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Modified Internal Traction Technique for Improved Exposure in Retroperitoneal Robot-Assisted Partial Nephrectomy for Dorsal Hilar Tumors: A Preliminary Single-Center Experience

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Abstract

Introduction: Retroperitoneal robot-assisted partial nephrectomy (rRAPN) provides direct access to dorsal renal hilar tumors, yet exposure remains limited by their proximity to renal vessels and the collecting system. This study aimed to evaluate the feasibility and efficacy of an internal traction technique (ITT) as technical refinement via the retroperitoneal approach in RAPN for dorsal hilar tumors.

Materials and Methods: This retrospective comparative cohort included 126 patients with dorsal hilar tumors who underwent rRAPN between November 2019 and December 2025. Suture-mediated renal traction was used in the ITT group (n = 63), which was compared with a conventional technique group (n = 63). Outcomes included warm ischemia time (WIT), estimated blood loss (EBL), operative time, postoperative recovery, and renal function.

Results: No patient required conversion to radical nephrectomy or open surgery. ITT was associated with shorter median WIT (17.00 [IQR, 16.00–18.50] vs. 21.00 [IQR, 18.00–24.00] min; P = 0.002) and lower mean EBL (116.48 ± 48.06 vs. 140.16 ± 42.87 mL; P = 0.004). Postoperative hospital stay and renal function were comparable between groups. All surgical margins were negative. Three minor intraoperative complications occurred and were controlled during surgery. One Clavien–Dindo grade II infection occurred in the conventional group. No recurrence or metastasis was documented within six months postoperatively.

Conclusion: The internal traction technique applied in rRAPN presents a practical and valuable surgical solution for dorsal hilar renal tumors. ITT enhances surgical exposure and reduces warm ischemia time without compromising perioperative safety.

Introduction

As a significant clinical entity, renal cell carcinoma (RCC) comprises 2–3% of adult cancers and carries the poorest prognosis among urological malignancies[1]. Partial nephrectomy (PN) represents the established standard for the surgical management of localized renal masses[2, 3]. Having become the favored minimally invasive technique over conventional laparoscopic partial nephrectomy (LPN), robot-assisted partial nephrectomy (RAPN) is frequently performed via the transperitoneal access[4, 5]. Retroperitoneal laparoscopic partial nephrectomy demonstrates a favorable safety and efficacy profile for intermediate-complexity renal hilar tumors[6].

However, in retroperitoneal robot-assisted partial nephrectomy (rRAPN), inadequate exposure of renal hilar tumors increases surgical difficulty, which may consequently lead to prolonged warm ischemic time (WIT) and elevated estimated blood loss (EBL)[7]. High tumor complexity may necessitate a more extensive procedure than originally planned, converting a robot-assisted partial nephrectomy to a radical nephrectomy[8, 9]. While several retraction aids exist, such as the use of a fourth robotic arm or the “polar flip” technique, a simple, reproducible, and tissue-preserving method for dedicated dorsal hilar retraction remains underexplored[10, 11]. To address the challenge of inadequate tumor exposure via the

retroperitoneal approach, we therefore describe and evaluate a newly developed internal traction technique (ITT) as technical refinement designed to mitigate these risks. This study details the development of the ITT and investigates its clinical applicability and performance through a retrospective comparative cohort analysis.

Materials and Methods

Patients

A total of 126 *consecutive* patients with dorsally located renal hilar tumors (≤7 cm), as identified by computed tomography (CT) or magnetic resonance imaging (MRI), underwent rRAPN from November 2019 to December 2025. Preoperative imaging and surgical evaluation confirmed that all tumors were localized, with a clear plane separating them from the lymph nodes and renal vessels. In this study, “hilar tumors” were objectively defined on preoperative cross-sectional imaging as those with the tumor edge lying within 5 mm of the main renal artery or vein. All patients were negative for metastases on preoperative evaluations, which included CT, radionuclide bone scintigraphy, and other specialized scans as indicated. A comprehensive assessment of tumor complexity was conducted through a multimodal approach, incorporating the R.E.N.A.L. nephrometry score alongside detailed anatomical data from CT, MRI, and 3D reconstructions[12]. All 126 procedures were successfully completed via the retroperitoneal approach, with 63 cases utilizing the ITT (ITT group), while the remaining 63 cases were performed using conventional RAPN (traditional technique group). Blood samples were collected from all patients preoperatively and postoperatively and were subsequently analyzed. To ensure procedural consistency, the entire surgical cohort (n=126) was carried out by the same urologic surgeons. This retrospective study collected data on: patient demographics; tumor characteristics (size and R.E.N.A.L. nephrometry score); preoperative laboratory values; key perioperative outcomes (WIT and EBL); surgical complications; pathological diagnoses; and postoperative recovery parameters (hospital stay and drainage status). All patients underwent protocol-guided monitoring for at least 6 months postoperatively[13, 14].

