

Comparison of three dimensional reconstruction and conventional computer tomography angiography in patients undergoing zero-ischemia laparoscopic partial nephrectomy

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Abstract

Background: Advances in three dimensional (3D) reconstruction and printing technology have fueled a rapidly growing interest in its applications in the field of urology. To our knowledge, the experience on the use of 3D reconstruction to facilitate zero-ischemia partial nephrectomy (PN) remains sparse and the role of 3D reconstruction is still needed to be defined. This study aimed to assess the role of 3D reconstruction and conventional computer tomography angiography (CTA) in zero-ischemia laparoscopic partial nephrectomy (LPN).

Methods: A total of 60 consecutive patients undergoing zero-ischemia LPN between October 2017 and March 2018 who underwent CTA (CTA group including 30 patients) and 3D reconstruction (3D group including the remaining 30 patients) preoperatively were included. 3D reconstruction and CTA images were prepared which were used to demonstrate the number and spatial interrelationships of the location of renal tumors and tumor feeding arteries. These radiological findings were directly correlated with intraoperative surgical findings at laparoscopy. Baseline, perioperative variables and the rate of accurate tumor feeding artery orientation were compared between groups.

Results: All the procedures were performed successfully without conversion to main renal artery clamping. Preoperative 3D reconstruction identified that 15 patients had only one tumor feeding artery, 12 had two, and another 3 had three, while the conventional CTA revealed that 22 patients had one tumor feeding artery, 8 had two ($P>0.05$). The mean operation time was shorter and estimated blood loss was less in the 3D group ($P<0.05$). 3D reconstruction group resulted in more accurate dissection of tumor artery (91.7%) as compared to conventional CTA (84.2%). There were no statistical differences in the baseline characteristics and renal function outcomes between two groups.

Conclusions: 3D reconstruction can provide comprehensive information for the preoperative evaluation and intraoperative orientation that may facilitate tumor resection during zero-ischemia LPN for renal tumors.

Background

Laparoscopic partial nephrectomy (LPN) has gained popularity as a promising minimally invasive nephron sparing option for clinical T1 renal tumors [1]. Minimizing or even eliminating warm ischemic injury was the aim for improving the functional outcomes of nephron sparing surgery. Recent advances in surgical technique now make it possible to eliminate global ischemia completely during partial nephrectomy (PN), such as zero-ischemia PN, unclamped "minimal-margin" PN and clampless techniques [2-4]. However, zero-ischemia LPN is a technically challenging operation. As such, a detailed and case-specific understanding of the particular renovascular anatomy is of great importance to surgical planning and even orientation.

At most centers, renal angiography has been the preferred imaging modality for preoperative evaluation of patients with renal tumors. Although helical computerized tomography (CT) allow high quality images

of the renal vasculature and soft tissue anatomy to be obtained in any plane, advances in the three dimensional (3D) reconstruction and printing technology have fueled a rapidly growing interest in its applications in the field of urology [5]. This image modality has been successfully used for preoperative evaluation of patients undergoing PN [6, 7]. Currently, the experience on the use of 3D reconstruction to facilitate zero-ischemia PN remains sparse, and the role of 3D reconstruction is still needed to be defined. We determined whether 3D reconstruction could be the preferred preoperative radiological examination, providing all information necessary for surgical planning and orientation for zero-ischemia LPN.

Methods

Patients

Between January 2018 and July 2018, 60 consecutive patients who underwent zero-ischemia LPN in our hospital were retrospectively analyzed. The patients with sporadic renal tumor at clinical T1N0M0 stage were included. Patients with tumors of solitary kidney, multiple tumors or bilateral renal tumors were excluded from this study. The study was approved by the Institutional Review Board of Ren Ji Hospital affiliated to School of Medicine of Shanghai Jiao Tong University. All the patients in this study received contrast-enhanced CT with angiography preoperatively, and additional 3D reconstruction was conducted in 30 patients.

