

Nephrectomies in Saudi Arabia: A Comprehensive Analysis of Outcomes from a High-Volume Minimally Invasive Surgery Center

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Abstract

Literature reporting on the outcomes of the different procedures of nephrectomies (open vs laparoscopic vs robotic) in Saudi Arabia remains limited. Compare surgical and oncological outcomes between open and minimally invasive nephrectomies. A retrospective cohort study. The present study included all adult patients who underwent nephrectomies between January 1, 2015 and January 31, 2023. We collected demographic, preoperative, intraoperative, and postoperative data on 408 adult cancer patients who underwent nephrectomies at our center between January 2015 and January 2023. Statistical differences were calculated between procedure types. Overall survival was calculated using Kaplan–Meier curves with log-rank tests. $P < 0.05$ was considered statistically significant. Measures of operative success (intraoperative blood loss, intraoperative and postoperative complications, and hospital stay) and oncological outcomes (local recurrence, metastatic progression, and chemotherapy use) between different procedure and nephrectomy types for cancer patients. A total of 408 cancer patients underwent nephrectomies. In cancer patients, open nephrectomy was associated with significantly higher intraoperative blood loss ($p < 0.001$), incidence of blood transfusions ($p < 0.001$), hospital stay ($p < 0.001$), intraoperative complications ($p = 0.027$ and $p = 0.001$, respectively), local recurrence ($p < 0.001$), metastatic progression ($p = 0.001$), and chemotherapy ($p = 0.001$) than minimally invasive surgery, but survival differences across procedure types were not statistically significant (log-rank p -value = 0.054). Regarding nephrectomy type, significant differences were observed in tumor size ($p < 0.001$), initial procedure type ($p < 0.001$), operation time ($p < 0.001$), blood transfusion ($p = 0.033$), length of hospital stay ($p = 0.004$), intraoperative complications ($p = 0.020$), postoperative complications ($p = 0.025$), Clavien classification ($p = 0.003$), mortality ($p = 0.022$), metastatic progression ($p < 0.001$), and chemotherapy use ($p = 0.001$) between simple/total nephrectomy, radical nephrectomy (RN), partial nephrectomy (PN), and nephroureterectomy. Survival differences between the four nephrectomy types were statistically significant (log-rank p value = 0.001). Minimally invasive nephrectomies reduce inpatient morbidity while conferring equivalent oncological and surgical outcomes.

Keywords: Nephrectomy, Minimally Invasive Surgery, Nephrectomy Outcomes, Saudi Arabia

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Introduction

Nephrectomy, a surgical procedure involving the removal of one or both kidneys, is commonly performed to treat various kidney diseases, such as renal cancer and end-stage kidney disease (ESKD). The main types of nephrectomies include radical and partial nephrectomy, with the latter considered nephron-sparing (1). The American Urological Association guidelines recommend partial nephrectomy as a first-line treatment for tumors between 4 and 7 cm in size—clinically classified as stage T1a or T1b—or for patients with absolute indications such as bilateral renal masses or a solitary kidney (2). Regardless of the type, nephrectomy has witnessed a significant shift toward minimally invasive surgery (MIS)—comprising laparoscopic and robotic approaches—in recent years due to its numerous advantages over traditional open surgery such as reduced perioperative blood loss and analgesia use, shorter hospital stay, quicker return to full function, and equivalent short- and long-term oncological outcomes (3–8). Both radical and partial nephrectomies can be performed openly or using minimally invasive laparoscopic and robotic approaches (9).

Comparisons of open and minimally invasive nephrectomy encompassing surgical and oncological outcomes in Saudi Arabia are limited. With the projected 33% increase in kidney cancer cases and the growing number of ESKD patients in Saudi Arabia, the burden for nephrectomies is naturally expected to rise (10, 11). Alhaidari et al. compared open nephrectomy ($n = 42$) to robotic nephrectomy ($n = 28$) in a cohort of 70 renal cancer patients, revealing significantly lower estimated blood loss and shorter hospital stay in the latter (12). Another regional study by Seyam et al. in 2019 retrospectively examined 101 patients undergoing robotic partial nephrectomy and reported favorable outcomes in terms of blood loss, warm ischemia time, operative time, and complication rate (13). They found that 73% of patients achieved a trifecta, which is the most common criterion used for assessing short-term nephrectomy outcome (13). However, this study lacked a comparison group, was limited by small sample size, and lacked an assessment of long-term surgical and oncological outcomes. A subsequent study by our group was the first regional study to compare partial nephrectomy outcomes based on procedure type (open, laparoscopic, and robotic) (14). However, experience with robot-assisted partial nephrectomy was limited in Saudi Arabia at the time and hence outcomes were not comparable to high-volume centers in the West (14).