Volumetric and functional analyses

All participating patients underwent contrast-enhanced CT or MRI within 3 - 5 days before surgery and again at 3 months postoperatively. Tumor and excisional volumes (excluding adipose tissue) were calculated using the same ellipsoid formula. Excisional parenchymal volume (EPV) was defined as excisional volume minus tumor volume. Preoperative and postoperative ipsilateral parenchymal volume (IPV) was assessed by freehand scripting to delineate the region of interest (excluding renal sinus fat, collecting system, vessels, cysts, and tumors) at 3 mm intervals on axial venous-phase images; volumetric analyses were performed using AnyPACS2.0 software (Picture Archiving and Communication Systems; Medcare Digital Engineering Limited)[15]. Serum creatinine (Scr)) was measured pre- and postoperatively at a single reference laboratory. Global estimated glomerular filtration rate (eGFR) was calculated using the modification-diet-renal-disease-2 equation.

Criteria for Technique Selection and Cohort Definition

This study is a retrospective analysis of patients who underwent partial nephrectomy via one of two techniques. The allocation to either the ITT or traditional technique group was not randomized but was determined *intraoperatively by the attending surgeon based on specific anatomic and technical considerations. The ITT technique was selectively employed when, following initial mobilization, the tumor was deemed to be in a position that would render conventional manipulation excessively difficult, and only if sufficient perinephric fat was present to permit secure and safe suture retraction. Patients for whom the conventional approach was utilized typically had less perinephric fat or a tumor location that was readily accessible after standard mobilization.* .For this comparative analysis, patients were retrospectively categorized according to the surgical technique performed, and outcomes were compared in the context of the documented anatomical and technical considerations that informed intraoperative technique selection.

Surgical technique

All patients underwent robot-assisted partial nephrectomy via a standardized retroperitoneal approach, *using the da Vinci Si surgical apparatus*. *Neither the ITT group nor the conventional technique group utilized a fourth robotic arm or additional ports, both procedures were performed using a standard three-arm robotic configuration.* Following anesthetic induction, patients were carefully positioned in a complete lateral decubitus position with the surgical side elevated. The operating table was then fully flexed to maximize the space between the 12th rib and the iliac crest, thereby facilitating trocar placement and instrument maneuverability. The primary trocar was inserted under direct visual control on the linea axillaris media, at a point equidistant from the arcus costalis and the crista iliaca. The retroperitoneal surgical field was meticulously developed through manual dissection to form the initial operative cavity. This was followed by insertion of a handmade balloon dilation device, which was inflated with 800–1000 mL of air to systematically expand the retroperitoneal compartment and create sufficient operative space. Following this, a 12-mm port was established as the primary camera access, and under endoscopic vision, two additional 8-mm robotic trocars were placed along the anterior and posterior axillary lines, each positioned approximately 7–8 cm from the camera port to allow optimal triangulation and instrument mobility. *The placement of ports were schematically illustrated in* Fig. 1. After docking the da Vinci surgical system, we utilized the psoas major muscle as the key anatomical structure, standardizing its appearance to a horizontal position in the console view. Gerota's fascia was entered longitudinally, a step preceded by the careful removal of the overlying extraperitoneal fat. Precise dissection was undertaken to skeletonize the renal artery and vein, which allowed rapid control during the anticipated period of ischemia. Subsequently, the perinephric fat was circumferentially stripped from the renal surface using sharp and blunt dissection. While most of the dorsal perirenal fat was removed to minimize interference and improve visualization, the fat tissue at the lateral renal edge was intentionally preserved to serve as an anchoring point for the subsequent traction sutures. The extent of fat preservation was adjusted intraoperatively based on the degree of adhesions between the renal capsule and the surrounding tissue. An intraoperative ultrasound probe was employed when necessary to

accurately identify tumor borders, depth of invasion, and relationship to adjacent vessels or collecting systems.

To address the limited exposure (Fig. 3A) typically associated with dorsal hilar tumors (Fig. 2), an internal traction technique was systematically implemented. A 2-0 unidirectional barbed suture was introduced through the assistant port and passed through the preserved lateral perirenal fat tissue. This suture was then retracted laterally toward the area of the abdominal wall corresponding to the peritoneal reflection (Fig. 3B), which effectively elevated the kidney and significantly improved exposure of the dorsal hilar region (Fig. 3C).

The traction suture was secured externally with a Hem-o-lok clip to provide steady traction. Following application of traction, the renal artery was occluded using laparoscopic bulldog clamps, and warm ischemia time was recorded. Using endoscopic scissors, an oncological plane was developed 0.1–0.5 cm beyond the palpable tumor edge to ensure an adequate safety margin. The traction was continuously adjusted during excision to maintain optimal visibility and surgical access.

Renorrhaphy was performed in two layers: the deep layer involved meticulous closure of detected collecting system defects and visibly bleeding vessels using a continuous 2-0 unidirectional barbed suture. The suture was anchored at one end with a Hem-o-lok clip and run continuously to achieve a watertight closure. A second, more superficial continuous suture layer was applied using the same barbed suture to approximate the renal parenchyma and achieve final hemostasis (Fig. 3D). *After the second suture layer was finished, the bulldog clamps were released and removed, thus completing the renal artery unclamping.* The resected specimen was introduced into an endoscopic retrieval bag and withdrawn by way of the assistant port. A closed suction drain was positioned in the retroperitoneal space under visual guidance, and all port sites were closed in a standard layered fashion to complete the procedure.