CTA and 3D reconstruction protocol

Before the examination of CTA, all patients were administered with one liter of water and then a 64-multidetector computed tomography scanner (VCT Light Speed, GE Healthcare, Pittsburgh, USA) was utilized to perform CTA. Non-enhanced, arterial and portal phases' images were obtained in a craniocaudal direction covered the area from the diaphragm to the lower kidney poles, and delayed nephrographic excretory phase's images were also obtained which covered the area from the diaphragm to the symphysis pubis. Contrast-enhanced images were gained after the administration of 150 ml of non-ionic contrast medium (Iopamiro, Bracco, Milan, Italy). The slice thickness was 1.25-mm, the pitch was 1.375 and the current was 110-380 mA. Non-enhanced nephrographic and excretory phases' images were reconstructed as 1.25-mm sections and the arterial phase' images were reconstructed at a 0.725-mm interval.

Based on the CTA examination, a dedicated software by Mimics, 3-matic and Magics (Materialise, Belgium) was used to process the images in DICOM format, and a 3D virtual model was then rendered. We reconstructed 3D images to fuse the key anatomic constructions including the renal tumors, semitransparent kidney, arterial vasculature and the collecting system. The arterial phase images with automated thresholding were used to perform the segmentation of kidney surface and the dynamic region growing method was used to reconstruct the renal pedicle, as well as tumor feeding arteries. The relative interactive 3D images and models were then created. After that, the urologists, along with radiologists and bioengineers reviewed the virtual renovascular-tumor models and assessed their accuracy in comparison with the CTA images (Figure.1). The number of renal tumor feeding arteries was

compared between the 2 imaging modalities and matched with intraoperative findings on laparoscopy, which were considered the gold standard.

Surgical technique

All procedures were performed by a single surgeon (D Liu). Patients were placed in a lateral decubitus position. A retroperitoneal approach was used in all operations. Zero ischemia LPN was performed under the guidance of CTA images in the CTA group, while 3D images from various angle views (e.g., anterior, posterior and lateral) were presented to the surgeon pre- and intra-operatively in the 3D group. After the Gerota's fascia was opened, the tumor was localized, dissected and exposed completely. Then the tumor was enucleated without reanl hilar clamping by blunt and sharp dissection. The tumor feeding arteries were clamped with Hem-o-lok clips (Figure.2) once they were found. Point-specific suturing were performed for homeostasis, and incised calyces were repaired when necessary. After then, continuous suturing with Hem-o-lok clips was used to reconstruct the defected parenchyma. A drain was left at the end of surgery and the tumor specimen were sent for pathological evaluation.

Outcome Measures

The general information, tumor characteristics including RENAL score [8], Kidney segmentation [9], intraoperative variables and the number of feeding arteries as well as the rate of accurate tumor feeding artery orientation were collected and compared. All complications within 30 days after surgery were considered being related to surgery, and staged according to the 2004 Clavien-Dindo grading system [10]. The estimated glomerular filtration rate (eGFR) was calculated for all patients preoperatively and 12 months postoperatively according to the Modification of Diet in Renal Disease Equation [11]. Follow-up was conducted at 3 and 6 months after surgery (since they were discharged) and once every 6 months thereafter. Statistical analysis was performed using Student *t*-test for continuous variables with normal distribution or Wilcoxon's rank sum test was used for the non-normal distributed continuous variables. The comparisons of categorized demographic or clinical variables among groups were done with Pearson Chi-square or Fisher exact test, and a value of P<0.05 was considered statistically significance.

Results

A total of 60 consecutive patients who underwent zero-ischemia LPN were included in this study. Patient demographics and surgical variables are reported in Table 1 and Table 2. The median tumor size was 4.0 and 3.75 cm in 3D group and CTA group respectively without statistical significance. There were also no significant differences between two groups in the age, gender, body mass index, RENAL score, and Kidney segmentation.

The number of tumor feeding arteries was identified preoperatively by 3D reconstruction and CTA, and then confirmed intraoperatively (Table 3). Preoperative 3D reconstruction identified that 15 patients had only one tumor feeding artery, 12 patients had two, and another 3 had three. While conventional CTA revealed that 22 patients had one tumor feeding artery and 8 patients had two, without significant

statistical difference as compared to the 3D group. However, under the guidance of 3D reconstruction images, more tumor feeding arteries were correctly identified during the surgery as compared to surgery under the guidance of conventional CTA ($P=0.03$). Although there was no significant difference between two groups, the rate of accurate tumor feeding artery orientation was higher in the 3D group than in the CTA group (91.7% vs. 84.2%, $p=0.285$).