To expand upon these findings, we present a detailed comparison of the surgical and oncological outcomes between open and minimally invasive nephrectomies at our center which boasts a high urology operating room volume of 4,000 procedures annually, encompassing all variations of nephrectomies.

Patients and Methods

Patient population

The present study included all adult patients who underwent nephrectomies between January 1, 2015, and January 31, 2023. Patients aged under 18 years and those who had undergone nephrectomies at another center but were following up at our center were excluded from the study. Demographic, preoperative, intraoperative, and postoperative variables were collected from the BESTCare system (ezCareTech, South Korea). Figures were created by Microsoft Excel 2019 (Microsoft Corporation, WA, USA) and statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 23.0 (IBM Corporation, NY, USA).

Statistical analysis

Categorical variables were presented as frequencies and percentages, while numerical variables were expressed as median and interquartile ranges (IQRs). Statistical differences between procedure types were assessed using Pearson's Chi-squared test or Fisher's exact test. The Wilcoxon rank sum test was used to evaluate differences between nephrectomy types (i.e., radical or partial) and the Kruskal–Wallis rank sum test was employed to assess differences between procedure types (open, laparoscopic, or robotic). Analysis of variance (ANOVA) was applied to explore the interaction between time (preoperative, 3–6 months, and 6–12 months) and procedure type on numerous laboratory parameters. Time was considered a within-subject effect, while procedure type was a between-subjects variable. Kaplan–Meier plots were used to depict survival curves, and differences in survival were assessed using a log-rank test. A p -value of < 0.05 indicated statistical significance.

Ethical considerations

The study was approved by the Institutional Review Board of King Abdullah International Medical Research Center, Ministry of National Guard-Health Affairs, Riyadh, Kingdom of Saudi Arabia (approval number RC18/163/R). Patient confidentiality was ensured.

Results

Data of a total of 408 cancer patients undergoing nephrectomies were included. The median age of patients was 59.0 years (IQR 49.5–68.0), with a median BMI of 30.3 kg/m² (IQR 25.7–34.0). Most of our patients were male (63.2%) and Saudis (93.1%). More details about the demographic characteristics are provided in Table 1.

Table 1: Demographic characteristics of renal cancer patients who underwent nephrectomies.

Parameter	Category	Cancer cohort	
		Description (n=408)	Missing
Age	Years	59.0 (49.5, 68.0)	1 (0.2%)
Height	m	1.7 (1.6, 1.7)	0 (0%)
Weight	kg	80.0 (69.0, 91.7)	0 (0%)
BMI	kg/m ²	30.3 (25.7, 34.0)	0 (0%)
Gender	Male	258 (63.2%)	0 (0%)
	Female	150 (36.8%)	
Nationality	Saudi	379 (93.1%)	1 (0.2%)
	Non-Saudi	28 (6.9%)	
Past Medical History (Renal)	None	301 (74.3%)	3 (0.7%)
	Pyeloplasty	0 (0.0%)	
	Past renal surgery	7 (1.7%)	
	Other	97 (24.0%)	

*Categorical variables are described as frequencies (percentages), and numerical data are described as median (IQR).

Operative characteristics and outcomes of patients with cancer by procedure type

Robotic surgeries had significantly higher rates of partial nephrectomy (90.7%) compared to laparoscopic (16.6%) and open surgeries (38.6%, $p < 0.001$) (Table 2). In addition, open nephrectomies were associated with significantly higher blood loss ($p < 0.001$), rates of blood transfusions ($p < 0.001$), intraoperative complications ($p = 0.001$), and postoperative complications ($p = 0.028$) than MIS approaches. We used the Clavien grading system for classifying intraoperative adverse events and found a significant difference between open, laparoscopic, and robotic nephrectomies ($p = 0.016$). Open procedures were significantly associated with higher rates of local recurrence ($p < 0.001$), metastatic progression ($p = 0.001$), and use of chemotherapy ($p = 0.001$) (Table 2). Analysis of laboratory parameters revealed a significant interaction between time and procedure type for changes in blood urea nitrogen ($p = 0.016$), while other laboratory indices did not show significant interactions (Figure 1). Death occurred among 4.7% of patients with cancer, with rates of 11.4% in open nephrectomy, 4.1% in laparoscopic nephrectomy group, and 1.0% in the robotic nephrectomy group. However, the difference in survival was not statistically significant across different procedure types (log-rank p value = 0.054, Figure 2).

