [7]. When tumor stage was a significant confounder in multivariate analysis, similar multivariate models were constructed for combined and individual tumor stages, with cT1a as the reference group. In a subset of patients with CKD stage IIb-III, similar multivariate models were constructed to identify whether this subgroup was at particular risk for poor cardiorenal-related outcomes.

Ethics

The ACS NSQIP database used in this study contains fully deidentified data. There were no human subjects involved. Therefore, no consent to participate was required. The research protocol of this study was determined to be exempt from our Institutional Review Board approval. No funding was received. This study uses data sourced from the NSQIP, which is under the oversight of participating hospitals and oversight of the ACS. These entities have not verified nor are responsible for the statistical validity of any analysis or conclusions reported by the study authors.

RESULTS

A total of 13,024 patients with cT1-T2/N0/M0 renal masses met inclusion and exclusion criteria, of which 9,418 (72.3%) underwent MIPN (Table 1). In this population, 8,496 (65.2%) had cT1a, 3,584 (27.5%) had cT1b, 716 (5.5%) had cT2a, and 228 (1.8%) had cT2b renal masses. In this population, MIPN was more common than MIRN for cT1a tumors (78.1% vs 31.7%), but less common for cT1b-T2b tumors (21.9% vs 68.3%). The mean age was 59.3 ± 12.1 for MIPN and 62.4 ± 12.3 for MIRN. Overall mean BMI was 31.3 ± 7.3 kg/m^2 and 8198 (63.0%) patients had high-risk ASA classification. Pre-operatively, patients that underwent MIPN had higher eGFR (84.4 ± 20.8 vs 81.2 ± 20.7 mL/min/1.73 m^2). Additional patient characteristics can be found in Table 1 and **Supplementary Table 12**.

Table 1
Pre-Operative Patient Characteristics for MIPN and MIRN

Pre-Operative Characteristics	Overall n = 13,024	Partial Nephrectomy n = 9,418 (72.3%)	Radical Nephrectomy n = 3,606 (27.7%)	p-value
Demographics				
Sex (Female)	4743 (36.4%)	3399 (36.1%)	1344 (37.3%)	0.22
Race				< 0.01*
Asian	532 (4.1%)	359 (3.8%)	173 (4.8%)	
Black or African American	1327 (10.2%)	983 (10.4%)	344 (9.5%)	
White	8895 (68.3%)	6484 (68.8%)	2411 (66.9%)	
Hispanic Ethnicity	1112 (8.5%)	870 (9.2%)	242 (6.7%)	< 0.01*
Age (yrs)	60.1 ± 12.2	59.3 ± 12.1	62.4 ± 12.3	< 0.01*
BMI (kg/m^2)	31.3 ± 7.3	31.3 ± 7.2	31.3 ± 7.4	0.98
Past Medical History				
5-mFI				< 0.01*
≥2	2959 (22.7%)	2065 (21.9%)	894 (24.8%)	
0–1	10065 (77.3%)	7353 (78.1%)	2712 (75.2%)	
ASA Physical Status				< 0.01*
High	8198 (63.0%)	5716 (60.7%)	2482 (68.9%)	
Low	4818 (37.0%)	36696 (39.3%)	1122 (31.1%)	
Bleeding Disorder	263 (2.0%)	168 (1.8%)	95 (2.6%)	< 0.01*

Ref: reference; BMI: body mass index, 5-mFI: Modified 5 Item Frailty Index, ASA: American Society of Anesthesiologists, CHF: congestive heart failure, COPD: chronic obstructive pulmonary disease, HTN: hypertension, eGFR: estimated Glomerular Filtration Rate, BUN: Blood Urea Nitrogen, HCT: Hematocrit, PTT: Partial Thromboplastin Time, INR: International Normalized Ratio. Parentheses indicate percentages for categorical variables and ± for standard deviations for continuous variables. *indicates statistical significance.

Reporting of baseline rates of various pre-operative patient characteristics for patients undergoing minimally-invasive partial or radical nephrectomy in NSQIP.