Zero-ischemia LPN was successfully performed in all the patients without conversion to main renal artery clamping, open surgery or radical nephrectomy. The mean operation time (OT) was 125.4 ± 19.7 min and 136.6 ± 15.1 min in the 3D group and CTA group, respectively ($P=0.017$). And the average estimated blood loss (EBL) was 130.3 ± 39.9 and 179.0 ± 77.2 ml in the 3D group and CTA group, respectively ($P= 0.003$). However, no statistical differences were found between two groups in the hospital stay, major surgical complications and change in mean eGFRs (Table1).

Histopathological results showed clear cell renal cell carcinoma (RCC) (3D group: n=26; CTA group: n=25), chromophobe RCC (3D group: n=1; CTA group: n=3), and papillary RCC (3D group: n=3; CTA group: n=2). There were no significant differences in the subtypes and Fuhrman grade between the two groups ($P>0.05$). The surgical margins were all negative, and no renal capsule invasion was found. The median duration of follow-up was 18 months in the subgroups, and no local recurrence or metastasis was observed.

Discussion

During conventional LPN, renal artery clamping could provide good intraoperative visualization and bleeding control, but inevitably causes warm ischemia injury [12]. Warm ischemia injury remains one of the most important factors influencing postoperative renal function during nephron sparing surgery. Several techniques have been developed to preserve better postoperative renal function, such as segmental artery clamping and thermal ablation techniques [13, 14].

The concept of zero-ischemia LPN was firstly introduced by Gill et al. [15]. They tried to eliminate global renal ischemia by meticulous microdissection of tertiary or quaternary renal arterial branches feeding the tumor, which is based on the concept of anatomical renovascular microdissection [3]. However, dissecting tumor feeding arteries from the renal hilum is technically difficult and time-consuming. Although off-clamp LPN has been developing and popularizing among the urologic communities [16, 17], the uncertainty of the intrarenal relationships of the tumor and feeding arteries makes off-clamp partial nephrectomy even more difficult. Therefore, preoperative understanding of the tumor and renal vascular anatomy is of great importance.

Preoperative CTA has been the preferred imaging modality for the evaluation of renal tumors in our hospital. With the development of CT and computer technology, it allows the generation of high quality images of the renal vasculature, tumor and collecting system at any plane [18]. It can also facilitate establishing conventional 3D models to visualize the arterial vasculature within the hilum, guiding in choosing the appropriate hilar approach and intraoperative target orientation during segmental artery

clamping [19]. However, conventional CTA has a poor capacity to display the precise location and the precise anatomical interrelationship of various intrarenal tributaries, especially the tumor feeding arteries. Moreover, conventional 3D models based on CTA typically display kidney, renal vascular and tumor as opaque, which makes it impossible to visualize the intrarenal relationships between the tumor and its adjacent feeding arteries [6]. As a well performed preoperative evaluation of the relevant intrarenal anatomy and intraoperative orientation of tumor feeding arteries is needed for zero-ischemia LPN, it is imperative to develop new techniques for radiologic guidance.

Conventional 3D CT reconstruction techniques typically present kidney, tumor and renal vessels as opaque, which makes it impossible to visualize the intrarenal relationships of the tumor and adjacent feeding arteries [6]. In this study, the patients in the 3D group underwent 3D reconstruction. The reconstruction images included 3D surface rendered semitransparent renal tumor, transparent kidney, collecting system and 3D course of extra- and intrarenal tumor feeding arteries (Figure 1C-D). Therefore, the relationship between the tumor and collecting system, and the location and number of tumor feeding arteries were clarified much more easily. In addition, the use of 3D reconstruction of renovascular tumor resulted in more accurate dissection of target tumor feeding artery than in the CTA group during the operation, thus decreasing intraoperative OT and EBL.

When compared to conventional CTA, 3D reconstruction techniques have several advantages [20, 21]. Porpiglia et al. compared robotic partial nephrectomies performed with or without the use of hyper-accurated 3D reconstructions, concluding that it allowed for a faithful representation of the kidney arterial vasculature, which could lead to avoiding ischemia of the healthy renal remnant [20].