Operative characteristics and outcomes of patients with cancer by nephrectomy type

Significant differences were also observed between different nephrectomy types in terms of tumor size ($p < 0.001$), initial procedure type ($p < 0.001$), operation time ($p < 0.001$), blood transfusion ($p = 0.033$), length of hospital stay ($p = 0.004$), intraoperative complications ($p = 0.020$), postoperative complications ($p = 0.025$), and Clavien classification ($p = 0.003$), as well as the rates of death ($p = 0.022$), metastatic progression ($p < 0.001$), and chemotherapy use ($p = 0.001$, Table 3). Differences in patient survival between the four types of nephrectomies were statistically significant (log rank p value < 0.001 , Figure 3).

Discussion

Open radical nephrectomy was once the standard of care for all renal tumors, but its indications are now decreasing in tandem with the increasing adoption of MIS nephrectomies, especially for stage 1 tumors (1a < 4 cm, 1b = 4–7 cm) (15, 16). Our results align with this trend, showing a significant difference in the mean tumor size between procedure types (12). Similarly, robotic nephrectomies (which were mostly partial) were mainly performed for stage T1 tumors, while most open and laparoscopic surgeries (which were

Table 2: Cancer-related and operative characteristics and outcomes of patients with cancer by the procedure type.

Parameter	Category	Overall, N = 408	Procedure type			p-value	Missing
			Open, N = 70	Laparoscopy, N = 241	Robotic, N = 97		
Tumor Size	cm	4.5 (3.0, 7.0)	7.0 (4.0, 12.4)	5.0 (3.5, 7.6)	3.0 (2.0, 4.0)	<0.001	43 (11%)
Stage T	TX	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	<0.001	60 (15%)
	T0	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)		
	T1	171 (49.1%)	17 (28.8%)	82 (39.8%)	72 (86.7%)		
	T2	20 (5.7%)	8 (13.6%)	12 (5.8%)	0 (0.0%)		
	T3	157 (45.1%)	34 (57.6%)	112 (54.4%)	11 (13.3%)		
Stage N	NX	305 (88.4%)	41 (67.2%)	182 (90.5%)	82 (98.8%)	<0.001	63 (15%)
	N0	25 (7.2%)	12 (19.7%)	13 (6.5%)	0 (0.0%)		
	N1	13 (3.8%)	7 (11.5%)	5 (2.5%)	1 (1.2%)		
	N2	1 (0.3%)	0 (0.0%)	1 (0.5%)	0 (0.0%)		
	N3	1 (0.3%)	1 (1.6%)	0 (0.0%)	0 (0.0%)		
Stage M	MX	342 (97.2%)	55 (87.3%)	204 (99.0%)	83 (100.0%)	<0.001	56 (14%)
	M0	2 (0.6%)	2 (3.2%)	0 (0.0%)	0 (0.0%)		
	M1	8 (2.3%)	6 (9.5%)	2 (1.0%)	0 (0.0%)		
Nephrectomy Type	Radical	231 (56.6%)	38 (54.3%)	187 (77.6%)	6 (6.2%)	<0.001	0 (0%)
	Partial	155 (38.0%)	27 (38.6%)	40 (16.6%)	88 (90.7%)		
	Simple/total	3 (0.7%)	2 (2.9%)	1 (0.4%)	0 (0.0%)		
	Nephroureterectomy	19 (4.7%)	3 (4.3%)	13 (5.4%)	3 (3.1%)		
Side	Right	199 (49.1%)	33 (47.8%)	115 (48.1%)	51 (52.6%)	0.360	3 (0.7%)
	Left	196 (48.4%)	33 (47.8%)	117 (49.0%)	46 (47.4%)		
	Both	10 (2.5%)	3 (4.3%)	7 (2.9%)	0 (0.0%)		
Converted to Open Surgery	No	343 (95.5%)	26 (100.0%)	225 (93.8%)	92 (98.9%)	0.078	49 (12%)
	Yes	16 (4.5%)	0 (0.0%)	15 (6.3%)	1 (1.1%)		
Reasons of Conversion*	Bleeding	6 (40.0%)	0 (NA%)	6 (42.9%)	0 (0.0%)	0.600	1 (6.3%)
	Difficult dissection	3 (20.0%)	0 (NA%)	3 (21.4%)	0 (0.0%)		
	Failure to progress	2 (13.3%)	0 (NA%)	2 (14.3%)	0 (0.0%)		
	Obesity	1 (6.7%)	0 (NA%)	1 (7.1%)	0 (0.0%)		
	Other	3 (20.0%)	0 (NA%)	2 (14.3%)	1 (100.0%)		
Operation Time (min)	Minutes	202.0 (161.0, 258.0)	228.0 (178.0, 295.0)	197.0 (160.0, 258.0)	197.0 (158.5, 247.8)	0.234	136 (33%)
Est. blood loss (mL)	mL	200.0 (150.0, 500.0)	500.0 (300.0, 1,000.0)	200.0 (100.0, 400.0)	200.0 (100.0, 245.0)	<0.001	128 (31%)

(continues)

Table 2: Continued.

