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Impact of robotic access and dedicated kidney surgery teams on nephron-sparing surgery for T1 renal masses: Evidence from a Spanish multicenter registry

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Abstract

Background

Partial nephrectomy is the gold standard for clinical stage T1 renal masses when technically feasible. However, real-world adoption may vary according to access to robotic platforms and organizational factors. Methods: Multicenter retrospective comparative study using the Spanish National Registry of Localized Renal Cancer during 2024 (30 hospitals). Adults with radiologic cT1 renal masses treated with scheduled surgery and malignant histology were included. Comparisons were robotic-assisted versus laparoscopy/open approaches, and centers with a dedicated kidney surgery team versus those without it. The primary endpoint was the rate of partial nephrectomy versus radical nephrectomy, analyzed overall T1 and stratified by cT1a/cT1b. Secondary endpoints (among partial nephrectomies) included ischemia use and ischemia time, and recorded reasons for not performing partial nephrectomy grouped as technical infeasibility versus other reasons. Results: Partial nephrectomy was performed more frequently in the robotic cohort than in the laparoscopy/open cohort for cT1 (88.4% vs 56.4%, $p < 0.001$), cT1a (90.2% vs 68.7%, $p < 0.001$), and cT1b (84.5% vs 32.5%, $p < 0.001$). Ischemia use was similar overall, while ischemia time was shorter in cT1a robotic cases (median 15 vs 18 min, $p = 0.031$). Dedicated-team centers did not show higher partial nephrectomy rates after substage stratification; however, technical infeasibility was less frequently recorded than in non-dedicated centers (45.9% vs 75.7%, $p < 0.001$). Conclusions: The Access to Robotic-assisted surgery was associated with substantially higher utilization of partial nephrectomy for cT1 renal masses—especially in cT1b tumors. Dedicated kidney surgery teams were not associated with higher partial nephrectomy rates after stratification but were associated with fewer cases recorded as technical infeasibility.

Introduction

Renal cell carcinoma (RCC) accounts for 5% of new solid tumor diagnoses in adult men and 3% in women, ranking 6th and 9th in incidence, respectively. In the USA, it is estimated that by 2025 there will be 52,410 new cases in men and 28,570 in women, with a 5-year survival rate that has increased from 50% in 1975 to 78% in 2020 (1).

The most common way RCC is diagnosed (37–61%) is incidentally. At the time of diagnosis, almost 90% are localized, and 10% of those initially localized will develop a distant disease. This significantly impacts survival: 5-year survival for localized RCC is 90–97%, whereas it drops to 28% for metastatic disease (2).

Nephron-sparing surgery (NSS), most commonly performed as partial nephrectomy, is a cornerstone in the management of clinical T1 renal masses and selected T2–T3a cases (3–4), aiming to achieve oncologic control while preserving renal function (5). NSS can be performed through open or minimally invasive approaches. Among minimally invasive techniques, robot-assisted partial nephrectomy (RAPN) has become a widely adopted option in centers where it is available, partly due to improved ergonomics, enhanced visualization, and increased instrument range of motion compared with conventional

laparoscopy (6). This may lower technical barriers—especially for more challenging tumors, such as larger lesions or anatomically unfavorable locations.

Despite these recommendations, the real-world adoption of NSS varies widely across health systems and institutions. This variability is likely multifactorial and may reflect differences in tumor complexity, patient selection, surgeon experience, and access to minimally invasive technology (7).

Beyond technology, organizational factors such as concentration of expertise (e.g., dedicated kidney surgery teams, high-volume centers, and multidisciplinary decision-making) have been proposed as strategies to standardize care and potentially improve outcomes after NSS (8). However, the extent to which dedicated teams translate into higher NSS rates at a national level—independent of robotic availability and case mix—remains uncertain.

Therefore, using the Spanish National Registry of Localized Renal Cancer, we aimed to evaluate the association of (1) robot-assisted surgery and (2) dedicated kidney surgery teams with the use of NSS in cT1 renal masses, overall and stratified by cT1a/cT1b. Secondary objectives were to describe ischemia-related metrics among partial nephrectomies and to explore recorded reasons for not performing partial nephrectomy when available.