Pre-Operative Characteristics	Overall n = 13,024	Partial Nephrectomy n = 9,418 (72.3%)	Radical Nephrectomy n = 3,606 (27.7%)	p-value
CHF	267 (2.1%)	162 (1.7%)	105 (2.9%)	< 0.01*
COPD	451 (3.5%)	299 (3.2%)	152 (4.2%)	< 0.01*
HTN	8077 (62.0%)	5749 (61.0%)	2328 (64.6%)	< 0.01*
Diabetes Mellitus	2986 (22.9%)	2139 (22.7%)	847 (24.5%)	0.36
Immunosuppressive Therapy	503 (3.9%)	318 (3.4%)	185 (5.1%)	< 0.01*
eGFR (mL/min/1.73 m²)	83.5 ± 20.8	84.4 ± 20.8	81.2 ± 20.7	< 0.01*
Pre-operative BUN	16.9 ± 6.9	16.8 ± 6.7	17.3 ± 7.6	< 0.01*
Pre-operative Creatinine	1 ± 0.3	1 ± 0.3	1 ± 0.3	< 0.01*
Pre-operative HCT (%)	42.1 ± 4.5	42.3 ± 4.4	41.5 ± 4.8	< 0.01*
Pre-operative PTT (sec)	30 ± 6.6	29.8 ± 6.6	30.7 ± 6.4	< 0.01*
INR (+ 0.1)	1 ± 0.3	1 ± 0.3	1.1 ± 0.3	< 0.01*
Clinical Tumor Stage				< 0.01*
T1a	8496 (65.2%)	7353 (78.1%)	1143 (31.7%)	
T1b	3584 (27.5%)	1880 (20.0%)	1704 (47.3%)	
T2a	716 (5.5%)	153 (1.6%)	563 (15.6%)	
T2b	228 (1.8%)	32 (0.3%)	196 (5.4%)	
Prior Pelvic Radiotherapy	139 (1.1%)	104 (1.1%)	35 (1%)	0.57
Prior Pelvic Operations	4281 (32.9%)	3149 (33.4%)	1132 (31.4%)	0.03

Ref: reference; BMI: body mass index, 5-mFI: Modified 5 Item Frailty Index, ASA: American Society of Anesthesiologists, CHF: congestive heart failure, COPD: chronic obstructive pulmonary disease, HTN: hypertension, eGFR: estimated Glomerular Filtration Rate, BUN: Blood Urea Nitrogen, HCT: Hematocrit, PTT: Partial Thromboplastin Time, INR: International Normalized Ratio. Parentheses indicate percentages for categorical variables and ± for standard deviations for continuous variables. *indicates statistical significance.

Reporting of baseline rates of various pre-operative patient characteristics for patients undergoing minimally-invasive partial or radical nephrectomy in NSQIP.

Pre-Operative Characteristics	Overall n = 13,024	Partial Nephrectomy n = 9,418 (72.3%)	Radical Nephrectomy n = 3,606 (27.7%)	p-value
Drain Placement	5229 (40.1%)	4834 (51.3%)	395 (11.0%)	< 0.01*

Ref: reference; BMI: body mass index, 5-mFI: Modified 5 Item Frailty Index, ASA: American Society of Anesthesiologists, CHF: congestive heart failure, COPD: chronic obstructive pulmonary disease, HTN: hypertension, eGFR: estimated Glomerular Filtration Rate, BUN: Blood Urea Nitrogen, HCT: Hematocrit, PTT: Partial Thromboplastin Time, INR: International Normalized Ratio. Parentheses indicate percentages for categorical variables and ± for standard deviations for continuous variables. *indicates statistical significance.

Reporting of baseline rates of various pre-operative patient characteristics for patients undergoing minimally-invasive partial or radical nephrectomy in NSQIP.

Post-operatively, those that underwent MIRN compared to MIPN had lower rates of urinary leak (0.1 vs 0.6%), stent placement (0.7 vs 1.6%), and prolonged operative time (4.6 vs 6.2%) (Table 2). However, MIRN was associated with higher rates of wound dehiscence (0.5 vs 0.1%), delayed discharge (30.5 vs 20.6%), AKI (5.3 vs 1.9%), ileus (1.5 vs 0.7%), myocardial infarction (0.5 vs 0.3%), MACE (1.0 vs 0.5%), and death (0.4 vs 0.1%). There was no difference in rates of transfusion (2.4 vs 2.0%), post-operative dialysis (0.3 vs 0.2%), CVA with neurologic deficit (0.2 vs 0.1%), cardiac arrest requiring CPR (0.2 vs 0.1%), related reoperation (1.2 vs 1.0%), or related readmission (3.3 vs 3.6%). Full univariate analyses can be found in **Supplementary Tables 1–6**.