Parameter	Category	Overall, N = 408	Procedure type			p-value	Missing
			Open, N = 70	Laparoscopy, N = 241	Robotic, N = 97		
Blood Transfusion	Yes	25 (6.3%)	12 (17.1%)	12 (5.1%)	1 (1.1%)	<0.001	9 (2.2%)
Hospital Stay (days)	Days	5.0 (3.0, 8.0)	8.0 (6.0, 13.0)	5.0 (3.0, 8.0)	4.0 (3.0, 5.0)	<0.001	4 (1.0%)
Intraoperative Complications	Yes	17 (4.2%)	8 (11.4%)	9 (3.7%)	0 (0.0%)	0.001	0 (0%)
Postoperative Complications	Yes	34 (8.3%)	11 (15.7%)	14 (5.8%)	9 (9.3%)	0.028	0 (0%)
Clavien Classification	No complications	307 (82.1%)	41 (68.3%)	196 (84.8%)	70 (84.3%)	0.016	34 (8.3%)
	1	15 (4.0%)	2 (3.3%)	8 (3.5%)	5 (6.0%)		
	2	10 (2.7%)	4 (6.7%)	5 (2.2%)	1 (1.2%)		
	3	14 (3.7%)	3 (5.0%)	6 (2.6%)	5 (6.0%)		
	4	12 (3.2%)	6 (10.0%)	6 (2.6%)	0 (0.0%)		
	None	16 (4.3%)	4 (6.7%)	10 (4.3%)	2 (2.4%)		
Local Recurrence	Yes	12 (3.1%)	7 (11.1%)	5 (2.1%)	0 (0.0%)	<0.001	20 (4.9%)
Metastatic Progression	Yes	44 (11.3%)	16 (24.2%)	21 (9.1%)	7 (7.6%)	0.001	20 (4.9%)
Chemotherapy	Yes	26 (6.7%)	12 (18.2%)	11 (4.7%)	3 (3.3%)	0.001	18 (4.4%)

*Descriptive data are based on 16 records of patients who had their surgeries converted to open procedures.

mostly radical) were mainly performed for stage T3 tumors. MIS significantly reduced perioperative morbidity in cancer patients, including estimated blood loss, duration of hospital stay, intraoperative complications, and postoperative complications (17). In addition, we observed significant differences in renal function across procedure types with robotic surgery featuring a higher mean eGFR and lower serum creatinine and BUN values at 1-year post-surgery, but this does not indicate that the robotic technique is in itself associated with better preservation of renal function because most robotic surgeries were partial nephrectomies (90.5%), which are known to better preserve renal function, while only 20.7% of open and 13.7% of laparoscopic surgeries were partial nephrectomies. However, overall survival of patients across the different procedure approaches was not statistically significant ($p = 0.054$), which agrees with previous research demonstrating the equivalence of MIS and open nephrectomy in terms of overall survival (18, 19). Recent

data show a significant survival advantage for patients who underwent MIS radical nephrectomy compared to open radical nephrectomy, but no significant difference is observed in locally advanced stage 3 disease (19, 20). The lack of a subgroup analysis distinguishing between the survival of early stage and late-stage cancer patients undergoing MIS and open nephrectomy in our cohort limits our ability to further clarify this discrepancy. Nevertheless, our results support the established data regarding the safety and effectiveness of MIS in renal cancer patients (19, 21, 22).

