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Original Article

Impact of three-dimensional vision in laparoscopic partial nephrectomy for renal tumors

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ABSTRACT

Objective: To compare three-dimensional (3D) with standard two-dimensional (2D) laparoscopic partial nephrectomy (LPN) with respect to intra- and postoperative outcomes.

Material and methods: Data from 112 patients who underwent transperitoneal LPN from 2012 to 2014 by a single experienced surgeon were collected. Sixty patients (group 1) underwent conventional 2D LPN and 52 patients (group 2) 3D LPN. Perioperative patient, procedure, and tumor data were recorded. The follow-up period was 1–5 years.

Results: The two groups had similar patient age (p=0.834) and body mass index (p=0.141). The total laparoscopy time (LT) was shorter in group 2 (119.0 vs. 106.0 min; p=0.009). Warm ischemia times (WITs) were also shorter in group 2 (11.5 vs. 10.0 min; p=0.032). The estimated blood loss (EBL) (350.0 vs. 250.0 mL; p<0.001) and hemoglobin (Hb) decrease (1.55 vs. 1.35 g/dL; p=0.536) were lower in the 3D LPN group. Creatinine (0 vs. 0 g/dL; p=0.610) increase and estimated glomerular filtration rate (eGFR) decrease (0 vs. 0 mL/min/1.73 m^2; p=0.553) did not demonstrate statistically significant differences. Duration of hospitalization (7 vs. 7 days; p=0.099) and complication rates (p=0.559) were similar between the two groups.

Conclusion: The new-generation 3D laparoscope has a great impact on significant LPN intraoperative parameters, mainly LT, WIT, and EBL. Hb decrease is also in favor of 3D vision, although not dramatically altered. Therefore, 3D LPN appears to be superior to conventional 2D LPNs.

Keywords: 3D camera; laparoscopic partial nephrectomy; renal cell carcinoma; three-dimensional vision; three-dimensional laparoscopy.

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Introduction

Nephron-sparing surgery is the preferred treatment for T1 renal tumors.[1] Partial nephrectomy can be performed with open, laparoscopic, or robotic approaches depending on tumor complexity, equipment availability, and surgeon's experience.[1,2] Nevertheless, despite its undeniable benefits, laparoscopic surgery is undermined by significant ergonomic limitations that hamper its distribution. The two-dimensional (2D) vision of a three-dimensional (3D) surgical field is the main contributor to increased mental stress and the long learning curve of laparoscopic partial nephrectomy (LPN), especially during reconstruction. 3D laparoscopy can improve stereoscopic perception, affecting spatial orientation and depth perception. New-generation 3D laparoscopes offer high-definition stable images, reducing the surgeon's visional and mental stress. 3D vision has already been tested in Pelvi trainer settings, achieving improved surgical speed and decreased surgeon discomfort.[3] However, current data regarding its impact on LPN remain limited to a few small series.[4,5] In this study, we compared 3D LPN with 2D LPN in terms of perioperative and renal functional outcomes in a cohort of patients with clinically localized renal tumors.

Material and methods

Study population

The records of 112 patients who underwent transperitoneal LPN due to renal tumor from

2012 to 2014 by a single experienced surgeon were collected. To minimize surgeon experience-related selection bias, procedures performed outside this time frame were not included. More specifically, the first consecutive 60 patients underwent 2D LPN, followed by 52 patients who underwent 3D LPN, as the 3D camera (Endoeye Flex LTF-S190-5, Olympus Europa SE & Co. KG, Hamburg, Germany) was introduced in the surgeon's department in 2013. Patient demographics including age, sex, and body mass index (BMI), and American Society of Anesthesiologists (ASA) scores were inserted in an Excel spreadsheet. Additionally, tumor characteristics including tumor side and Preoperative Aspects and Dimensions Used for an Anatomical (PADUA) Classification score, as well as perioperative outcomes (preoperative hemoglobin [Hb], creatinine level and estimated glomerular filtration rate [eGFR], operation time, warm ischemia time [WIT], estimated blood loss [EBL], transfusion, mean Hb decrease, mean creatinine level increase, mean eGFR change, length of hospitalization, and complications) and pathology features (T stage, tumor type, and Fuhrman tumor grade), were recorded. Inclusion criteria were a T1 tumor stage according to computerized tomography and patients with normal contralateral kidneys. The exclusion criteria were multiple renal tumors, tumor vein thrombus, a solitary kidney, severe cerebrovascular or cardiopulmonary disease, and uncorrected coagulopathy. The ASA, PADUA, and Clavien-Dindo scores were utilized to describe patient comorbidity, tumor complexity, and complication severity, respectively. PADUA and Clavien-Dindo scores were calculated by two experienced urologists in our study group (TT, IL). The follow-up period ranged from one to five years (mean, 3.46). This work is a retrospective audit of outcomes; there was no intervention outside routine clinical praxis, no additional diagnostic or therapeutic measures, or no additional burden to the patients, and the treatment strategy was not set in advance. Hence, the study can be characterized as observational, and formal ethical committee approval was not deemed necessary.