Table 2
Post-Operative Outcomes Following MIPN and MIRN

30-Day Post-Operative Complications	Overall n = 13,024	MIPN n = 9,418 (72.3%)	MIRN n = 3,606 (27.7%)	p-value
Surgical				
Wound Dehiscence	23 (0.2%)	6 (0.1%)	17 (0.5%)	< 0.01*
Urinary Leak/Fistula	61 (0.5%)	57 (0.6%)	4 (0.1%)	< 0.01*
Stent Placement	174 (1.3%)	149 (1.6%)	25 (0.7%)	< 0.01*
Transfusion < 72hr	278 (2.1%)	192 (2.0%)	86 (2.4%)	0.25
Ileus	117 (0.9%)	64 (0.7%)	53 (1.5%)	< 0.01*
Prolonged Operative Time ≥5hr	750 (5.8%)	584 (6.2%)	166 (4.6%)	< 0.01*
Delayed Discharge ≥3d	3042 (23.4%)	1943 (20.6%)	1099 (30.5%)	< 0.01*
Unplanned Related Reoperation	140 (1.1%)	98 (1.0%)	42 (1.2%)	0.6
Clinical				
Post-operative Dialysis	29 (0.2%)	18 (0.2%)	11 (0.3%)	0.3
Post-operative AKI	299 (2.9%)	144 (1.9%)	155 (5.3%)	< 0.01*
CVA with Neurologic Deficit	19 (0.1%)	11 (0.1%)	8 (0.2%)	0.25
Cardiac Arrest	18 (0.1%)	11 (0.1%)	7 (0.2%)	0.42
Myocardial Infarction	41 (0.3%)	24 (0.3%)	17 (0.5%)	0.07*
Major Adverse Cardiac Events	83 (0.6%)	47 (0.5%)	36 (1.0%)	< 0.01*
Unplanned Related Readmission	461 (3.5%)	342 (3.6%)	119 (3.3%)	0.39
Death	26 (0.2%)	13 (0.1%)	13 (0.4%)	0.02*
AKI: Acute Kidney Injury; CVA: Cerebral Vascular Accident				
Parentheses indicate percentages for categorical variables. * indicates statistical significance.				
Reporting of rates of various 30-day post-operative complications for patients undergoing minimally-invasive partial or radical nephrectomy in NSQIP.				

In multivariate analysis, MIRN was significantly associated with higher odds of wound dehiscence (OR 5.25; 95% CI 1.86–16.68), ileus (OR 2.23; 95% CI 1.51–3.28), AKI (OR 2.83; 95% CI 2.12–3.80), MACE (OR 1.71; 95% CI 1.08–2.69), and delayed discharge (OR 2.48; 95% CI 2.12–2.89) compared to MIPN (Table 3). MIRN was also significantly associated with lower odds of urine leak (OR 0.31; 95% CI 0.09–

0.80) compared to MIPN (Table 3). There was no significant difference with respect to stent placement, prolonged operation, myocardial infarction, or death. Full multivariate analyses can be found in **Supplementary Tables 7–10**.

Table 3
Multivariate Analysis of Association Between Surgical Approach and Outcomes

30-Day Post-Operative Complications	**MIRN (vs MIPN)** **OR (95% CI)**
Surgical Site	
Wound Dehiscence	5.25 (1.86–16.68)*
Urinary Leak/Fistula	0.31 (0.09–0.80)*
Stent Placement	0.68 (0.42–1.05)
Ileus	2.23 (1.51–3.28)*
Prolonged Operation Time ≥5hr	0.94 (0.68–1.28)
Delayed Discharge ≥3d	2.48 (2.12–2.89)*
Clinical	
Post-operative AKI	2.83 (2.12–3.80)*
Myocardial Infarction	1.46 (0.76–2.74)
Major Adverse Cardiac Event	1.71 (1.08–2.69)*
Death	1.61 (0.66–3.93)
AKI: Acute Kidney Injury	
Adjusted odds ratios and 95% confidence intervals of surgical approach in multivariate logistic regression modeling of various 30-day post-operative complications for patients undergoing MIRN and MIPN in NSQIP.	

In multivariate analysis of tumor stage, combined cT1b-cT2 was significantly associated with higher odds of transfusion (OR 1.61; 95% CI 1.16–2.24) and delayed discharge (OR 1.14; 95% CI 1.00-1.31) when compared to cT1a (Table 4). Analysis by individual T stage revealed that cT1b tumors had higher odds of transfusion (OR 1.63; 95% CI 1.15–2.31) and delayed discharge (OR 1.15; 95% CI 1.00-1.32) when compared to cT1a tumors, but no difference in odds was found for cT2a or cT2b tumors (Table 5).