Most nephrectomies at our institute, radical or partial, were performed using MIS, with 81.0% of radical nephrectomies being laparoscopic and 56.8% of partial nephrectomies being robotic. This contrasts with the study by Asker et al. (14), where laparoscopic partial nephrectomies were more common than robotic (42.0% vs 31.9%, respectively), and the Alhaidari et al. study (12), where open radical nephrectomies were more common than robotic (60 vs 40%,

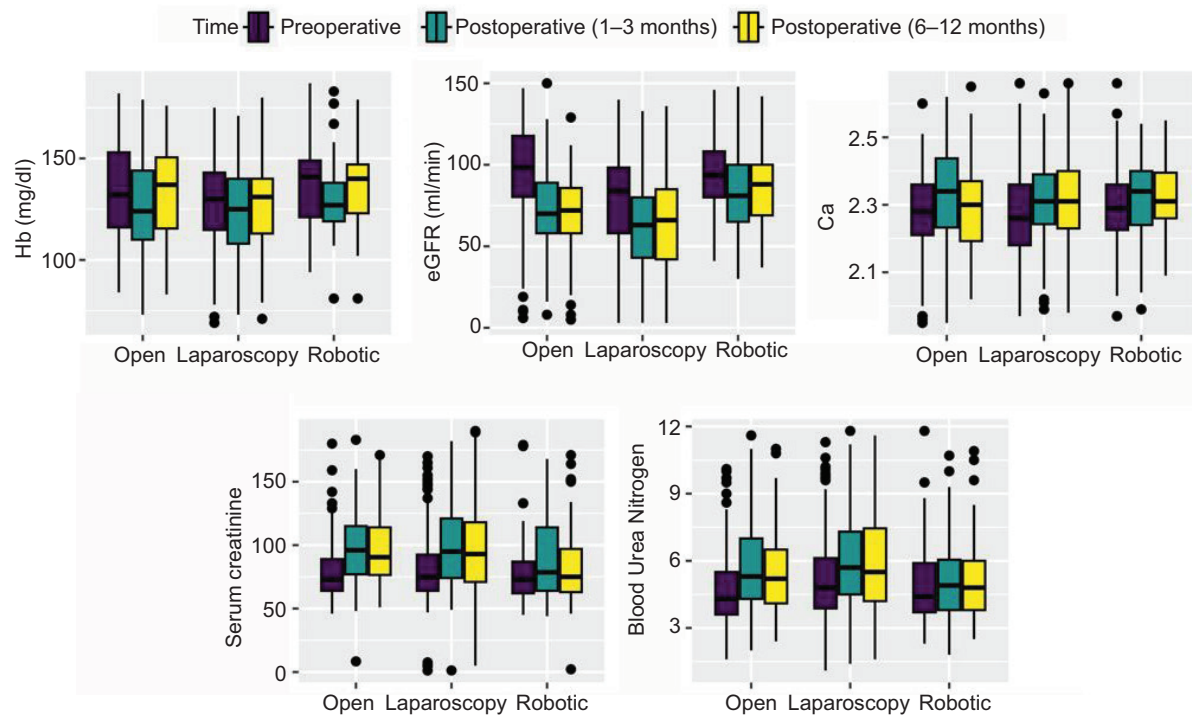


Figure 1: Box plots of the concentration of laboratory parameters across different time points and procedure types among patients with cancer (n = 408).

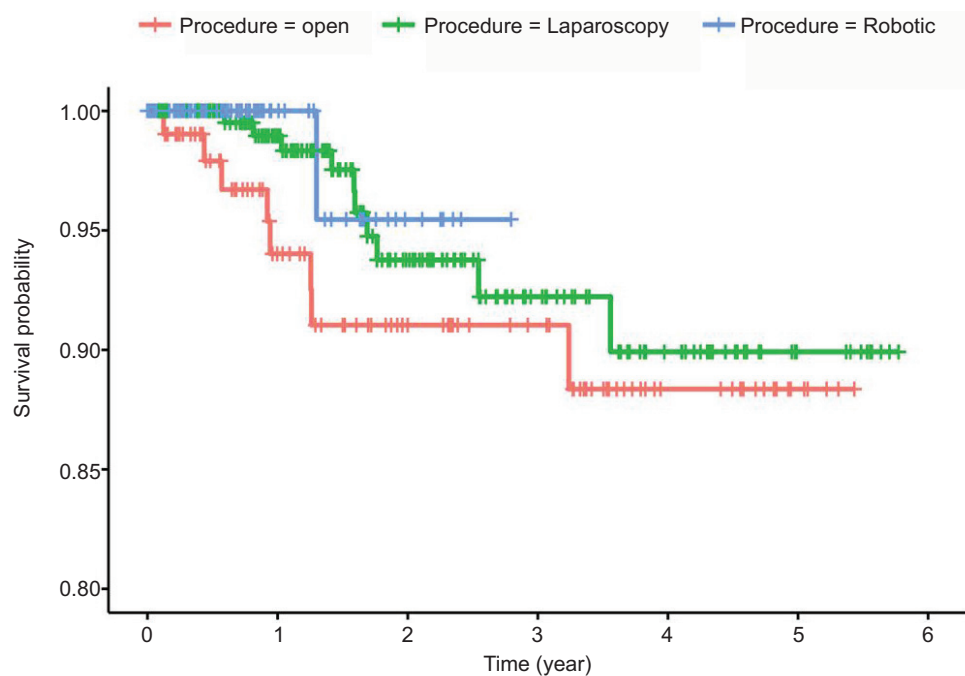


Figure 2: A Kaplan–Meier plot depicting survival curves across different procedure types among patients with cancer (n = 408).

