Original Article

Absence of asymptomatic unruptured renal artery pseudoaneurysm on contrast-enhanced computed tomography after robot-assisted partial nephrectomy without parenchymal renorrhaphy

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Abstract *Objective:* To assess the incidence of asymptomatic unruptured renal artery pseudoaneurysm (RAP) on contrast-enhanced computed tomography (CE-CT) after robot-assisted partial nephrectomy (RAPN) without parenchymal renorrhaphy.
Methods: From May 2016 to December 2017, 78 patients underwent RAPN for renal tumors. Inner suture was performed in the opened collecting system or renal sinus, whereas parenchymal renorrhaphy was not. For hemostasis, the soft coagulation system was used, and absorbable hemostats were placed on the resection bed. CE-CT was carried out within 7 days after surgery. Data on these patients were prospectively collected. A single radiologist determined the diagnosis of RAP.
Results: Median (range) data were as follows: Patient age, 65 (19−82) years; radiographic tumor size, 30 (12−95) mm; operating time, 166 (102−294) min; warm ischemic time, 16 (7−67) min; and blood loss, 15 (0−4450) mL. One patient (1.6%) required a perioperative blood transfusion. No patient required conversion to open surgery or nephrectomy. CE-CT was carried out

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at median 6 (3−7) days after surgery. CE-CT showed no RAP development in all 61 patients. Urinary leakage was not observed. One patient had acute cholecystitis, a postoperative complication classified as Clavien-Dindo grade higher than 3, which was treated with cholecystectomy. Positive surgical margin was identified in four patients (6.6%).

Conclusion: RAPN using soft coagulation and absorbable hemostats without renorrhaphy appears to be feasible and safe. Our technique could eliminate the risk of RAP.

1. Introduction

Today, partial nephrectomy (PN) has been a standard option for small renal tumors. PN has been used widely with various indications because it has the same oncological outcomes as radical nephrectomy, and in view of the renal function, it decreases overall mortality and cardiovascular events and deaths [1,2].

Meanwhile, the complication rate of laparoscopic partial nephrectomy (LPN) remains higher than that of open partial nephrectomy [3], of which renal artery pseudoaneurysm (RAP) can be a life-threatening complication, even if it is asymptomatic, depending on the degree of bleeding [4,5]. Moreover, at Kobe City Medical Center General Hospital, we performed LPN between 2002 and 2016, and of the 130 patients who underwent parenchymal renorrhaphy, six (4.6%) patients developed symptomatic RAP and then underwent transarterial embolization. RAP is less frequent, but previous reports stated that the incidence of asymptomatic unruptured RAP was higher than expected, at 15.0% [6] and 21.7% [7]. The latter report was about laparoscopic or robotic PN, which included parenchymal renorrhaphy that caused RAP. Considering the results, we performed PN without parenchymal renorrhaphy, and used soft-coagulation system and absorbable hemostats for hemostasis of the resection bed. Hence, this study aimed to examine the presence of asymptomatic unruptured RAP on contrast-enhanced computed tomography (CE-CT) after robot-assisted PN (RAPN) using our surgical approach.

2. Patients and methods

2.1. Patient population

From May 2016 to December 2017, 78 patients underwent RAPN for renal tumors at our institution. Seventeen patients were excluded because CE-CT was ineligible for some reasons, such as asthma, allergy to contrast medium, or renal dysfunction. Finally, 61 patients were examined. Tumor size and diameter (mm) were determined by CT. Perioperative complications were graded by the Clavien-Dindo classification [8]. This study was approved by the Institutional Review Board of Kobe City Medical Center General Hospital. Waiver of informed consent was obtained given the nature of the study.

2.2. Surgical technique

All operations were performed using da Vinci Si® robotic platform (Intuitive Surgical, Inc., Sunnyvale, CA, USA). Six or seven ports were placed, of which two or three were for the assistant surgeons. Surgeries were performed by four surgeons, and a single surgeon participated in surgery for all cases. The approach was chosen depending on the tumor location. The transperitoneal approach is generally used for lesions located anterior to or within the kidney. In contrast, the retroperitoneal approach is used for lesions located posterior to or outside the kidney. If appropriate, we chose the latter approach as much as possible. In general, an extra-arm was used. No ureteral catheters were used. An intraoperative ultrasonography probe (L43K®: Hitachi, Tokyo, Japan) was used to confirm the margins of the tumor. Briefly, the renal hilum was dissected, allowing individual clamping of renal arteries. The resection margin was delineated with ultrasound guidance. Unclamping RAPN was indicated for tumor depth at around 10 mm into the renal parenchyma. In clamping method, bulldog clamps were used for renal artery clamping, and the decreasing blood flow to the tumor was checked by ultrasonography. The tumor was bluntly dissected and enucleated with thin margin to preserve the normal parenchyma as much as possible. Only when the collecting system or renal sinus was opened, it was repaired by inner running suture (15 cm 3-0 V-Loc 180 V20: Covidien, New Haven, CT, USA). After inner suture, the clamps (if used) were removed. As a rule, parenchymal renorrhaphy was not performed. For hemostasis, the soft-coagulation system of VIO 300D (ERBE Elektromedizin GmbH, Tübingen, Germany) was used with the effect level set at 7 and output of 80 W, using ball-type electrode, and absorbable hemostats (TachoSil®; CSL Behring, Tokyo, Japan) were placed on the resection bed.