Surgical technique

All LPNs were performed in a standard transperitoneal fashion. The optic trocar is placed paraumbilically, with two working trocars (10 mm and 5 mm) and one assistant trocar (5 mm) inserted into the left or right upper or lower abdominal cavity at the level of the midclavicular line. The left/right colon flexure and the descending and ascending colon are mobilized. The Gerota's fascia is incised at the level of the lower pole of the kidney, the ureter and the psoas muscle are exposed, and the kidney is mobilized dorso-cranially. The renal artery and vein are being prepared, the kidney is inspected, and the tumor is identified. The renal artery was temporarily clamped with the aid of a bulldog clamp. The decision to clamp the renal artery is based on surgeon preference, which is mainly based on tumor size and localization. The tumor is resected, and renorrhaphy is usually performed in one layer with interrupted polyglactin sutures. The bulldog clamp is removed, and hemostatic material (TachoSil®, Nycomed, Linz, Austria) is additionally applied. Perirenal fat is usually adapted over the resection area. An easy-flow drain is placed through the lower trocar.

Main Points:

- Three-dimensional vision significantly decreases total laparoscopy and warm ischemia times during laparoscopic partial nephrectomy.
- Three-dimensional vision significantly reduces estimated blood loss during laparoscopic partial nephrectomy.
- Three-dimensional laparoscopic partial nephrectomy also decreases hemoglobin levels, although the difference is not statistically significant.

Statistical analysis

IBM Statistical Package for the Social Sciences Statistics 20 software (IBM Corp., Armonk, NY, USA) was used for statistical analysis. The distribution of the continuous variables was analyzed using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Due to the non-normal distribution, the nonparametric

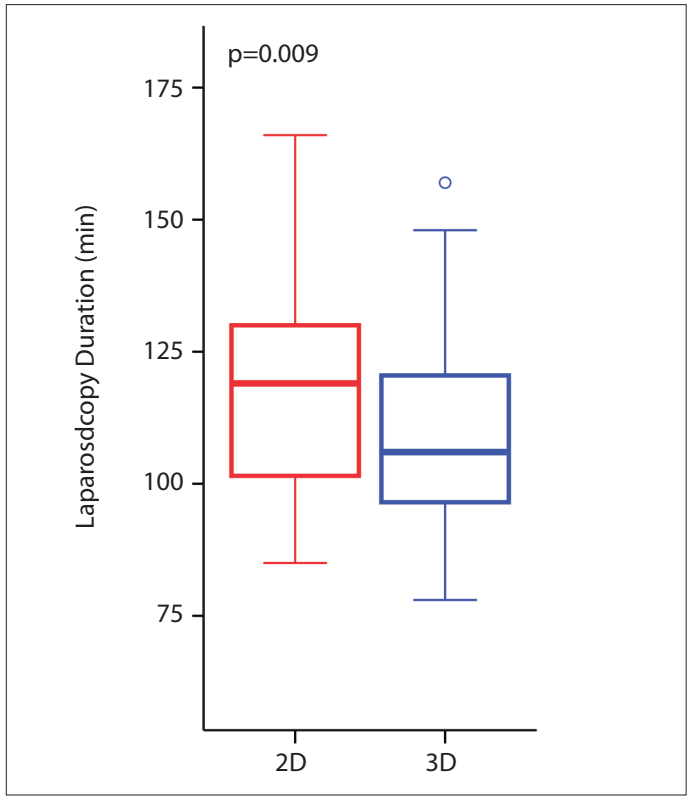

Figure 1. Box plot demonstrating laparoscopy time (LT) difference between the two groups