Materials and Methods

Multicenter retrospective comparative study using the Spanish National Registry of Localized Renal Cancer. Thirty Spanish hospitals, equitably representing diverse geographical areas and healthcare settings, contributed including data from patients treated between January 2024 and December 2024. The ethics committee from the Principality of Asturias (CEImPA) approved the project with the following code AEU-PIEM/2024/003. We included adult patients with radiological clinical stage T1 (cT1) renal masses who underwent scheduled surgery. Eligible cases required malignant histology, including renal cell carcinoma (clear cell, papillary, chromophobe); other malignant histologies were included and classified as “other.” We excluded benign tumors (oncocytoma, angiomyolipoma, and other benign histologies), urgent/emergency surgery, and patients with nodal or metastatic disease (cN + and/or cM+); cases with pN + on final pathology were also excluded.

Comparisons were: Robotic-assisted approach versus non-robotic approaches (laparoscopic and/or open); and centers with a dedicated kidney surgery team versus those without. The two comparisons were conducted on partially overlapping cohorts: centers without robotic access contributed only to the dedicated-team analysis, resulting in a larger sample for that comparison (n = 1,121) than for the robotic versus laparoscopy/open analysis (n = 891). The primary endpoint was nephron-sparing surgery (partial nephrectomy) versus radical nephrectomy, analyzed overall and stratified by cT1a/cT1b. Secondary endpoints (among partial nephrectomies) included ischemia use and ischemia time, and—when available—recorded reasons for not performing partial nephrectomy were analyzed using a grouped variable and categorized as "technical infeasibility (unfavorable location)" versus "other reasons" (a composite category including all remaining recorded reasons). Ischemia use (yes/no) and recorded

ischemia time were extracted as separate registry variables. Recorded ischemia time may include 0-minute values (off-clamp procedures).

Missing data were reported for each variable, and percentages were calculated using available cases.

Categorical variables are presented as counts and percentages and were compared using Pearson's chi-square or Fisher's exact test when appropriate. Effect size was reported as odds ratios (OR) with 95% confidence intervals (95% CI). Continuous variables are presented as median (interquartile range). Analyses were performed in R (R Development Core Team), version 3.4.4, using two-sided tests with $p < 0.05$ considered statistically significant.

Results

Robotic versus laparoscopy/open approaches

A total of 891 surgically treated cT1 cases were analyzed (robotic: n = 301; laparoscopy/open: n = 590).

Baseline characteristics are summarized in Table 1. Patients in the robotic cohort were younger than those treated with laparoscopy/open surgery (mean age 61.34 vs 64.83 years; $p < 0.001$). Sex distribution and radiologic substage (cT1a/cT1b) were similar between approach groups, whereas prior abdominal surgery was more common in the robotic cohort (44.67% vs 34.10%; $p = 0.003$).

Table 1
Baseline characteristics of the study cohort by surgical approach and by dedicated kidney surgery team status

Age, mean (SD)		**Non Robot**	**Robotic**	**p-value**
		64,83 (11.24)	**61,34 (12.31)**	**< 0.001**
Sex (%)	Female	30.34	30.92	0.858
	Male	69.66	69.08	
cT(%)	T1a	66.05	67.76	0.606
	T1b	33.95	32.24	
Prior abdominal surgery (%)	No	65.9	55.33	0.003
	Yes	34.1	44.67	
		Non-Dedicated Team	**Dedicated Team**	**p-value**
Age, mean (SD)		64.74 (11.62)	64.70 (11.70)	0.952
Sex (%)	Female	31.37	31.36	0.997
	Male	68.63	68.64	
cT (%)	T1a	76.91	66.13	< 0.001
	T1b	23.09	33.87	
Prior abdominal surgery (%)	No	67.29	52.91	< 0.001
	Yes	32.71	47.09	

For cT1 tumors, partial nephrectomy was more frequent in the robotic group (266/301, 88.4%) than in the laparoscopy/open group (333/590, 56.4%, p < 0.001). This difference persisted by substage: in cT1a, partial nephrectomy was performed in 184/204 (90.2%) robotic cases versus 268/390 (68.7%) laparoscopy/open cases (p < 0.001), and in cT1b in 82/97 (84.5%) versus 65/200 (32.5%), respectively (p < 0.001).