Statistical analysis

The normality of all continuous variables was assessed for each study group using the Shapiro-Wilk test. If the data for a variable passed the normality test in both groups, it was reported as mean ± standard deviation (SD) and analyzed by the Welch's two-sample t-test. If the data for a variable violated the normality assumption in either group, it was reported as median (interquartile range, IQR) and analyzed using the non-parametric Mann-Whitney U test. Associations between categorical variables were examined with the Chi-square or Fisher's exact test, where appropriate. All analyses were two-tailed and performed using SPSS (Version 26.0), with a p-value of less than 0.05 considered statistically significant.

Results

A total of 126 patients were enrolled and underwent rRAPN during the period from November 2019 to December 2025. There was no intraoperative conversion to open surgery. The ITT was employed in 63 patients (**ITT group**), while it was not utilized in the remaining 63 patients (**conventional technique**

group). The characteristics of the study cohort and perioperative outcomes are summarized in **Table 1**. The two groups showed no significant differences in terms of mean age, sex, BMI, tumor size, operative time, or R.E.N.A.L. sco**re.** Compared with the conventional technique group, the ITT group had a shorter median WIT (17.00 [IQR, 16.00–18.50] vs. 21.00 [18.00–24.00] min; P = 0.002), lower mean EBL (116.48 ± 48.06 vs. 140.16 ± 42.87 mL; P = 0.004), and lower EPV (28.00 [25.00–35.00] vs. 33.00 [30.00–37.00] cm^3; P = 0.003). The median IPV preservation rate was also higher in the ITT group (80.45% [75.38%–83.22%] vs. 78.05% [74.26%–81.33%]; P = 0.048).

Table 1 Demographics and perioperative outcomes of patients

Variable	ITT group (n=63)	conventional technique group (n=63)	p-value
Age (years)	68.00 (51.00-76.50)	75.00 (51.00-80.00)	0.327
BMI (kg/m^2)	23.19 (21.27-24.82)	23.16 (21.45-24.85)	0.996
Female (n, %)	34 (53.97)	28 (44.44)	0.373
R.E.N.A.L. score (points)	8.00 (7.00-8.00)	8.00 (7.00-8.00)	0.968
Complexity category, n (%)			
Low (4 - 6)	13 (20.63)	10 (15.87)	0.645
Intermediate (7 - 9)	50 (79.37)	53 (84.13)	0.645
High (10 - 12)	0 (0.00)	0 (0.00)	1.000
Tumor size (cm)	3.38 (2.88-3.73)	3.51 (3.01-3.71)	0.210
WIT (**min**)	17.00 (16.00-18.50)	21.00 (18.00-24.00)	0.002
EBL (mL)	116.48 ± 48.06	140.16 ± 42.87	0.004
Operation time (min)	156.29 ± 26.60	155.56 ± 28.13	0.881
Post-operative hospital stays (days)	4.00 (3.00-4.00)	4.00 (3.00-4.50)	0.511
Pre-operative Scr (μmol/L)	74.95 ± 11.50	73.59 ± 10.97	0.497
Post-operative Scr (μmol/L)	81.22 ± 11.53	80.11 ± 11.07	0.582
Pre-operative eGFR (mL/min/1.73 m²)	87.50 ± 5.00	87.51 ± 5.48	0.991
Post-operative eGFR (mL/min/1.73 m²)	83.49 ± 4.96	82.66 ± 5.35	0.363
EPV (cm^3)	28.00 (25.00-35.00)	33.00 (30.00-37.00)	0.003
Pre-operative IPV (cm^3)	147.00 (130.50-159.00)	154.00 (126.00-173.00)	0.111
Post-operative IPV (cm^3)	116.00 (101.50-126.50)	119.00 (95.00-139.00)	0.388
IPV Preserved Rate (%)	80.45 (75.38-83.22)	78.05 (74.26-81.33)	0.048
Drainage volume (mL)	314.35 ± 133.62	329.70 ± 121.07	0.501
Drainage tube indwelling time (days)	4.00 (3.00-5.00)	4.00 (3.00-5.00)	0.365
Overall complication	2(3.17)	5(7.94)	0.440

BMI: body mass index, WIT: **warm ischemia time,** EBL: **estimated blood loss, Scr: serum creatinine,** eGFR: estimated glomerular filtration rate, EPV: excisional parenchymal volume, IPV: ipsilateral parenchymal volume Values are mean ± SD or median (IQR). Tests were Welch's t, Mann–Whitney U, or Fisher's exact test, selected as appropriate after Shapiro–Wilk assessment.