Table 3: Cancer-related and operative characteristics and outcomes of patients with cancer by the type of nephrectomy.

Parameter	Category	Overall, N = 408	Nephrectomy type			p-value	Missing
			Radical, N = 231	Partial, N = 155	Simple/Total, N = 3	Nephroureterectomy, N = 19	
Tumor Size (cm)	cm	4.5 (3.0, 7.0)	6.1 (4.5, 9.0)	3.0 (2.0, 4.0)	12.0 (7.5, 13.0)	6.0 (4.0, 9.3)	43 (11%)
Stage T	TX	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	60 (15%)
	T0	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
	T1	171 (49.1%)	58 (28.0%)	111 (86.7%)	1 (33.3%)	1 (10.0%)	
	T2	20 (5.7%)	19 (9.2%)	0 (0.0%)	1 (33.3%)	0 (0.0%)	
	T3	157 (45.1%)	130 (62.8%)	17 (13.3%)	1 (33.3%)	9 (90.0%)	
Stage N	NX	305 (88.4%)	164 (82.0%)	124 (98.4%)	2 (66.7%)	15 (93.8%)	63 (15%)
	N0	25 (7.2%)	23 (11.5%)	2 (1.6%)	0 (0.0%)	0 (0.0%)	
	N1	13 (3.8%)	12 (6.0%)	0 (0.0%)	1 (33.3%)	0 (0.0%)	
	N2	1 (0.3%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (6.3%)	
	N3	1 (0.3%)	1 (0.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
	MX	342 (97.2%)	195 (95.6%)	126 (100.0%)	3 (100.0%)	18 (94.7%)	56 (14%)
Stage M	M0	2 (0.6%)	2 (1.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	
	M1	8 (2.3%)	7 (3.4%)	0 (0.0%)	0 (0.0%)	1 (5.3%)	
	Open	70 (17.2%)	38 (16.5%)	27 (17.4%)	2 (66.7%)	3 (15.8%)	0 (0%)
Started Procedure Type	Laparoscopy	241 (59.1%)	187 (81.0%)	40 (25.8%)	1 (33.3%)	13 (68.4%)	
	Robotic	97 (23.8%)	6 (2.6%)	88 (56.8%)	0 (0.0%)	3 (15.8%)	
Side	Right	199 (49.1%)	110 (48.0%)	79 (51.3%)	1 (33.3%)	9 (47.4%)	3 (0.7%)
	Left	196 (48.4%)	112 (48.9%)	73 (47.4%)	1 (33.3%)	10 (52.6%)	
	Both	10 (2.5%)	7 (3.1%)	2 (1.3%)	1 (33.3%)	0 (0.0%)	
Converted to Open Surgery	Yes	16 (4.5%)	7 (3.4%)	8 (5.8%)	0 (0.0%)	1 (5.9%)	49 (12%)
Operation Time (min)	Minute	202.0 (161.0, 258.0)	180.0 (138.5, 226.0)	221.5 (180.0, 279.0)	232.0 (220.0, 243.5)	300.0 (290.0, 352.0)	136 (33%)

(continues)

Table 3: Continued.