Similarly, Bertolo et al. compared 3D reconstructions with the standard imaging in the capability of expanding the indications to a nephron sparing surgery for very complex renal masses. More than 20% responders changed their indication from radical to partial nephrectomy after reviewing the 3D reconstruction and it might represent a significant step toward the validation of the use of 3D reconstruction for surgical planning in patients undergoing robotic kidney surgery [21].

In summary, based on our findings, we confirmed that 3D reconstruction techniques could clearly display the intrarenal arterial tree and the detailed anatomical relationships between the tumor, collecting system and intrarenal arteries. The reconstructed images can also be rotated to clarify the number and location of tumor feeding arteries. It can not only provide reference for the preoperative evaluation and determination of appropriate dissection strategy, but also for the intraoperative orientation, therefore avoiding invisible injury to other interlobar arteries during zero-ischemia LPN.

There were also several limitations in this study. First, this was a single-center retrospective study with small sample size and patients received only short-term follow up, the evaluation of long-term outcomes is still awaited. Second, the median tumor size was 4.0 and 3.75 cm in each subgroup, whether this approach is also applicable in the management of larger T1b renal tumors is still unclear. Robot assisted zero-ischemia partial nephrectomy may be helpful for better tumor resection, renorrhaphy and renal function preservation in the management of T1b or even complicated renal tumors [4,22], but our

experience is also lacking in this field. Third, the 3D reconstruction technique based on CT images is not applicable to magnetic resonance imaging. Thus, patients who cannot receive enhanced CT or CTA are excluded from the study. Although the tumor feeding arteries were confirmed more accurately under the guidance of 3D reconstruction technique, the rate of accurately tumor feeding arteries orientation was only 91.7%, without statistical significance as compared with conventional CTA technique.

Conclusions

Our study indicates 3D reconstruction technique might be a useful tool, which can provide comprehensive information of intrarenal interrelationships between renal tumor and its feeding arteries. The 3D model seems to facilitate tumor feeding artery orientation and dissection, therefore improving the surgical outcome after zero-ischemia LPN.

List Of Abbreviations

3D: three dimensional; CT: computerized tomography; CTA: computer tomography angiography; EBL: estimated blood loss; eGFR: estimated glomerular filtration rate; LPN: laparoscopic partial nephrectomy; OT: operation time; PN: partial nephrectomy; RCC: renal cell carcinoma

Declarations

Ethical approval and consent to participate

This study was approved by our Institutional review board (Shanghai Jiao Tong University School of Medicine affiliated Ren Ji Hospital, Shanghai, China) and patients' written consent to participate was also obtained.

Consent for publication

Not applicable.

Availability of data and materials

All data are fully available upon reasonable request. The corresponding author should be contacted if someone wants to request the data.

Competing interests

The authors declare no competing interests.

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Authors' contributions

Study concepts and design: XW, CJ, DL and WX; literature research and data collection: XW, CJ, GW, CS, QF and YC; statistical analysis: CS, QF and YC; manuscript preparation: XW, CJ, GW and CS; manuscript editing: DL and WX. All authors have read and approved the manuscript.

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None.

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References

1. Salagierski M, Wojciechowska A, Zajac K, Klatte T, Thompson RH, Cadeddu JA, et al. The Role of Ablation and Minimally Invasive Techniques in the Management of Small Renal Masses. *Eur Urol Oncol.* 2018; 1(5):395-402.
2. Li Y, Zhou L, Bian T, Xiang Z, Xu Y, Zhu Y, et al. The zero ischemia index (ZII): a novel criterion for predicting complexity and outcomes of off-clamp partial nephrectomy. *World J Urol.* 2017; 35(7):1095-1102.
3. Satkunasivam R, Tsai S, Syan S, Bernhard JC, de Castro Abreu AL, Chopra S, et al. Robotic Unclamped "Minimal-margin" Partial Nephrectomy: Ongoing Refinement of the Anatomic Zero-ischemia Concept. *Eur Urol.* 2015; 68(4): 705-12.
4. Bertolo R, Simone G, Garisto J, Nakhoul G, Armanyous S, Agudelo J, et al. Off-clamp vs on-clamp robotic partial nephrectomy: Perioperative, functional and oncological outcomes from a propensity-score matching between two high-volume centers. *Eur J Surg Oncol.* 2019; 45(7): 1232-1237.
5. Youssef RF, Spradling K, Yoon R, Dolan B, Chamberlin J, Okhunov Z, et al. Applications of three-dimensional printing technology in urological practice. *BJU Int.* 2015; 116(5): 697-702.