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Table 1. Patients' general demographic and preoperative data

	2D (n=60)	3D (n=52)	p
Gender (%)			
Male	41 (68.3)	36 (69.2)	
Female	19 (31.7)	16 (30.8)	
Median age (range) year	66.50 (41–83)	68.50 (39-84)	0.834
Median BMI in kg/m^2(range)	23.65 (18.7–37.3)	24.35 (20.2–37.9)	0.141
Tumor side (%)			
Left	35 (58.3)	24 (46.2)	0.136
Right	25 (41.7)	28 (53.8)	
ASA score (%)			
1	17 (28.3)	12 (23.1)	**0.034**
2	28 (46.7)	15 (28.8)	
3	15 (25)	25 (48.1)	
Median clinical tumor size in cm	3.00 (1.00–5.00)	3.70 (1.50–6.40)	0.847
Median pathological tumor size in cm	3.13 (1.2–5.3)	3.90 (1.80–6.20)	0.756
PADUA score (%)			
6–7	32 (53.3)	18 (34.6)	0.129
8–9	22 (36.7)	28 (53.8)	
≥10	6 (10)	6 (11.5)	
Median preoperative Hb level (g/dL)	14.15 (11.00–16.9)	14.40 (10.60–17.3)	0.728
Median preoperative creatinine level (mg/dL)	1.00 (0.50–1.70)	0.90 (0.70–1.50)	0.948
Median preoperative eGFR level (based on MDRD) in mL/min/1.73 m^2	76.80 (35.50–175.80)	78.80 (36.20–109.20)	0.949

BMI: body mass index; ASA: American Society of Anesthesiologists; PADUA score: Preoperative Aspects and Dimensions Used for an Anatomical Classification score; Hb: hemoglobin; eGFR: estimated glomerular filtration rate; MDRD: Modification of Diet in Renal Disease

Mann-Whitney U test was performed to analyze the differences in continuous variables, while Pearson's chi-square test was used for categorical data. P<0.05 indicated statistical significance.

Results

From January 2012 to December 2014, 131 patients underwent LPN due to a renal tumor. Of these, 19 patients were finally excluded. The data of the included patients are presented in Table 1. Sixty patients underwent 2D LPN (group 1) and 52 patients 3D LPN (group 2). Of the 112 patients, 77 were men and 35 women. The two groups were statistically similar according to patient age (66.50 vs. 68.50 years; p=0.834) and BMI (23.65 vs. 24.35 kg/m^2; p=0.141). The 3D LPN patients had a higher ASA score (p=0.034); however, the two groups had similar clinical (3.00 vs. 3.70 cm; p=0.847) and pathological (3.13 vs. 3.90 cm; p=0.756) tumor size as well as PADUA scores (p=0.129). Mean preoperative Hb (14.15 vs. 14.40 g/dL; p=0.728), creatinine (1.00 vs 0.90 mg/dL; p=0.948), and eGFR levels (76.80 vs. 78.80 mL/min/1.73m^2; p=0.949) were similar in both groups.

The tumor stage (p=0.781) and grade (p=0.245) were comparable. Different intra- and postoperative outcomes are presented in Table 2. The total laparoscopy time (LT) was significantly shorter in the 3D group (119.0 vs. 106.0 minutes; p=0.009; Figure 1). Warm ischemia times (WITs) were also significantly shorter in group 2 (11.5 vs. 10.0 minutes; p=0.032; Figure 2). The EBL was also significantly decreased in the 3D laparoscope group (350 vs. 250 mL; p<0.001; Figure 3). The first postoperative Hb decrease was lower in 3D LPN cases; however, this difference was not