Among partial nephrectomies, ischemia use (yes/no) did not differ between approaches overall (robotic 41/263, 15.6% vs laparoscopy/open 61/319, 19.1%; p = 0.265) or within cT1a (p = 0.964) and cT1b (p = 0.059). Ischemia time was lower in the robotic group for cT1a (median 15.0 vs 18.0 min; p = 0.031), whereas no significant differences were observed for cT1 overall (median 17.0 vs 19.0 min; p = 0.095) or cT1b (median 20.0 vs 23.5 min; p = 0.393).

Among cases with a recorded reason for not performing partial nephrectomy, "technical infeasibility (unfavorable location)" was reported in 166/294 (56.5%) robotic cases and 38/62 (61.3%) laparoscopy/open cases, with no significant difference between groups (p = 0.462). In subgroup

analyses, technical infeasibility rates similarly did not differ in cT1a (61/161 [37.9%] vs 15/32 [46.9%]; p = 0.168) or cT1b (105/133 [78.9%] vs 23/30 [76.7%]; p = 0.737). Tables 2–4

Table 2
Partial nephrectomy rates by surgical approach and radiologic substage (cT1).

Clinical substage	Partial nephrectomy – Robotic n/N (%)	Partial nephrectomy – Lap/Open n/N (%)	p-value
cT1	266/301 (88.4)	333/590 (56.4)	< 0.001
cT1a	184/204 (90.2)	268/390 (68.7)	< 0.001
cT1b	82/97 (84.5)	65/200 (32.5)	< 0.001

Table 3
Ischemia metrics among partial nephrectomies (robotic vs laparoscopy/open)

Stratum	Ischemia used n/N (%)	p-value	Median ischemia time, min (IQR)	p-value
cT1	Robot 41/263 (15.6%) vs Lap/Open 61/319 (19.1%)	0.265	Robot 17.0 (12.0–22.5) vs Lap/Open 19.0 (12.0–25.0)	0.095
cT1a	Robot 38/182 (20.9%) vs Lap/Open 53/256 (20.7%)	0.964	Robot 15.0 (9.0–21.0) vs Lap/Open 18.0 (11.0–24.0)	0.031
cT1b	Robot 3/81 (3.7%) vs Lap/Open 8/63 (12.7%)	0.059	Robot 20.0 (16.0–26.5) vs Lap/Open 23.5 (17.25–30.0)	0.393

Table 4
Reasons for not performing partial nephrectomy by surgical approach and radiologic substage.

Reason for not performing PN	cT1 Lap/Open (n = 62) %	cT1 Robotic (n = 294) %	cT1a Lap/Open (n = 32) %	cT1a Robotic (n = 161) %	cT1b Lap/Open (n = 30) %	cT1b Robotic (n = 133) %
Teaching case	4.8	0.3	6.3	0.0	3.3	0.8
Comorbidities	9.7	12.2	12.5	21.1	6.7	1.5
Intraoperative complication	11.3	4.8	12.5	7.5	10.0	1.5
Patient decision	1.6	7.1	3.1	11.2	0.0	2.3
Advanced age	1.6	3.1	3.1	3.7	0.0	2.3
Technical infeasibility (unfavorable location)	61.3	56.5	46.9	37.9	76.7	78.9
Other (specified)	9.7	16.0	15.6	18.6	3.3	12.8
Percentages are column percentages within each approach for the corresponding radiologic substage (available-case analysis)						

Dedicated kidney surgery team versus non-dedicated centers

A total of 1,121 surgically treated cT1 cases were included in the dedicated-team analysis (dedicated team: n = 558; non-dedicated: n = 563). In the dedicated-team comparison, age and sex distribution were similar between groups; however, radiologic substage distribution differed, with a higher proportion of cT1b tumors in dedicated-team centers (33.87% vs 23.09%; $p < 0.001$), and prior abdominal surgery was more common (47.09% vs 32.71%; $p < 0.001$) (Table 1).