Parameters of post-operative recovery, including hospital stay, drainage, Scr levels, and eGFR levels, were comparable between groups (all p > 0.05). *Specifically, for our primary outcomes of WIT and EBL,* WIT was non-normally distributed and was therefore reported as the median (IQR) and compared using the Mann–Whitney U test. In contrast, EBL was approximately normally distributed and was reported as the mean ± standard deviation and compared using Welch's two-sample t-test.*To quantify the magnitude of these statistically significant differences, we calculated the corresponding non-parametric effect size,* Effect-size analyses yielded a rank-biserial correlation of r = −0.32 for WIT and Cohen's d = −0.52 for EBL (**Table 2**). Both estimates indicated moderate effects according to conventional benchmarks, with the negative values reflecting lower WIT and EBL in the ITT group.

Table 2 Effect sizes for primary perioperative outcomes

Outcome	Test statistic	Effect size
WIT (min)	U = 1352.00	Rank-biserial r = -0.32
EBL (mL)	t = -2.92	Cohen's d = -0.52

Negative effect sizes indicate lower values in the ITT group. WIT was analysed using the Mann-Whitney U test; EBL was analysed using Welch's t-test.

Perioperative complications were uncommon in both treatment groups (**Table 3**). EAUiaiC-classified intraoperative complications occurred in 3 of 126 patients (2.38%), including 1 of 63 patients (1.59%) in the ITT group and 2 of 63 patients (3.17%) in the conventional technique group. All three events involved minor small-vessel bleeding and were controlled intraoperatively by electrocoagulation, clip application, or simple suturing. The incidence did not differ significantly between the groups (P = 0.559). Postoperatively, one patient in the conventional technique group developed an infection on postoperative day 2. The infection resolved after 5 days of intravenous antimicrobial therapy and was classified as a Clavien–Dindo grade II complication (1/63, 1.59%). No corresponding postoperative complication occurred in the ITT group (P = 0.315).The postoperative course was devoid of major complications such as ileus, significant bleeding, symptomatic perirenal collections, or urinary leakage. On pathological examination, clear cell renal cell carcinoma was present in 85.7% (n=54) of the ITT group compared to 87.3% (n=55) of the conventional technique group (**Table 4**). No positive surgical margins were identified on post-operative pathological examination in any of the patients. Subsequent management for all patients was conducted in accordance with contemporary guideline recommendations. Throughout the follow-up period (minimum 6 months), no cases of local recurrence were detected in the entire cohort.

Table 3 Achievement of tetrafecta Outcomes

	Overall Cohort (n=126)	ITT group (n=63)	Conventional technique group (n=63)	P-value
Tetrafecta Achievement rate, n (%)	119 (94.44)	61 (96.83)	58 (92.06)	0.243
Component Details				
Intraoperative EAUiaiC complications, n (%)	3 (2.38)	1 (1.59)	2 (3.17)	0.559
Postoperative Clavien-Dindo Grade ≥II complications, n (%)	1 (0.79)	0 (0.00)	1 (1.59)	0.315
Positive Surgical Margins, n (%)	0 (0.00)	0 (0.00)	0 (0.00)	-
eGFR decline ≥30% at 90-day postoperative, n (%)	3 (2.38)	1 (1.59)	2 (3.17)	0.559

Values are presented as n (%). P values were calculated using Pearson's chi-square test without continuity correction. The P value for positive surgical margins was not estimable because no events occurred in either group. Owing to the low expected cell counts for several rare outcomes, the corresponding chi-square results should be interpreted with caution. EAUiaiC, European Association of Urology Intraoperative Adverse Incident Classification; eGFR, estimated glomerular filtration rate.

Table 4 Pathological characteristics

	ITT group, n (%) (n=63)	conventional technique group, n (%) (n=63)
Clear cell RCC	54 (85.7)	55 (87.3)
Papillary RCC	4 (6.3)	4 (6.3)
Chromophobe RCC	4 (6.3)	3 (4.8)
Renal angiomyolipoma	1 (1.6)	1 (1.6)

RCC: renal cell carcinoma

No positive surgical margins were observed in either group. One postoperative Clavien–Dindo grade II complication occurred in the conventional technique group, whereas none occurred in the ITT group. The ITT group also showed numerically lower rates of intraoperative EAUiaiC complications and a ≥30% decline in eGFR at 90 days, although neither difference was statistically significant. Overall tetrafecta achievement was numerically higher in the ITT group than in the conventional technique group (96.83% vs. 92.06%; P = 0.243). Given the low event counts and modest sample size, these findings should be interpreted cautiously and do not establish superiority. Larger prospective studies are required to determine whether ITT improves tetrafecta achievement or its individual components.

Discussion

PN is the established standard for localized renal tumors [2, 3], with LPN approaches demonstrating well-documented safety and efficacy[16]. The global adoption of RAPN has grown in parallel with advances in robotic technology. Compared with open partial nephrectomy (OPN), RAPN offers shorter hospital stay, lower overall and major complication rates, and reduced transfusions, while showing comparable EBL, minor complications, recovery time, WIT, and short-term renal function decline[17]. RAPN and LPN yield comparable procedural outcomes, but RAPN significantly reduces EBL, positioning it as the preferable approach[18]. In RAPN, 3D reconstruction reduces EBL, operative time, and hospital stay—benefits that are amplified in complex tumors, where it also lowers intraoperative complications, transfusions, and Clavien–Dindo morbidity, with greater reductions in estimated blood loss and hospitalization[19]. The retroperitoneal approach significantly reduces EBL, transfusion requirements, and length of stay compared to the transperitoneal route[20, 21]. However, inadequate exposure of dorsal hilar tumors impedes resection, prolongs operative time and WIT, and thus limits the utility and effectiveness of rRAPN.