Table 2. Comparison of intraoperative and postoperative outcomes

	2D (n=60)	3D (n=52)	p
pT (%)			0.781
pT1a	43 (74.1)	37 (71.2)	
pT1b	14 (24.1)	13 (25.0)	
pT2a	1 (1.7)	2 (3.8)	
NA	2 (3.3)		
Fuhrman grade			0.245
1	6 (10.9)	3 (6.0)	
2	43 (78.2)	45 (90.0)	
3	6 (10.9)	2 (4.0)	
Histology (%)			0.647
Clear cell RCC	40 (67)	36 (69)	
Papillary RCC (type 1)	5 (8.3)	5 (9.6)	
Papillary RCC (type 2)	3 (5)	3 (5.8)	
Chromophobe RCC	12 (20)	8 (15.38)	
Median LT in minutes (range)	119 (85–166)	106 (78–157)	**0.009**
Median WIT in minutes (range)	11.50 (0–28)	10.00 (0–25)	**0.032**
Median EBL in mL (range)	350 (150–900)	250 (100–550)	**<0.001**
Transfusion (%)	0 (0)	0 (0)	-
Median Hb decrease in g/dL* (range)	1.55 (-0.60–5.90)	1.4 (-3.60–3.40)	0.536
Median creatinine increase in g/dL* (range)	0.00 (-0.2–1.0)	0.00 (-0.2–0.7)	0.610
Median eGFR (based on MDRD) decrease in mL/min/1.73m^2* (range)	0 (-23.9–126.3)	0 (-29.2–38.3)	0.553
Median duration of hospitalization in days (range)	7 (5–32)	7 (4–12)	0.099
Complications (%)			0.559
Clavien 0	56 (93.3)	48 (92.3)	
Clavien 1	2 (3.3)	3 (5.8)	
Clavien 2	2 (3.3)	1 (1.9)	

RCC: renal cell carcinoma; LT: laparoscopy time; WIT: warm ischemia time; EBL: estimated blood loss; Hb: hemoglobin; eGFR: estimated glomerular filtration rate; MDRD: Modification of Diet in Renal Disease
*Postoperative values are taken from the time of discharge of the patients

statistically significant (1.55 vs. 1.35 g/dL; p=0.084). Discharge creatinine increase (0 vs. 0 g/dL; p=0.610) and eGFR decrease (0 vs. 0 mL/min/1.73m^2; p=0.553) did not demonstrate statistically significant differences between the two groups. No conversion to open partial nephrectomy or laparoscopic radical nephrectomy and no transfusion were recorded. Finally, hospitalization times (7 vs. 7 days; p=0.099) and complication rates (p=0.559) were similar between the two groups. No major complications and tumor recurrences were recorded during follow-up.

Discussion

Nephron-sparing surgery, performed either open, laparoscopically, or robotically assisted, is currently the standard of care

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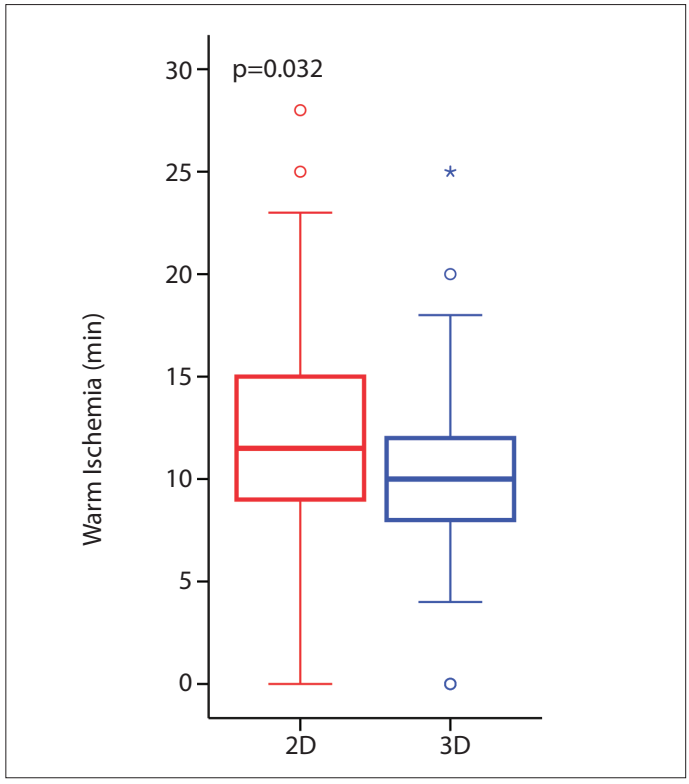