Table 4
Multivariate Analysis of Association Between Grouped Tumor Stage and Outcomes

30-Day Post-Operative Complications	**cT1b-T2b (vs cT1a)** **OR (95% CI)**
Surgical	
Transfusion < 72hr	1.61 (1.16–2.24)*
Wound Dehiscence	0.92 (0.38–2.35)
Prolonged Operation Time ≥5hr	1.26 (0.98–1.60)
Delayed Discharge ≥3d	1.14 (1.00-1.31)*
Clinical	
Post-operative Dialysis	1.52 (0.69–3.41)
Post-operative AKI	1.27 (0.97–1.65)
Cardiac Arrest	1.79 (0.67–5.02)
Unplanned Related Readmission	1.11 (0.91–1.36)
Death	1.29 (0.54–3.18)
AKI: Acute Kidney Injury	
Adjusted odds ratios and 95% confidence intervals in multivariate logistic regression modeling of various 30-day post-operative complications for patients undergoing minimally-invasive nephrectomy in NSQIP.	

Table 5
Multivariate Analysis of Association Between Individual Tumor Stage and Outcomes

30-Day Post-Operative Complications	**Reference: cT1a**	**cT1b** **OR (95% CI)**	**cT2a** **OR (95% CI)**	**cT2b** **OR (95% CI)**
Transfusion < 72hr	-	1.63 (1.15–2.31)*	1.62 (0.87–2.85)	1.36 (0.45–3.33)
Delayed Discharge ≥3d	-	1.15 (1.00-1.32)*	1.06 (0.82–1.36)	1.34 (0.88–2.01)
AKI: Acute Kidney Injury				
Adjusted odds ratios and 95% confidence intervals of transfusion in multivariate logistic regression modeling of various 30-day post-operative complications for patients undergoing minimally-invasive nephrectomy in NSQIP.				

In multivariate analysis of cardiorenal outcomes in patients with CKD Stage IIb-III, MIRN was associated with higher odds of death (OR 2.02; 95% CI 0.72–5.84) when compared to MIPN, but there was no

significant difference with respect to post-operative AKI or MACE (Table 6). Higher pre-operative eGFR was significantly associated with lower odds of post-operative AKI (OR 0.84; 95% CI 0.71–0.98), but no difference in odds was found for post-operative dialysis, death, CVA with neurologic deficit, cardiac arrest, or MACE (Table 6). Analysis by combined tumor stage cT1b-cT2 showed no significant difference in odds for post-operative AKI, myocardial infarction, or MACE when compared to cT1a.

Table 6
Multivariate Analysis of Cardiorenal Outcomes in 4088 Patients with CKD Stage IIb-III

30-Day Post-Operative Complications	**MIRN (vs MIPN)** **OR (95% CI)**	**cT1b-T2 (vs cT1a)** **OR (95% CI)**	**Pre-Operative eGFR (+ 10)** **OR (95% CI)**
Post-operative Dialysis	-	-	0.77 (0.51–1.18)
Post-operative AKI	1.71 (1.15–2.54)	1.30 (0.88–1.92)	0.84 (0.71–0.98)*
Death	2.02 (0.72–5.84)*	-	0.70 (0.45–1.10)
CVA with Neurologic Deficit	-	-	0.62 (0.33–1.16)
Cardiac Arrest	-	-	0.73 (0.42–1.26)
Myocardial Infarction	-	1.74 (0.74–4.28)	-
MACE	1.88 (0.94–3.81)	1.09 (0.55–2.17)	0.82 (0.62–1.09)

Dialysis model adjusted for pre-operative eGFR, steroid use, prior surgery, age, and BMI. AKI model adjusted for approach, T-stage, mFI-5, ASA classification, pre-operative eGFR, age, pre-operative hematocrit, and year of surgery. Death adjusted for surgical approach, pre-operative eGFR, age, pre-operative hematocrit, and year of surgery. Stroke adjusted for mFI-5 and pre-operative eGFR. Cardiac arrest adjusted for pre-operative eGFR, bleeding disorder, age, pre-operative hematocrit, pre-operative platelets, and operative time. Myocardial infarction adjusted for T-stage, ASA classification, and age. MACE adjusted for approach, T-stage, 5-mFI, ASA classification, pre-operative eGFR, bleeding disorder, age, pre-operative hematocrit, and pre-operative platelets.