Parameter	Category	Overall, N = 408	Nephrectomy type				p-value	Missing
			Radical, N = 231	Partial, N = 155	Simple/Total, N = 3	Nephroureterectomy, N = 19		
Est. Blood Loss (mL)	mL	200.0 (150.0, 500.0)	200.0 (100.0, 500.0)	200.0 (150.0, 400.0)	300.0 (300.0, 650.0)	350.0 (220.0, 500.0)	0.114	128 (31%)
Blood Transfusion	Yes	25 (6.3%)	19 (8.5%)	5 (3.2%)	1 (33.3%)	0 (0.0%)	0.033	9 (2.2%)
Hospital Stay (days)	Days	5.0 (3.0, 8.0)	5.0 (3.0, 9.0)	4.0 (3.3, 7.0)	7.0 (5.0, 16.0)	11.0 (5.0, 16.5)	0.004	4 (1.0%)
Reasons of Conversion	Bleeding	6 (40.0%)	5 (71.4%)	1 (14.3%)	0 (NA%)	0 (0.0%)	0.069	393 (96%)
	Difficult dissection	3 (20.0%)	0 (0.0%)	2 (28.6%)	0 (NA%)	1 (100.0%)		
	Failure to progress	2 (13.3%)	0 (0.0%)	2 (28.6%)	0 (NA%)	0 (0.0%)		
	Obesity	1 (6.7%)	0 (0.0%)	1 (14.3%)	0 (NA%)	0 (0.0%)		
Intraoperative Complications	Other	3 (20.0%)	2 (28.6%)	1 (14.3%)	0 (NA%)	0 (0.0%)		
	Yes	17 (4.2%)	13 (5.6%)	2 (1.3%)	1 (33.3%)	1 (5.3%)	0.02	0 (0%)
Postoperative Complications	Yes	34 (8.3%)	21 (9.1%)	11 (7.1%)	2 (66.7%)	0 (0.0%)	0.025	0 (0%)
Clavien Classification	No complications	307 (82.1%)	168 (79.6%)	123 (87.2%)	0 (0.0%)	16 (84.2%)	0.003	34 (8.3%)
	1	15 (4.0%)	7 (3.3%)	6 (4.3%)	1 (33.3%)	1 (5.3%)		
	2	10 (2.7%)	6 (2.8%)	3 (2.1%)	0 (0.0%)	1 (5.3%)		
	3	14 (3.7%)	7 (3.3%)	6 (4.3%)	0 (0.0%)	1 (5.3%)		
	4	12 (3.2%)	9 (4.3%)	1 (0.7%)	2 (66.7%)	0 (0.0%)		
	None	16 (4.3%)	14 (6.6%)	2 (1.4%)	0 (0.0%)	0 (0.0%)		
Death	Yes	19 (4.7%)	11 (4.8%)	3 (1.9%)	1 (33.3%)	4 (21.1%)	0.002	0 (0%)
Local Recurrence	Yes	12 (3.1%)	9 (4.1%)	2 (1.4%)	1 (33.3%)	0 (0.0%)	0.06	20 (4.9%)
Metastatic Progression	Yes	44 (11.3%)	32 (14.5%)	4 (2.7%)	1 (33.3%)	7 (36.8%)	<0.001	20 (4.9%)
Chemotherapy	Yes	26 (6.7%)	18 (8.2%)	3 (2.0%)	1 (33.3%)	4 (21.1%)	0.001	18 (4.4%)

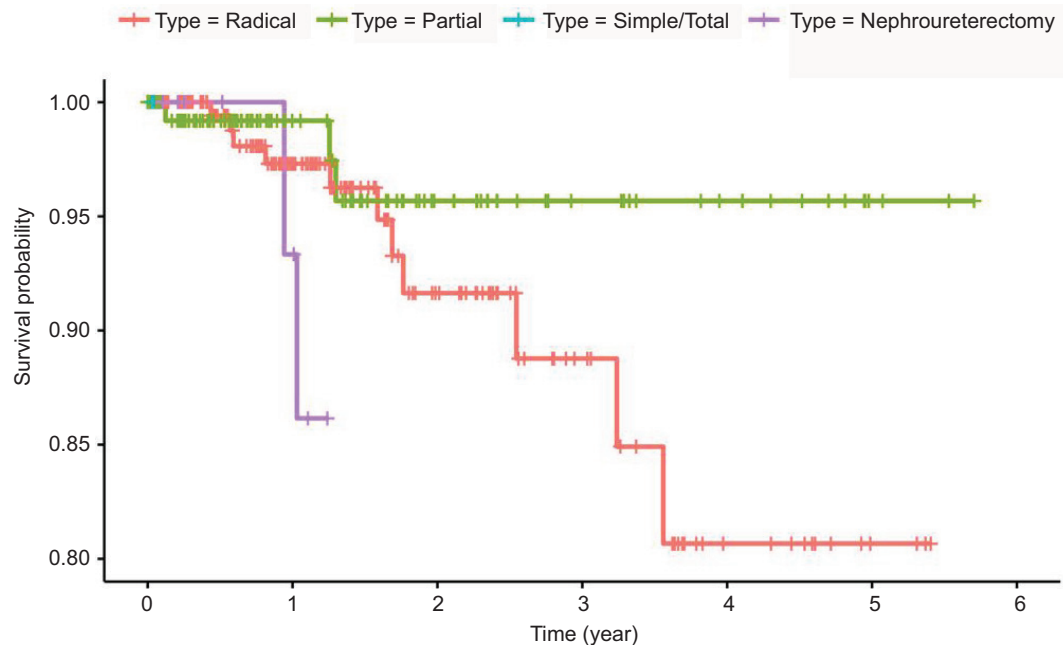


Figure 3: A Kaplan–Meier plot depicting survival curves across types of nephrectomies among patients with cancer (n = 147).