Overall, partial nephrectomy was performed in 274/442 (62.0%) dedicated-team cases and 326/481 (67.8%) non-dedicated cases ($p = 0.076$). After stratification by radiologic substage, partial nephrectomy rates were similar: cT1a 189/253 (74.7%) vs 264/355 (74.4%) ($p = 0.94$) and cT1b 85/189 (45.0%) vs 62/126 (49.2%) ($p = 0.46$).

Among partial nephrectomies, ischemia use (yes/no) data were available in 260/274 (94.9%) dedicated-team cases and 323/326 (99.1%) non-dedicated cases. Ischemia was used in 52/260 (20.0%) and 50/323 (15.5%), respectively ($p = 0.153$). Median recorded ischemia time was 16 min (IQR 11–22) in dedicated-team centers and 20 min (IQR 13–25) in non-dedicated centers ($p = 0.012$). By substage, median recorded ischemia time (min) was higher in cT1b than cT1a in both groups (dedicated team: 15 [9–20] vs 20 [16–28]; non-dedicated: 18 [12–24] vs 24 [19–30]). Reasons for not performing partial nephrectomy were available for 220 dedicated-team and 136 non-dedicated cases (n = 356). “Technical

infeasibility (unfavorable location)" was reported less frequently in dedicated-team centers (101/220, 45.9%) than in non-dedicated centers (103/136, 75.7%) ($p < 0.001$). Tables 5–7

Table 5
Partial nephrectomy rates by dedicated kidney surgery team status and radiologic substage (cT1)

Radiologic substage	Partial nephrectomy – Dedicated team n/N (%)	Partial nephrectomy – Non-dedicated n/N (%)	p-value
cT1	274/442 (62.0)	326/481 (67.8)	0.076
cT1a	189/253 (74.7)	264/355 (74.4)	0.94
cT1b	85/189 (45.0)	62/126 (49.2)	0.46

Table 6
Ischemia metrics among partial nephrectomies (dedicated kidney surgery team vs non-dedicated).

Stratum	Ischemia used, n/N (%)	p-value	Ischemia time, median (IQR), min	p-value
cT1	Dedicated team 52/260 (20.0) vs non-dedicated 50/323 (15.5)	0.153	Dedicated team 16.0 (11.0–22.0) vs non-dedicated 20.0 (13.0–25.0)	0.012
cT1a	Dedicated team 48/178 (27.0) vs non-dedicated 43/261 (16.5)	0.008	Dedicated team 15.0 (9.0–20.0) vs non-dedicated 18.0 (12.0–24.0)	0.001
cT1b	Dedicated team 4/82 (4.9) vs non-dedicated 7/62 (11.3)	0.207	Dedicated team 20.0 (16.0–28.0) vs non-dedicated 24.0 (19.0–30.0)	0.435
Ischemia time is reported as recorded in the registry and may include 0-minute (off-clamp) values				

Table 7
Reasons for not performing partial nephrectomy (column %), by substage and dedicated kidney team status.

Reason	cT1 No dedicated (N = 136) %	cT1 Dedicated (N = 220) %	cT1a No dedicated (N = 73) %	cT1a Dedicated (N = 120) %	cT1b No dedicated (N = 63) %	cT1b Dedicated (N = 100) %
Teaching case	0.7	1.4	0.0	1.7	1.6	1.0
Comorbidities	5.1	15.9	9.6	25.8	0.0	4.0
Intraoperative complication	5.9	5.9	8.2	8.3	3.2	3.0
Patient decision	2.2	8.6	1.4	15.0	3.2	1.0
Advanced age	1.5	3.6	1.4	5.0	1.6	2.0
Technical infeasibility (unfavorable location)	75.7	45.9	67.1	22.5	85.7	74.0
Other (free text)	8.8	18.6	12.3	21.7	4.8	15.0
Percentages are column percentages within each approach for the corresponding radiologic substage (available-case analysis)						