- indicates relationship did not achieve statistical significance ($p < 0.10$) in univariate testing.

MIRN was significantly associated with lower rates of reoperation for urinary tract injury (0.0 vs 0.5%), but higher rates for exploratory laparotomy or laparoscopy (0.3 vs 0.1%) and hernia repair or wound dehiscence (0.5 vs 0.1%) than MIPN (**Supplementary Table 11**). There was no significant difference in reoperation rates for nephrectomy or GI tract injury.

DISCUSSION

Although MIPN is preferred over MIRN for cT1a renal masses, there is limited research on how they differ in terms of peri-operative outcomes for cT1b-T2 masses. In this study, we found significant associations between MIPN and lower odds of ileus, wound dehiscence, and delayed discharge

compared to MIRN without impact on other surgical complications such as need for blood transfusion, prolonged operating time, related reoperation, or related readmission. For clinical outcomes, MIPN was associated with lower odds of post-operative AKI and MACE. Larger tumor size increases odds of transfusion and delayed discharge regardless of surgical approach. Overall, our study supports the safety of MIPN for larger cT1b-T2b tumors and provides national level outcomes data to inform preoperative risk counseling.

We found that patients undergoing MIPN had lower odds of ileus, wound dehiscence, and delayed discharge when compared to MIRN, which is consistent with our experience that MIPN often requires smaller incisions, less bowel mobilization, and is generally performed in healthier patients, which may account for prompt discharge. Interestingly, we did not find that surgical approach impacted odds of prolonged operative time, need for blood transfusion, related reoperation, or related readmission. A smaller NSQIP review of 2,094 cT1b-T2 masses from 2019–2020 found that PN was associated with transfusion in univariate analysis, though no multivariate analysis was performed [6]. A review of 317,843 nephrectomies from 2005–2021 in the GRAND database found PN had lower risks of prolonged hospitalization, in-hospital transfusion, and ICU admission, although tumor size or stage were not accounted for [8]. While PN is perceived to be more surgically complex, we did not find difference in operating time, which is consistent with a 2016 meta-analysis of 21 case-control studies [3]. This suggests that advances in MIS techniques have reduced the technical challenges historically ascribed to PN and therefore improved the surgical outcomes of MIPN in cT1b-T2 tumors, which we appreciated on a population level. Compared to MIRN, MIPN for cT1b-T2 renal masses confers better 30-day surgical outcomes in properly selected patients without increasing risk of poor outcomes.

We found that patients undergoing MIPN had lower 30-day odds of post-operative AKI and MACE when compared to those undergoing MIRN, but we did not find an association between approach and post-operative dialysis, MI, cardiac arrest, CVA, or death. Our finding of better post-operative renal function in MIPN for cT1b-T2 renal masses is well supported. A 2024 multi-institutional study reported lower rates of post-operative AKI in PN vs RN for patients with cT1b-T2 renal masses [9], which agrees with prior studies [3, 10]. Moreover, pre-operative eGFR < 60 mL/min/1.73 m^2 (CKD Stage 3) has been associated with higher risk of post-operative AKI and need for dialysis [11, 12]. Although there was unexpectedly higher pre-operative eGFR in patients undergoing MIPN vs MIRN in our study, the difference was small and may be attributed to stricter selection criteria and thus healthier patients who received MIPN. Additionally, we found that MIRN was associated with increased odds of 30-day MACE compared to MIPN. The cardiovascular benefit of PN is thought to be mediated primarily through the preservation of renal function [3, 13]. A 2023 meta-analysis found PN was significantly associated with reduced cardiac events when compared to RN [14]. In a 2012 study of cT1b tumors, RN resulted significantly increased risk of cardiac death and all-cause death compared to PN [15]. Furthermore, a 2014 study of 1,331 patients with cT1a-T1b tumors found lower risk of cardiac events for PN than RN, even after accounting for individual cardiovascular risk [13]. Our study finds that the preservation of renal function to reduce 30-day MACE outcomes is significant and should be considered in pre-operative risk counseling or when deciding on appropriate surgical approach.