respectively); hence, our findings reflect an increasing trend toward MIS for both radical and partial nephrectomies at tertiary care centers in Saudi Arabia. Nevertheless, radical nephrectomy is usually performed for patients with more complex tumors, which likely explain their higher incidence of blood transfusions, perioperative complications, longer hospital stays, and worse oncological and survival outcomes (12, 23, 24). When solely considering early stage tumors (T1 and T2), studies did not suggest a markedly improved survival associated with partial nephrectomy (25, 26), although it is still preferred due to a significantly lower risk of developing CKD and cardiovascular events post-surgery (25–27).

A major limitation of the overall analysis is that patients undergoing open nephrectomies had likely more complex tumors compared to the minimally invasive group, which can explain their worse surgical and oncological outcomes. Therefore, our group recently performed a subgroup analysis of outcomes of locally advanced stage T3 renal cancer patients (from the cohort of the present study) who underwent radical nephrectomy (mainly performed openly/laparoscopically) or partial nephrectomy (mainly performed robotically) to evaluate the use of MIS in more complex cases (28). T3 RCC, or locally advanced RCC, is defined as tumor extension beyond the renal capsule into the venous or collecting systems or invasion into the peripheric or renal sinus fat (29). Stage T3 RCC was historically considered an absolute indication for radical nephrectomy (RN), and this remains the standard per current guidelines (30). However,

recent studies have challenged this notion and suggested a place for partial nephrectomy (PN) in the management of these lesions. An RCC stage of T3 and beyond imparts a significantly greater risk of preoperative CKD (31), making renal preservation an increasingly important consideration to improve long-term patient outcomes in terms of function and quality of life. Our results indicated that PN, predominantly performed robotically at our institute, achieves comparable oncological outcomes of local recurrence ($p=0.597$), metastatic progression ($p=0.129$), chemotherapy use ($p=0.367$), and survival outcomes (log-rank p -value = 0.852) based on the type of nephrectomy (28). Andrade et al. similarly demonstrated comparable 3-year cancer-specific survival and recurrence-free survival rates between robot-assisted PN and robot-assisted RN, but significantly better preservation of renal function in the latter (32). Other studies investigating the utility of PN in patients clinically upstaged to stage T3 have also demonstrated statistically insignificant differences in oncological outcomes between PN and RN, with the former offering superior renal preservation (33–35). A study by Yim et al. studying PN for stage T3 renal cancer reported that 64% of patients achieved a trifecta, of which 37.6% achieved an optimal outcome, defined as patients who additionally preserved > 90% of their eGFR and had no increase in their CKD stage (36). A multivariate analysis identified significant predictors of failure to achieve a trifecta or optimal outcome, including higher age, increased RENAL nephrometry score, and an intraoperative blood

loss > 300 mL (36). Our results show a significantly younger age in stage T3 patients who underwent PN, which may partly explain the comparable outcomes achieved in the radical group. Overall, therefore, MIS approaches may offer good oncological outcomes even in more complex cases while offering better preservation of renal function and improving operative parameters.

Limitations

The single-center nature and small sample size limit the generalizability of our findings. Retrospective studies also have inherent limitations such as missing data and inaccurate documentation, which may introduce information bias.

Conclusion

The present study is the most comprehensive study on nephrectomy outcomes in Saudi Arabia. Our findings are consistent with published data on the safety and efficacy of MIS nephrectomies in terms of reducing inpatient morbidity and hospital stay while conferring equivalent oncological and surgical outcomes. We also highlighted current gaps in our knowledge—particularly the use of partial nephrectomies in later stage renal cancer—for future research to address.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

All authors contributed to the research and/or preparation of the manuscript. MA, AS, and BNS participated in the study design and wrote the first draft of the manuscript. AA, YN, MA, AS, BNS, MAS, AHE, MB, MAO, BA, RA, KA, and SBO collected and processed the data. MA participated in the study design and performed the statistical analyses. MA, AS, and BNS reviewed and finalized the manuscript. All authors read and approved the final manuscript.

Ethics Approval

The study was approved by the Institutional Review Board of King Abdullah International Medical Research Center, Ministry of National Guard-Health Affairs, Riyadh, Kingdom of Saudi Arabia (approval number RC18/163/R). Patient confidentiality was ensured.

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