Undoubtedly, the difficulty in achieving adequate exposure poses a central challenge that must be addressed in partial nephrectomy for dorsally located hilar renal masses. Feliciano et al. reported their initial experience with rRAPN with a novel 4-arm approach and preliminarily validated that the fourth arm could offer superior tissue retraction in pivotal maneuvers, which could lead to improved tumor exposure[22]. Johnson et al. maintained that three robotic arms could provide sufficient capability for safe RAPN performance, while concluding that a fourth arm was not routinely mandated[10]. Furthermore, Zhang et al. found that the adoption of the four-arm over the three-arm RAPN strategy posed an increased economic burden, totaling 8,515.8 RMB (approximately 280–413 USD, a range reported internationally), identified as a direct consequence of the supplementary robotic instrumentation[23]. Chiruvella et al. introduced a new “polar flip” technique applied to transperitoneal laparoscopic partial nephrectomy (TPLPN), they rotated the kidney approximately 45°-60° after dissecting the ureter away from the lower pole, resulting in complete exposure of the entire posterior surface for dissection[11]. However, Takagi et al. found that the retroperitoneal approach for RAPN yielded better surgical results than the transperitoneal approach in the treatment of posterior renal tumors, supporting its role as the preferred technique for carefully selected patients[24]. Therefore, to further improve the exposure of dorsal hilar tumors during rRAPN, we created a technical refinement named the ITT, specifically designed for this purpose.

In our study, to address the characteristically limited exposure of dorsal hilar tumors, we systematically employed an internal traction technique: a 2 − 0 unidirectional barbed suture was introduced through the assistant port and deliberately passed through a secure anchorage point within the preserved lateral perirenal fat, often targeting its denser fibrous septa. Under continuous visual monitoring, the suture was then retracted laterally toward the abdominal wall at the level of the peritoneal reflection. The external end of the suture was secured using a sequential two-Hem-o-lok clip system for precise tension control: the first clip was applied near the skin exit under the desired moderate tension to establish primary

fixation, followed by a second clip placed approximately 1.5–2.0 cm outward on the slack segment, thereby creating a deliberate buffer loop. This design absorbs sudden traction forces and allows fine intraoperative adjustment by sliding the suture between the clips, effectively preventing excessive stress on the fatty anchorage while maintaining stable retraction to significantly improve exposure of the dorsal hilar region in a controlled and reproducible manner.

Our method involves mobilization and fixation of the kidney against the abdominal wall, effectively expanding the operative field for tumor resection. Utilizing the ITT ensures continuous and controlled traction on the tumor during its resection, which not only optimizes the surgical field but also eliminates the need for an additional trocar. This approach provides adequate exposure for dorsally located hilar tumors without requiring additional trocars, thereby reducing medical costs. Prolonged WIT was shown to result in irreversible renal damage, with a critical threshold observed at approximately 25–30 min[25]. Therefore, it is imperative to maintain warm ischemia time within the range. In this study, the ITT group demonstrated a significantly shorter median WIT of 17.00 min, which was deemed sufficiently short. Most importantly, this reduction in WIT suggests potential for improved renal functional recovery[26]. Renal function preservation remains a critical consideration in treating localized renal masses [27]. While this study demonstrated statistically significant reductions in WIT and EBL with the described technique, its clinical relevance warrants careful consideration. No significant differences were observed in total operative time, major complication rates, or length of hospital stay. It should be noted, however, that favorable, non-significant trends were observed in the intervention group across several of these endpoints, including operative time, hospital stay, and overall complication rates. Encouragingly, the ITT group had a smaller EPV and a higher IPV preserved rate, suggesting a potential advantage in renal function preservation. The modest sample size of this study likely underpowered it to detect statistically significant differences in these secondary clinical outcomes, a recognized limitation of preliminary technical evaluations. The higher tetrafecta[28] achievement rate in the ITT group, primarily driven by its superior WIT control, provides integrated evidence of a favorable safety-efficacy profile for this technique, even in the absence of differences in individual complication rates. The mobilization of the kidney with preservation of the lateral perirenal fat also constitutes a crucial step in this technique.

The potential effects of the learning curve on WIT and EBL were carefully considered. Although the introduction of any new surgical technique may involve an initial learning phase, several factors may have mitigated this concern. All procedures were performed by the same primary surgeon, working with a surgical team of two to three members. The surgeon had substantial prior experience in robotic urologic surgery before adopting ITT. Moreover, the ITT and conventional procedures were interspersed throughout the study period. Tumor retraction to the abdominal wall was completed before renal artery clamping; therefore, the time required to establish internal traction was not included in the WIT. These factors may have reduced, but cannot exclude, the influence of the learning curve. Furthermore, an analysis of the chronological case distribution demonstrated that ITT cases were not clustered later in the study period, nor were conventional cases confined to the earlier phase. Instead, the ITT approach was introduced selectively relatively early, while conventional procedures continued to be performed throughout the entire study timeline. Therefore, the significant reductions in WIT and EBL observed in the

ITT cohort are unlikely to be explained primarily by a learning curve effect, but are more plausibly attributed to the application of the ITT technique itself.