6. Ukimura O, Nakamoto M, Gill IS. Three-Dimensional Reconstruction of Renovascular-Tumor Anatomy to Facilitate Zero-Ischemia Partial Nephrectomy. *Eur Urol*. 2012; 61(1): 211-7.
7. Porpiglia F, Bertolo R, Checcucci E, Amparore D, Autorino R, Dasgupta P, et al. Development and validation of 3D printed virtual models for robot-assisted radical prostatectomy and partial nephrectomy: urologists' and patients' perception. *World J Urol*. 2018; 36(2): 201-207.
8. Kutikov A, Uzzo RG. The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. *J Urol*. 2009; 182(3): 844-53.
9. Papalia R, De Castro Abreu AL, Panebianco V, Duddalwar V, Simone G, Leslie S, et al. Novel kidney segmentation system to describe tumour location for nephron-sparing surgery. *World J Urol*. 2015; 33(6): 865-71.
10. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg*. 2004; 240(2): 205-13.
11. Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF 3rd, Feldman HI, et al. A new equation to estimate glomerular filtration rate. *Ann Intern Med*. 2009; 150(9): 604-12.
12. Lieberman L, Barod R, Dalela D, Diaz-Insua M, Abaza R, Adshead J, et al. Use of Main Renal Artery Clamping Predominates Over Minimal Clamping Techniques During Robotic Partial Nephrectomy for Complex Tumors. *J Endourol*. 2017; 31(2): 149-152.
13. Shao P, Tang L, Li P, Xu Y, Qin C, Cao Q, et al. Application of a vasculature model and standardization of the renal hilar approach in laparoscopic partial nephrectomy for precise segmental artery clamping. *Eur Urol*. 2013; 63(6): 1072-81.
14. Huang J, Zhang J, Wang Y, Kong W, Xue W, Liu D, et al. Comparing Zero Ischemia Laparoscopic Radiofrequency Ablation Assisted Tumor Enucleation and Laparoscopic Partial Nephrectomy for Clinical T1a Renal Tumor: A Randomized Clinical Trial. *J Urol*. 2016; 195(6): 1677-83.
15. Gill IS, Eisenberg MS, Aron M, Berger A, Ukimura O, Patil MB, et al. **"Zero ischemia" partial nephrectomy: novel laparoscopic and robotic technique**. *Eur Urol*. 2011; 59(1): 128-34.
16. Anderson BG, Potretzke AM, Du K, Vetter JM, Bergeron K, Paradis AG, et al. Comparing Off-clamp and On-clamp Robot-assisted Partial Nephrectomy: A Prospective Randomized Trial. *Urology*. 2019; 126: 102-109.
17. Simone G, Tuderti G, Anceschi U, Ferriero M, Costantini M, Minisola F, et al. "Ride the Green Light": Indocyanine Green-marked Off-clamp Robotic Partial Nephrectomy for Totally Endophytic Renal Masses. *Eur Urol*. 2019; 75(6):1008-1014.
18. Shao P, Tang L, Li P, Xu Y, Qin C, Cao Q, et al. Precise segmental renal artery clamping under the guidance of dual-source computed tomography angiography during laparoscopic partial nephrectomy. *Eur Urol*. 2012; 62(6): 1001-8.
19. Shao P, Li P, Xu Y, Cao Q, Ju X, Qin C, et al. Application of combined computed tomography arteriography, venography, and urography in laparoscopic partial nephrectomy with segmental artery clamping. *Urology*. 2014; 84(6): 1361-5.