We found that a higher tumor stage was significantly associated with higher odds of transfusion and delayed discharge, which is consistent with prior literature. Several studies have established larger tumor size as an independent risk factor for intraoperative blood transfusion or hemorrhage in PN [16, 17, 18, 19]. Additionally, A 2022 study of 392 MIPNs found tumor size directly correlated to length of stay [20]. Perioperative complications including blood loss have been strongly associated with delayed discharge as well [21]. Larger tumors have even been associated with higher rates of conversion to open surgery in PN due to hemorrhage, upstaging, and tumor complexity, among other factors [22]. Although cT2a and cT2b did not show significant associations with bleeding and discharge on secondary analysis in our study, these substages and events were rare and thus our study was likely underpowered to detect a relationship. In all, our study finds that larger tumors can be more difficult to operate on independent of surgical approach and should warrant additional consideration.

We found that in patients with CKD stage IIb-III, higher pre-operative eGFR was significantly associated with lower odds of post-operative AKI, while surgical approach and tumor stage had no impact. While effects of CKD are especially pronounced at stage III, we included CKD stage IIb in our analysis as prior evidence has found that patients with CKD stage IIb undergoing PN or RN are at a higher risk of developing post-operative eGFR < 45 compared to patients with CKD stage IIa [23]. Interestingly, eGFR did not impact odds for post-operative dialysis in our data, although NSQIP was limited to capturing 30-day outcomes, so receipt of lifelong dialysis is unknown. MIRN was associated with higher odds of death when compared to MIPN without any association with AKI and MACE, in contrast to our primary analysis of patients with any preoperative eGFR. Our findings are supported by other studies that find drops in post-operative eGFR decrease in magnitude with increasing severity of CKD, with no difference in renal outcomes by surgical approach for patients with CKD stage IV [24, 25]. Overall, our study finds that pre-operative CKD modulates the effect of surgical approach on cardiorenal outcomes, and emphasizes the importance of individualized risk counseling.

Strengths of this study include examining a large national database over a longer time and isolating outcomes of minimally-invasive surgeries for cT1b-cT2 renal masses. As with any retrospective study, this study has limitations. Due to the retrospective nature of this study, numerous confounders were unable to be studied. The standard NSQIP database combines robot-assisted and standard laparoscopic surgical approaches under the same CPT code, which may have obscured trends as robot-assisted PN is associated with lower estimated blood loss, rate of CKD onset, and length of hospital stay when compared to laparoscopic or open PN [26]. Our study was limited to 30-day outcomes and as such lacked granular oncologic data such as post-operative pathology, or long-term outcomes such as delayed dialysis, or recurrence-free or metastasis-free survival. We were unable to evaluate additional predictors for CKD progression, including degree of albuminuria [27]. Our study is vulnerable to selection bias as patients with renal masses may not equally be offered MIRN or MIPN, based on patient characteristics or surgeon experience. For example, patients in this study that received MIPN were younger and had lower rates of comorbidities than those who received MIRN. As a national registry-based study, detailed risk stratification tools such as imaging data, validated risk scores (e.g., RENAL Nephrometry), or other surgical planning variables could not be incorporated [28, 29, 30]. Lastly, the

NSQIP database is limited to participating institutions in the US, which could limit the generalizability of this study.

CONCLUSIONS

For patients with cT1b-T2 renal masses in the NSQIP database, MIPN is associated with lower 30-day odds of ileus, wound dehiscence, delayed discharge, AKI, and MACE without any impact on need for blood transfusion, prolonged operating time, related reoperation, or related readmission. Larger tumor size increases odds of transfusion and delayed discharge regardless of approach. Our study supports the use of MIPN in managing cT1b-T2 renal masses, with better perioperative surgical and clinical outcomes than MIRN in properly selected patients.

Declarations

Generative AI in Scientific Writing Statement

The authors did not use generative AI or AI-assisted technologies in the development of this manuscript.

AUTHORS' CONTRIBUTION

JJ Song: Conceptualization, Methodology, Software, Formal Analysis, Investigation, Resources, Data Curation, Validation, Writing – Original Draft, Writing – Review & Editing, Visualization

NG Donohoo: Investigation, Resources, Data Curation, Validation, Writing – original draft, Writing – Review & Editing, Visualization

SZ Lee: Methodology, Writing – Review & Editing

JM Jones: Methodology, Writing – Review & Editing

D Chen: Resources, Writing – Review & Editing, Supervision

F Meng: Resources, Writing – Review & Editing

MH Katz: Conceptualization, Writing – Review & Editing, Supervision

DS Wang: Conceptualization, Writing – Review & Editing, Supervision, Project administration

Data Availability

The data that support the findings of this study are available from the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP). Restrictions apply to the availability of these data, which were accessed under a data use agreement by a participating institution, and so are

not publicly available. Data may be obtained from the American College of Surgeons with permission and completion of the appropriate data use agreements.