Figure 2. Box plot demonstrating warm ischemia time (WIT) difference between the two groups

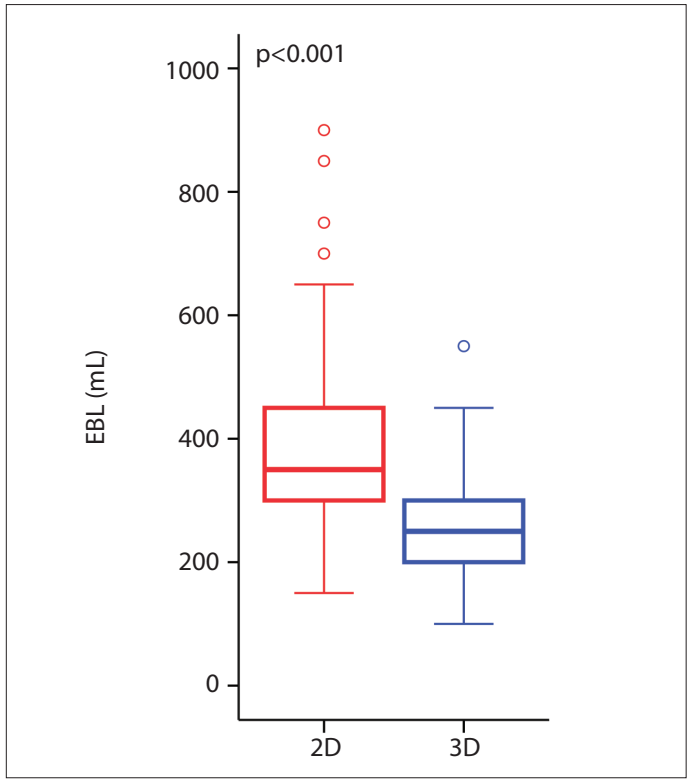

Figure 3. Box plot demonstrating estimated blood loss (EBL) difference between the two groups

for tumors smaller than or equal to 7 cm.[1] However, the open procedure is characterized by increased postoperative pain and prolonged recovery rates, mainly due to the muscular layer cutting and open incisions. Consequently, minimally invasive approaches have gained popularity by demonstrating safety and efficiency.[2] Nonetheless, laparoscopic procedures are handicapped by significant visual and ergonomic limitations, such as impaired hand-eye coordination and stereoscopic perception, which become more prominent during the tedious steps of reconstruction. 3D visual systems were introduced to diminish these predicaments and improve mental and physical stress. As the first-generation devices did not get in on the ground floor because they did not significantly improve vision or perceived surgical performance,[6] the later generations achieved improved laparoscopic precision without the side effects reported from previous systems.[7] New-technology 3D cameras have been tested in dry[3,8,9] and wet[10,11] lab settings and demonstrated increased surgical speed and precision as well as decreased error rates. Therefore, 3D vision was applied in the clinical setting and was rapidly introduced in urological operating theaters.[12-15] Two recently published systematic reviews showed that 3D laparoscopy mainly improves depth perception and visibility, which is important for some complex urological surgeries such as partial nephrectomy, pyeloplasty, and radical prostatectomy.[4,5] However, researchers agree that data regarding LPN remain scanty, as only one comparative trial could be identified in the current literature,[16] probably due to the rapid introduction and implementation of robotic surgery in urology. Our work offers a relatively large sample of patients and demonstrates a clear advantage of 3D LPN in terms of LT, WIT, and EBL.