20. Porpiglia F, Fiori C, Checcucci E, Amparore D, Bertolo R. Hyperaccuracy Three-dimensional Reconstruction Is Able to Maximize the Efficacy of Selective Clamping During Robot-assisted Partial Nephrectomy for Complex Renal Masses. *Eur Urol*. 2018; 74(5): 651-660.
21. Bertolo R, Autorino R, Fiori C, Amparore D, Checcucci E, Mottrie A, et al. Expanding the Indications of Robotic Partial Nephrectomy for Highly Complex Renal Tumors: Urologists' Perception of the Impact of Hyperaccuracy Three-Dimensional Reconstruction. *J Laparoendosc Adv Surg Tech A*. 2019; 29(2): 233-239.
22. Antonelli A, Veccia A, Francavilla S, Bertolo R, Bove P, Hampton LJ, et al. On-clamp versus off-clamp robotic partial nephrectomy: A systematic review and meta-analysis. *Urologia*. 2019; 86(2): 52-62.

Tables

Table 1 Patients' demographics and surgical variables

Variables	3D group (30 cases)	CTA group (30 cases)	p value
Gender, n (%)			0.774
Male	22 (73.3)	21 (70)	
Female	8 (26.7)	9 (30)	
Age (years, mean±SD)	57.6±11.7	56.4±9.8	0.669
BMI (mean±SD)	25.2±2.8	24.9±2.5	0.622
Tumor size (cm, median)	4.0	3.75	0.082
Operative time (min, mean±SD)	125.4±19.7	136.6±15.1	0.017
Estimated blood loss (ml, mean±SD)	130.3±39.9	179.0±77.2	0.003
Hospital stay (days, mean±SD)	5.0±1.1	5.4±1.0	0.114
Pathologic subtype, n (%)			0.543
Clear cell	26 (86.7)	25 (83.3)	
Chromophobe	1 (3.3)	3 (10)	
Papillary	3 (10)	2 (6.7)	
Furhman grade, n (%)			0.740
I	10 (33.3)	12 (40)	
II	16 (53.4)	13 (43.3)	
III	4 (13.3)	5 (16.7)	
Complications , n (%)			0.365
Fever	1 (3.3%)	0	
Hematuria	1 (3.3)	3 (10%)	
eGFR change (ml/min/1.73m ² , mean ± SD)	-8.67±8.8	-10.6±11.5	0.459

Table 2. Tumor characteristics of the patients

Variables	3D group	CTA group	p value
Renal Score, n (%)			0.339
4-6	11 (36.6)	12 (40)	
7-9	17 (56.7)	15 (50)	
10-12	2 (6.7)	3 (10)	
Kidney S system , n (%)			0.949
No. of segments			
1	4 (13.3)	5 (16.6)	
2	15 (50)	14 (46.7)	
3	9 (30)	8 (26.7)	
4	2 (6.7)	3 (10)	
Segments location			0.914
Lateral	10 (33.3)	10 (33.3)	
Medial	6 (20)	6 (20)	
Polar	10 (33.3)	11 (36.7)	
Middle	4 (13.3)	3 (10)	

Table 3. Tumor feeding arteries according to 3D reconstruction of renovascular-tumor, conventional CTA and surgically confirmed findings in 60 patients

Variables	3D group	CTA group	p value
Preoperative findings of tumor feeding arteries, n (%)			0.077
1	15 (50)	22(73.3)	
2	12 (40)	8(26.7)	
3	3 (10)	0 (0)	
No. surgically confirmed findings, n (%)			0.03
0	1 (3.3)	1 (3.3)	
1	16 (53.3)	26 (86.7)	
2	11 (36.7)	3 (10)	
3	2 (6.7)	0 (0)	
Rate of accurately tumor feeding arteries orientation	91.7% (44/48)	84.2% (32/38)	0.285