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Figures

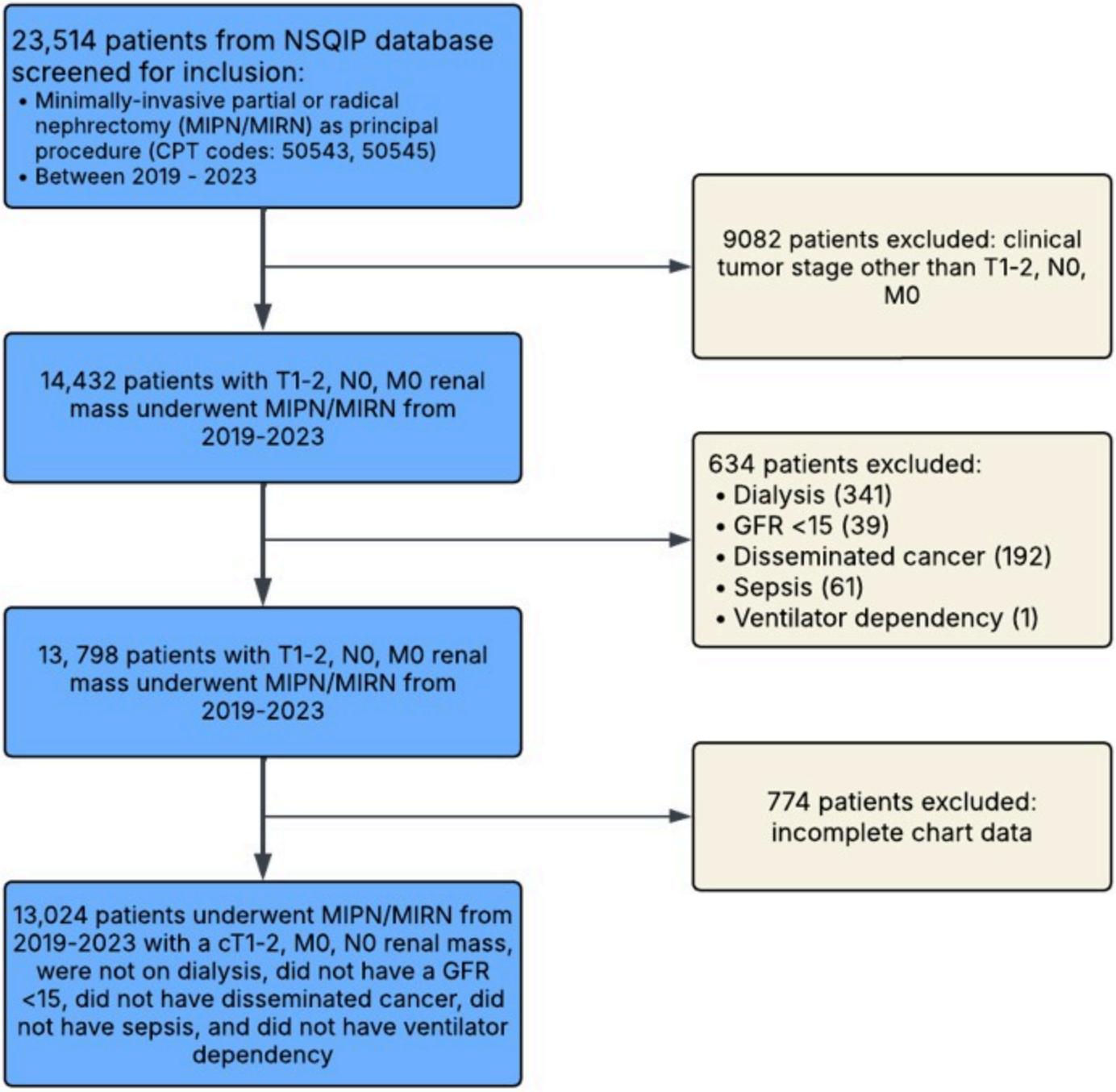

Figure 1

Cohort Diagram

Cohort diagram of inclusion and exclusion criteria.

Supplementary Files

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