By providing superior stabilization, this method facilitated a more controlled tumor resection, a critical step in preventing capsular injury. In the current investigation, postoperative histological examination confirmed negative surgical margins in all patients. The two groups demonstrated comparable safety profiles. Importantly, no local recurrence or metastasis was documented in any patient throughout the follow-up period (≥ 6 months).

This study has several limitations that should be acknowledged. First, its retrospective, single-center design introduces inherent selection bias and limits the generalizability of our findings. Despite efforts to adjust for confounders, unmeasured variables may still influence the results. Second, the modest sample size, particularly after subgroup stratification, restricts statistical power and precludes robust multivariable analysis. Third, the relatively short follow-up period precludes assessment of long-term oncologic and functional outcomes. And Severe obesity, thick or adherent perirenal fat, and extremely posteriorly located tumors may limit the feasibility and efficacy of ITT. Due to the modest sample size and missing Mayo Adhesive Probability (MAP) score data, propensity score matching was not feasible in this pilot study, residual confounding cannot be entirely excluded. Future prospective studies with larger, balanced cohorts are warranted to validate our findings using propensity score matching or inverse probability of treatment weighting. As such, our findings should be considered preliminary and hypothesis-generating rather than definitive. Prospective, multi-center studies with larger cohorts and extended follow-up are warranted to validate and build upon our observations.

Conclusion

Based on our initial experience, the internal traction technique applied in retroperitoneal RAPN is a feasible and effective approach for managing dorsal hilar renal tumors. The application of the ITT was associated with superior exposure, shorter WIT, and lower EBL relative to the conventional method.

Abbreviations

rRAPN: retroperitoneal robot-assisted partial nephrectomy; ITT: internal traction technique; WIT: warm ischemia time; EBL: estimated blood loss; EPV: excisional parenchymal volume, IPV: ipsilateral parenchymal volume; RCC: renal cell carcinoma; PN: partial nephrectomy; RAPN: robot-assisted partial nephrectomy; LPN: laparoscopic partial nephrectomy; CT: computed tomography; MRI: magnetic resonance imaging; SD: standard deviation; IQR: interquartile range; Scr: serum creatinine; OPN: open partial nephrectomy; eGFR: estimated glomerular filtration rate; TPLPN: transperitoneal laparoscopic partial nephrectomy; BMI: body mass index.

Declarations

Ethics approval and consent to participate

All procedures used in research involving human subjects were compliant with the 1964 Declaration of Helsinki and its subsequent amendments, as well as the ethical requirements of the national and/or institutional research committees. The Yuhuangding Hospital Ethics Committee permitted the project. The informed consent was signed by each participant.

Availability of data and materials

The patient-level clinical data generated and analyzed during this study are not publicly available because they contain sensitive health information from patients treated at Yantai Yuhuangding Hospital. Unrestricted disclosure could compromise patient privacy and confidentiality, including a residual risk of re-identification. De-identified data may be made available from the corresponding author upon reasonable request, subject to approval by the Ethics Committee of Yantai Yuhuangding Hospital and execution of an appropriate data-use agreement.

Competing interests

The authors declare no competing interests.

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Authors' contributions

CYL, GLT, and WCS drafted the manuscript. HWZ performed the surgical procedures. MZS, JDZ, and FL collected the clinical data and conducted postoperative follow-up. HL performed the statistical analyses. CYL and ZYN prepared the figures and tables. JTW critically reviewed the manuscript and supervised the study. All authors reviewed and approved the final manuscript.