Discussion

In this multicenter and real-world data registry analysis of surgically treated cT1 renal masses, a robotic-assisted approach was associated with a markedly higher utilization of partial nephrectomy compared with laparoscopy/open approaches. This pattern was consistent across radiologic substages and was particularly pronounced in cT1b tumors, where partial nephrectomy rates differed substantially between approaches. These findings are consistent with prior reports from national registries and contemporary literature describing higher partial nephrectomy utilization in settings with broader access to robotic surgery. (7–9)

Several factors may explain the higher utilization of partial nephrectomy observed in the robotic cohort. Robotic platforms provide enhanced visualization and greater instrument dexterity compared with conventional laparoscopy (10). These technical features can facilitate tumor excision and renal reconstruction in minimally invasive partial nephrectomy and may help expand nephron-sparing surgery to anatomically challenging cases (11). In population-based analyses, acquisition of robotic technology has been associated with increased use of partial nephrectomy (12). Consistent with this rationale, propensity score–matched comparative analyses have reported shorter warm ischemia time and improved renal functional preservation with RAPN compared with LPN (13).

Notably, patients in the robotic cohort had a higher rate of prior abdominal surgery compared with the laparoscopy/open group (44.67% vs 34.10%; p = 0.003), despite similar substage distribution. This finding suggests that robotic-assisted surgery may be adopted preferentially in more complex surgical scenarios beyond tumor anatomy alone — including previously operated patients, in whom adhesions and altered anatomy may increase technical difficulty. This complements the well-established advantages of robotic platforms in anatomically challenging renal tumors (10, 11) and further supports the notion that robotic access may expand nephron-sparing surgery to a broader and more complex patient population (12).

Notably, among cases with a recorded reason for not performing partial nephrectomy, the frequency of “technical infeasibility” did not differ between robotic and laparoscopy/open approaches. This suggests that the higher partial nephrectomy utilization observed with robotics is not explained by differences in this grouped “technical infeasibility” variable alone and may also reflect other factors such as surgeon experience, local practice patterns, or unmeasured tumor complexity. Prior studies have shown that partial nephrectomy outcomes are influenced by case complexity and surgeon/center experience and volume. (8, 14)

When focusing on ischemia-related metrics among partial nephrectomies, we observed largely similar patterns between approaches. Ischemia use (yes/no) did not differ significantly in the overall cT1 cohort or within cT1a, while a non-significant trend toward lower clamp use was observed in cT1b robotic cases. Ischemia time showed small absolute differences: the robotic approach was associated with a significantly shorter median ischemia time in cT1a (15 vs 18 minutes), whereas differences in cT1 overall and cT1b were not statistically significant. From a clinical standpoint, these differences are modest in magnitude and should be interpreted cautiously, particularly in the absence of long-term functional endpoints in the current dataset (15).

In contrast to the strong association observed for robotic-assisted surgery, the presence of a dedicated kidney surgery team was not associated with higher partial nephrectomy utilization after stratification by cT1a/cT1b. This suggests that organizational structure alone may be insufficient to increase nephron-sparing utilization at a national level, or that its impact may be mediated by factors not captured in the current dataset. Although ischemia time was significantly shorter in dedicated-team centers overall (p = 0.012) and in cT1a (p = 0.001), the absolute differences were small (3–4 minutes). Recent evidence reaffirms that warm ischemia times below 25–30 minutes are unlikely to cause significant renal damage (16), suggesting that these statistically significant differences may have limited clinical relevance

It is also worth noting that dedicated-team centers treated a higher proportion of cT1b tumors (33.87% vs 23.09%; p < 0.001) and patients with prior abdominal surgery (47.09% vs 32.71%; p < 0.001) compared with non-dedicated centers. This suggests a more complex case mix in dedicated-team settings, possibly reflecting referral patterns toward specialized units. In this context, the similar partial nephrectomy rates observed after substage stratification may actually represent a favorable result, as

dedicated teams appear to achieve equivalent nephron-sparing utilization despite treating a more surgically challenging population.