Figures

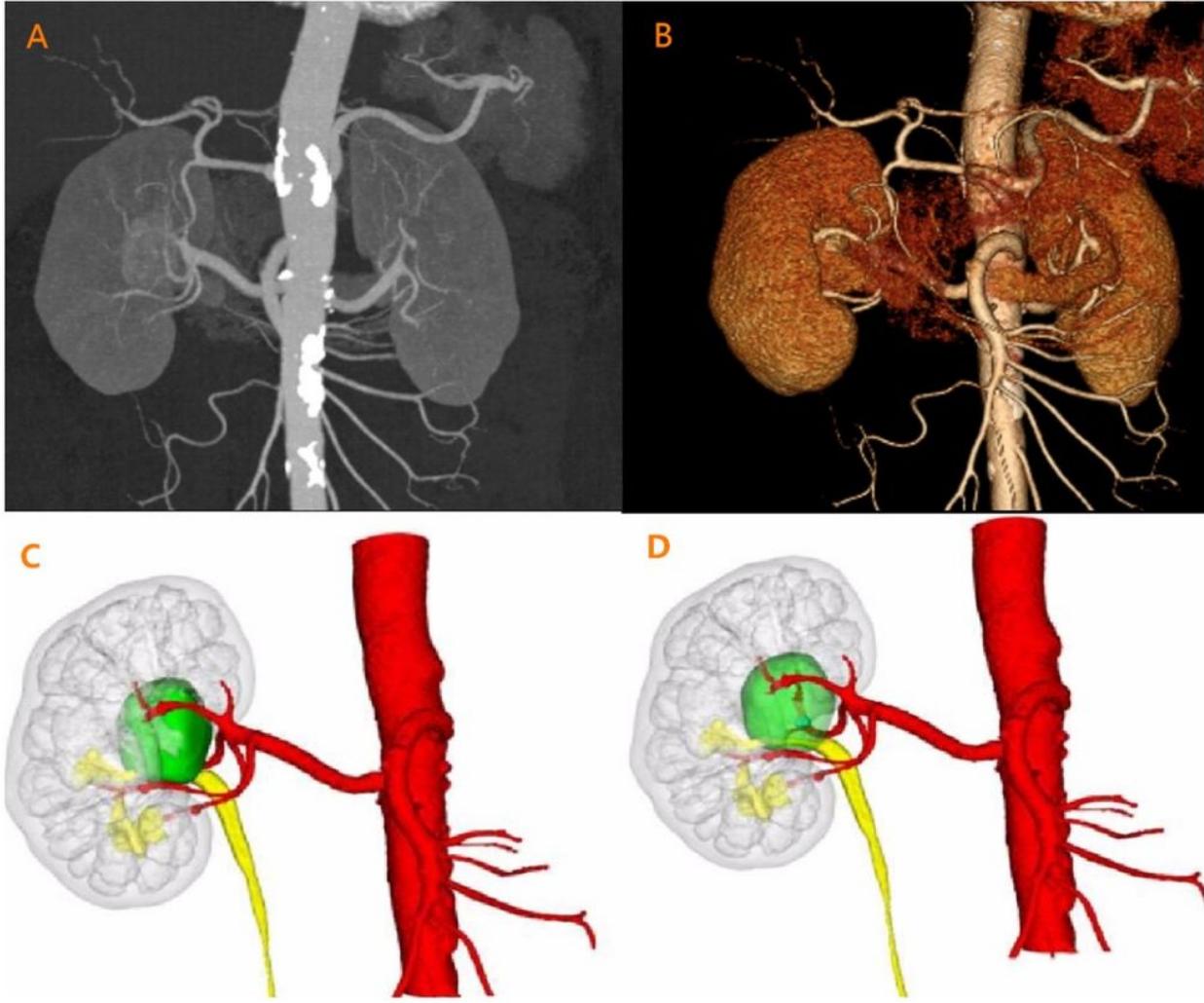


Figure 1

Conventional CTA and 3D reconstruction demonstrated a tumor located at the renal hilum. A: Conventional CTA image could identify extrarenal arteries and the tumor, and sometimes the intrarenal artery branches, but failed to illustrate the relationship between tumor and its feeding arteries. B: Conventional 3D reconstruction based on the CTA could reveal the relationship between kidney, tumor and extrarenal arteries, but it typically present kidney, tumor and renal vessels as opaque, which makes it impossible to visualize the intrarenal anatomy and tumor feeding arteries. C-D: The 3D reconstruction images in our study included transparent kidney and 3D course of extra- and intrarenal tumor feeding arteries (C) and 3D surface rendered semitransparent renal tumor, which make it possible to show the target feeding arteries all around the tumor (D).