Ruan et al.[16] recruited a total of 90 patients with clinical T1 renal tumors to assess the feasibility and effectiveness of 3D LPN with selective segmental artery clamping and compared it with conventional 2D LPN. By successfully performing all procedures, the authors reported similar operative and dissection times, but shorter suturing times and WITs. Additionally, better postoperative ipsilateral renal function could be obtained. Nevertheless, 3D LPN was associated with higher EBL. No major complication rates and tumor recurrence were recorded during a follow-up period of 16.8 months. Our results are comparable, with our LT being approximately 118 min for 2D LPN and 108 min for 3D LPN, a difference reaching statistical significance. In line with the results of Ruan et al.[16], our WIT differences were significantly lower for the 3D LPNs. Conversely, we could also demonstrate a significantly lower EBL during 3D procedures, although this fact was not translated to significantly decreased postoperative Hb values or transfusion needs. The postoperative kidney function was similar between the two groups and comparable with the results of selected clamping

reported by Ruan et al.[16] Although selected arterial clamping was performed in many cases in our patient sample, it was not recorded in our Excel spreadsheet. No cases were converted to laparoscopic radical nephrectomies or open partial nephrectomies in either group. Our patients did not suffer any major complications, with minor complication rates of around 4% for both groups, and no tumor recurrences were recorded in a follow-up period of 1–5 years.

The da Vinci surgical robot was developed to provide surgeons with an attractive, user-friendly interface while maintaining minimal invasiveness. It offers significantly improved ergonomics providing consoles with 3D vision and instruments with 7 degrees of freedom. The system has been widely adopted worldwide, and since its introduction, the number of complex urological laparoscopic procedures started to decline.[17] Interestingly, however, by separately assessing the ergonomic advantages and not depending on the biomechanical advantages of the console in vitro, 3D vision is an important factor that allows for significant improvement in performance times and error rates.[18,19] All surgeons seem to benefit; however, the difference is more pronounced in novices. Well-trained laparoscopic surgeons may not really benefit from robot systems if 3D laparoscopy is available.[20] In particular, robot-assisted partial nephrectomy has a noticeable but rapid learning curve, and after it is overcome, it results in perioperative outcomes similar to those achieved with conventional LPN performed by an experienced surgeon.[21] Recent studies show a clear superiority of the robot regarding EBL, WIT, intraoperative complications, and early renal functional preservation.[22,23] However, by reviewing the current literature, there is still no clear evidence demonstrating the superiority of the robot.[2,24,25] The intra- and postoperative outcomes presented by our group are comparable to those reported by expert robotic surgeons.[26,27]

Our study is not without limitations, the main being its retrospective nature and the nonrandomized sample of patients. Nevertheless, the two groups were statistically similar according to BMI and tumor complexity. Most importantly, we utilized the ASA and PADUA scores to offer a precise stratification of our patients before LPN regarding potential threats and benefits of nephron-sparing surgery.[28] Furthermore, additional comorbid diseases that could affect the postoperative renal functional outcomes could not be collected, a factor that could undermine the evaluation of eGFR decrease. Long-term follow-up Hb, creatinine, and eGFR levels could not be retrieved and are not presented in our patient outcomes. Long-term total renal function loss could be of clinical significance, as it reaches 10% after partial nephrectomy in patients with a two-kidney model.[29] Finally, as WIT did also differ statistically between the two groups, tumor resection and renorrhaphy seem to benefit from 3D technology in this cohort. At this point, surgeon experience may play a role that is not dependent on the advantage of 3D technology, taking into account that our initial experience was with 2D and our recent experience with 3D technology. Hence, further research investigating the impact of 3D technology in less experienced surgeons would add valuable information.

The new-generation 3D laparoscope has a great impact on significant LPN intraoperative parameters, mainly LT, WIT, and EBL. Hb decrease is also in favor of 3D vision, although it is not dramatically altered. Therefore, 3D LPN appears superior to the conventional 2D LPN.

Ethics Committee Approval: Authors declared that the research was conducted according to the principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects", (amended in October 2013).

Informed Consent: This work is a retrospective audit of outcomes. Written informed consent was not obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – T.T.; Design – T.T.; Supervision – A.S.G.; Data Collection and/or Processing – I.L.; Analysis and/or Interpretation – M.A.; Literature Search – I.L.; Writing Manuscript – T.T.; Critical Review – U.N.

Conflict of Interest: The authors have no conflicts of interest to declare.

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