Interestingly, “technical infeasibility” was less frequently recorded in dedicated-team centers, which may reflect differences in registry reporting practices or institutional thresholds for attempting partial nephrectomy. One potential explanation is referral and case-mix: dedicated-team centers may receive a higher proportion of complex tumors referred from other institutions, which could reduce the observed proportion of partial nephrectomy. However, tumor complexity metrics were not available in the registry export, and this hypothesis cannot be directly tested in the present analysis.

Beyond organizational labels such as “dedicated team,” surgical volume and centralization may be key determinants of nephron-sparing utilization and quality. Guideline statements and systematic evidence support a volume–outcome relationship for partial nephrectomy, suggesting that complex nephron-sparing procedures may benefit from concentration in experienced, high-volume settings (3, 4, 8). Observational and systematic evidence further indicates that both hospital volume and surgeon volume are associated with perioperative outcomes following nephrectomy and partial nephrectomy, reinforcing the relevance of experience when interpreting real-world practice patterns (17, 18, 19). Future analyses incorporating hospital and surgeon volume metrics will be important to disentangle the relative contributions of technology, organization, and experience to nephron-sparing adoption.

This study has limitations inherent to retrospective registry analyses. Residual confounding is likely, particularly given the absence of tumor anatomy/complexity metrics (e.g., nephrometry scores), baseline renal function, and surgeon-level variables that influence selection of nephron-sparing surgery. Reasons for not performing partial nephrectomy were available only for a subset of cases and were analyzed as a grouped variable, which may not capture the full clinical heterogeneity underlying surgical decision-making. Missing data—particularly in surgery-type variables within the dedicated-team comparison—may also influence estimates despite transparent reporting and available-case analyses. Inter-surgeon and inter-center variability in partial nephrectomy outcomes has also been demonstrated in large cohorts, underscoring the potential contribution of experience and unmeasured factors (19, 20, 21).

Nonetheless, the multicenter design and inclusion of real-world practice across multiple hospitals provide a contemporary overview of nephron-sparing utilization in cT1 disease, complementing prior national registry reporting and offering additional insight into the association of robotic access and dedicated teams with surgical selection (22). Overall, robotic-assisted surgery was associated with substantially higher partial nephrectomy utilization—especially in cT1b tumors—while dedicated kidney surgery teams were not associated with higher partial nephrectomy rates after stratification by substage.

Conclusion

In this national multicenter registry analysis of surgically treated cT1 renal masses, a robotic-assisted approach was associated with substantially higher utilization of partial nephrectomy, particularly for

cT1b tumors, compared with laparoscopy/open approaches. Ischemia metrics were similar between approaches, with only small absolute differences in ischemia time. The presence of a dedicated kidney surgery team was not associated with higher partial nephrectomy rates after stratification by substage; however, “technical infeasibility” was less frequently recorded in dedicated-team centers. Future analyses incorporating tumor complexity and center/surgeon volume are warranted to better clarify drivers of nephron-sparing adoption.

Tables

Declarations

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Data availability: The data that support the findings of this study are available from the Spanish National Registry of Localized Renal Cancer, but restrictions apply to the availability of these data, which were used under license for the current study and are not publicly available.

Author Contribution

All authors contributed to the study conception and design. Data extraction was performed by the responsable investigator of each centre (I.T.S, D.P-F, I.B.F, M.DA.A, D.R.B, M.S.L, E.J.A, J.C.N, P.I.OU, C.F.H, F.C.P, A.L.S, M.S.DP, R.B.M, V.H.P). Statistical analysis was performed by Statistical department from University of Oviedo. The first draft of the manuscript was written by I.T.S and S.P-F, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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