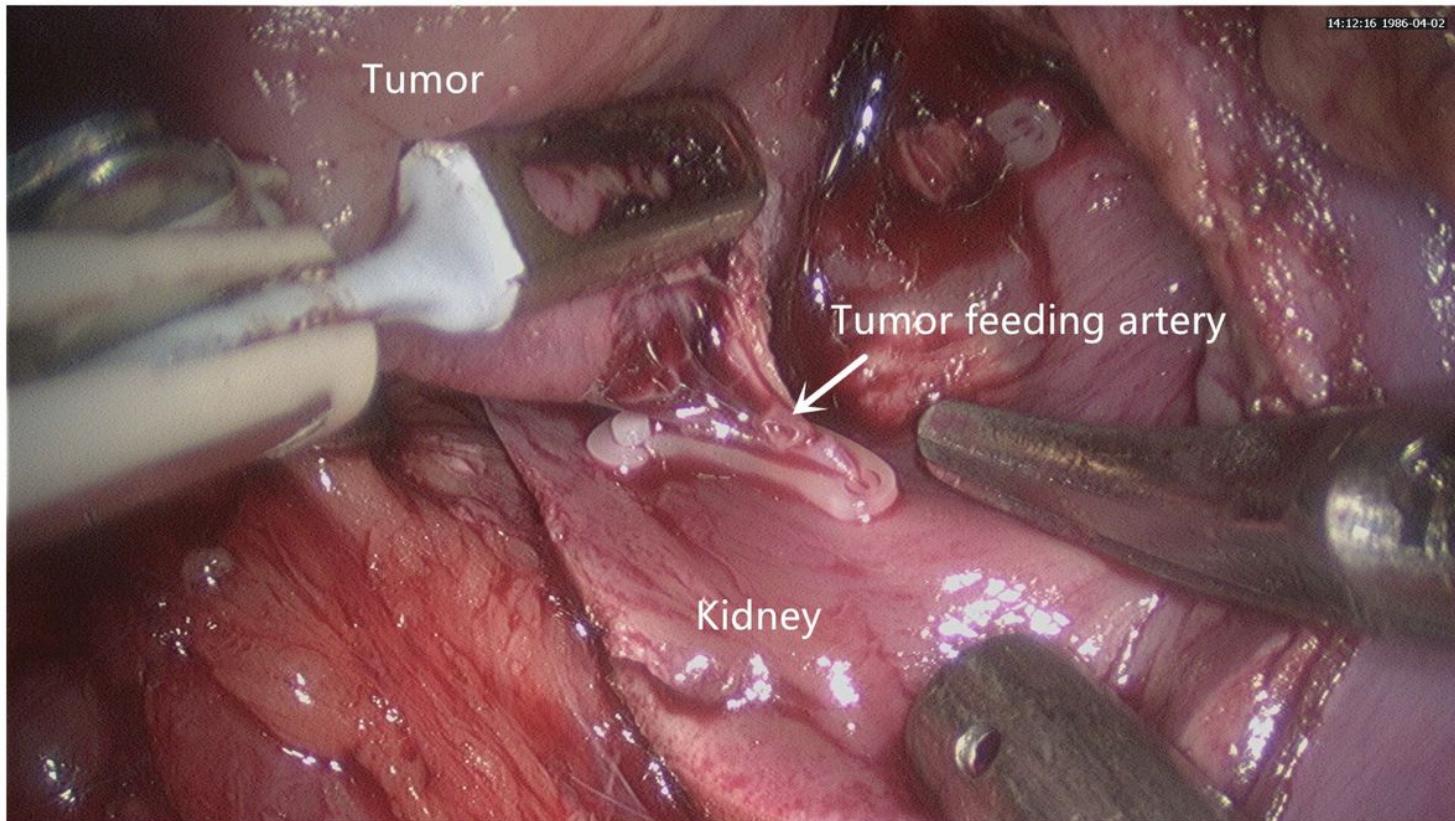


Figure 2

The tumor was excised with blunt dissection along its capsule. Under the guidance of 3D reconstructed images, the tumor specific feeding artery (white arrow) could be identified and then clamped with the Hem-o-lok clips during the operation.