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Figures

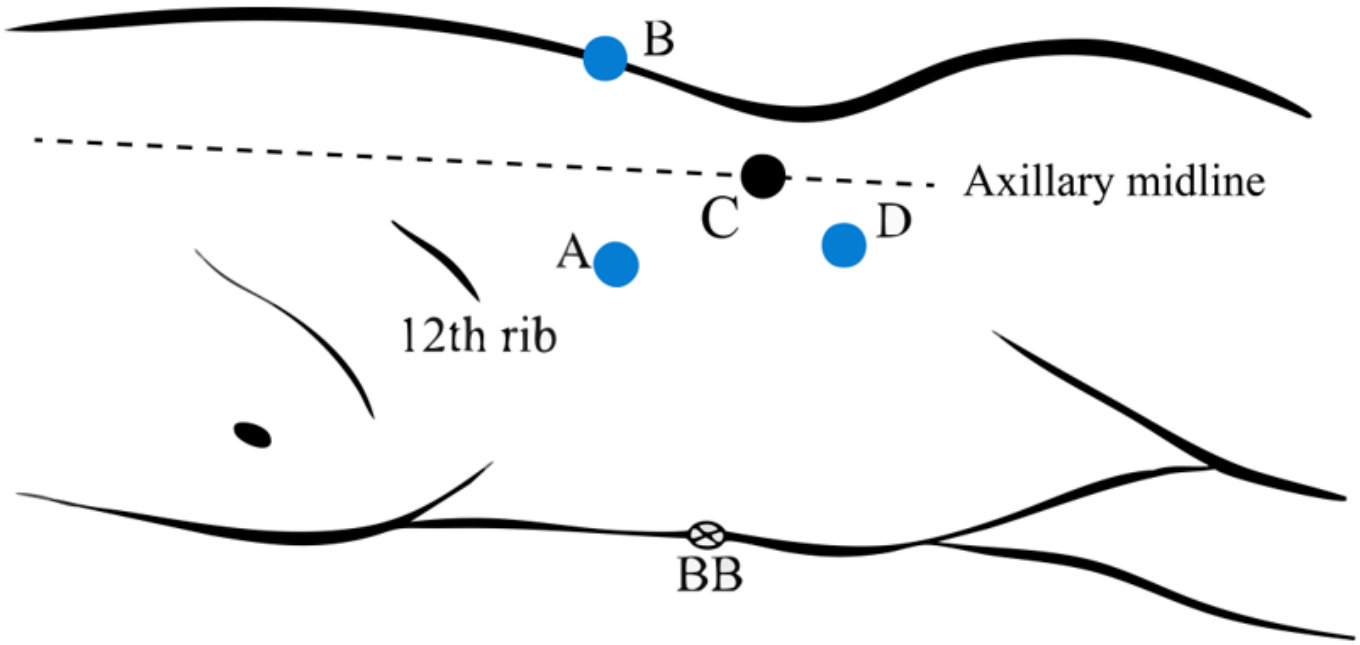


Figure 1

Schematic illustration of trocar placement.

(A) Robotic arm port:an 8-mm trocar is placed along or near the anterior axillary line, approximately 7-8 cm from port C; (B) Robotic arm port:an 8-mm trocar is placed along or near the posterior axillary line, approximately 7-8 cm from port C; (C) Camera port: a 12-mm trocar is inserted approximately 4 cm above the anterior superior iliac spine; (D) Assistant port: A 12 mm trocar was placed near the extension of the perpendicular bisector of the line between port A and port C, approximately 4 cm from port C; (BB) represents the belly button.

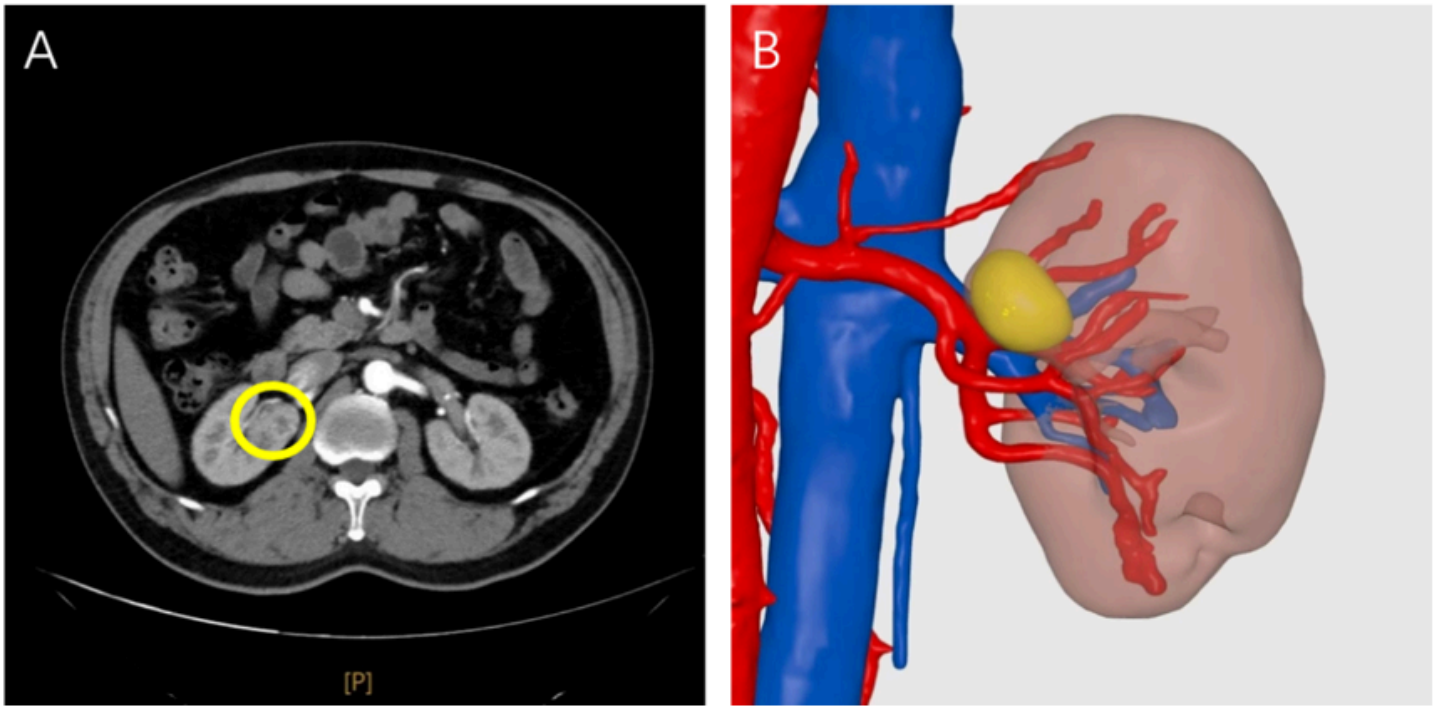


Figure 2

Dorsal hilar renal tumor (in yellow).

(A)Computed tomography transverse view. (B) Three-dimensional reconstruction.

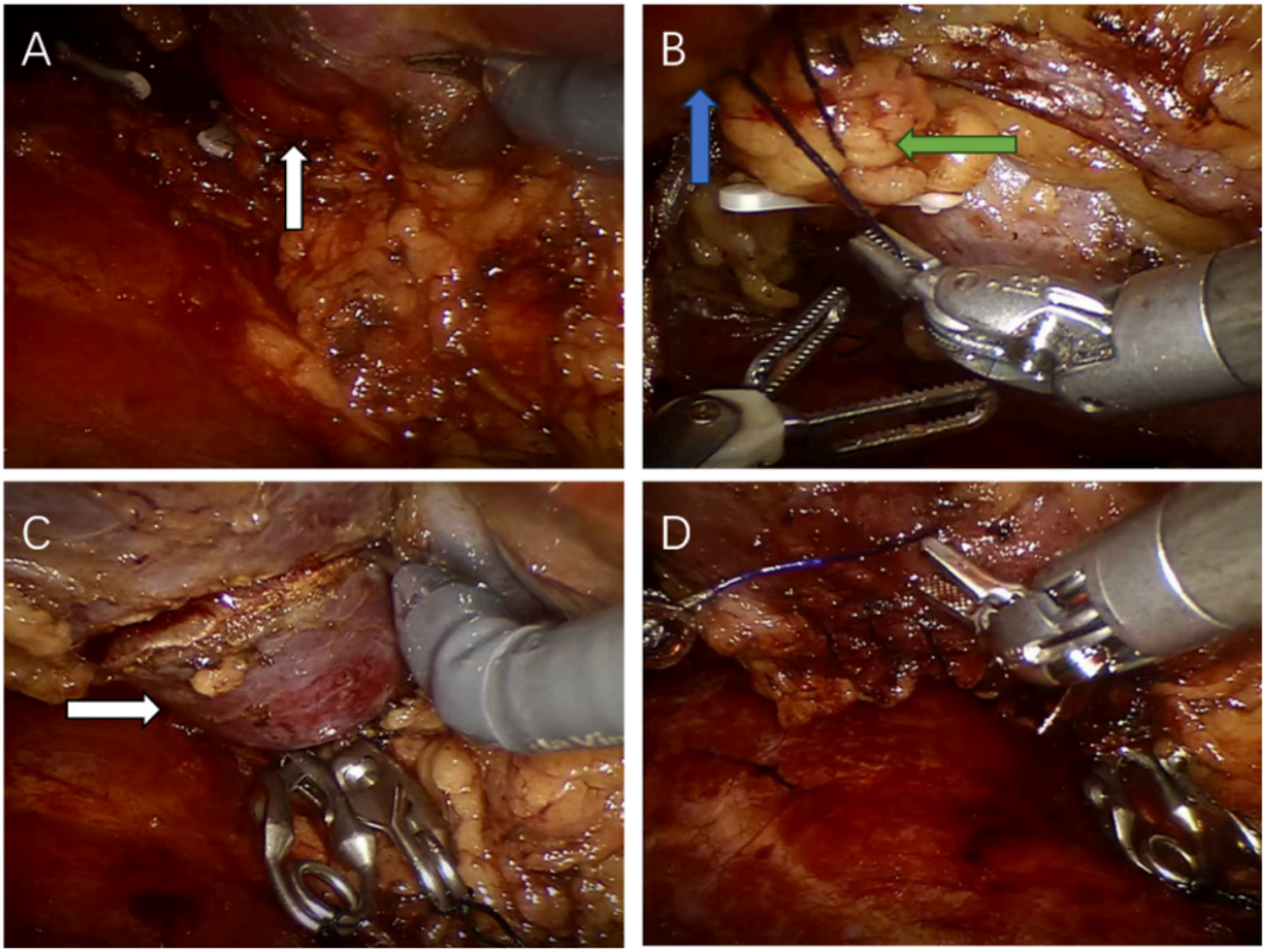


Figure 3

chematic diagram of the ITT in rRAPN for dorsal hilar renal tumors.

(A) Poor tumor (white arrow) exposure. (B) The suture was used to pull the perirenal fat (greenarrow) to the abdominal wall (blue arrow). (C) Adequate tumor exposure (white arrow) was achieved during resection. (D) The tumor was well exposed during renal reconstruction.