2.3. CT imaging and analysis

To assess the incidence of asymptomatic RAP, routine CE-CT was carried out after RAPN within 7 days after surgery. CT examination was carried out using 750 HD (GE Medical Systems Japan, Tokyo, Japan) and Aquilion ONE (TOSHIBA Medical Systems, Tochigi, Japan). Then, 600 mg/kg of non-ionic iodine contrast agent was administered. The injection rate was 3 mL/s. The bolus tracking method was used: The early arterial phase was taken 10 s after the CT value of the bifurcation level of the celiac artery of the abdominal aorta reached +150 HU. A single radiologist diagnosed the

presence of RAP on the grounds that the vascular stump at the resection bed was expanded like a nodule.

3. Results

Patient characteristics were detailed in Table 1. The mean (range) patient age was 65 (19—82) years, mean radiographic tumor size was 30 (12—95) mm, and the radius (tumor size as maximal diameter), exophytic/endophytic properties of tumor, nearness of tumor deepest portion to collecting system or sinus, anterior/posterior descriptor and location relative to polar line (R.E.N.A.L.) nephrometry scores were 4—6 in 23 patients (37.7%), 7—9 in 26 patients (42.6%), and 10—12 in 12 patients (19.7%). An

Table 1 Patients' characteristics.

Characteristics	Data
Patients, n	61
Age, mean (range), year	65 (19—82)
BMI, mean (range), kg/m^2	24.6 (19.0—41.6)
Charlson comorbidity index, mean (range)	2 (2—10)
Tumor side, n	
Left	35
Right	26
Tumor size, mean (range), mm	30 (12—95)
R.E.N.A.L. score, n (%)	
Low (4—6)	23 (37.7)
Moderate (7—9)	26 (42.6)
High (10—12)	12 (19.7)

BMI, body mass index; R.E.N.A.L., radius (tumor size as maximal diameter), exophytic/endophytic properties of tumor, nearness of tumor deepest portion to collecting system or sinus, anterior/posterior descriptor and location relative to polar line.

Table 2 Perioperative outcomes.

Variables	Data
Approach, n	
Transperitoneal	28
Retroperitoneal	33
Operating time, mean (range), min	166 (97—294)
Consol time, mean (range), min	98 (27—227)
Blood loss, mean (range), mL	15 (0—4450)
Warm ischemic time, mean (range), min	16 (7—67)
Renal artery clamp, n	
Total	47
Selective	7
Unclamp	7
Inner suture, n (%)	38 (62.2)
Conversions, n	0
Transfusions, n (%)	1 (1.6)
CE-CT follow-up time, mean (range), day	6 (3—7)
Postoperative hospital stay, mean (range), day	7 (3—11)

CE-CT, contrast-enhanced computed tomography.

antithrombotic drug was administered orally in 11 patients (18.0%), but in all cases, the surgery was performed with continuation.

Table 2 showed the perioperative outcomes. Mean (range) data were as follows: Total operating time, 166 (97—294) min; console time, 98 (27—227) min; warm ischemic time, 16 (7—67) min; blood loss, 15 (0—4450) mL. Only one patient (1.6%) required perioperative blood transfusion. Total and selective clamping methods were performed in 47 and seven cases, respectively, but in seven cases, clamping was not performed. No case was converted to open surgery and nephrectomy.

Table 3 shows the pathological findings. Overall, 58 (95.1%) patients were diagnosed with malignancy. Positive surgical margin (PSM) was found in four cases (6.6%).

Data on 30-day postoperative complications by events were presented in Table 4. A major complication of Clavien-Dindo grade 3 or higher was found, that is, cholecystitis, requiring cholecystectomy. CE-CT was carried out at a median of 6 (3—7) days after surgery, and no RAP was reported in 61 patients. Urinary leakage was not observed.

4. Discussion

Previous reports stated that the incidence rate of RAP after PN was at 1%—5% [9], and the incidence of RAP after LPN was reported to remain higher than that after open PN [10—12]. These studies reported that RAP can be a life-threatening complication depending on the degree of bleeding and should not be ignored. Furthermore, Takagi et al. [6] and Omae et al. [7] have reported that the incidence rates of asymptomatic unruptured RAP on CE-CT after PN were 15.0% and 21.7%, respectively. The frequency of asymptomatic unruptured RAP can be said to be higher than expected. While RAPN is increasingly

Table 3 Pathological reports.

Variables	Data
Malignant, n (%)	58 (95)
Pathological stage, n	
T1a	49
T1b	6
T2a	1
T3a	2
Fuhrman grade, n	
1	16
2	37
3	3
4	2
Histology, n	
Clear cell RCC	53
Chromophobe RCC	2
Papillary RCC	3
Angiomyolipoma	1
Oncocytoma	1
Others	1
Positive surgical margin, n (%)	4 (6.6)

RCC, renal cell carcinoma.

Table 4   Details of 30 days postoperative complications by events.

Complications	Clavien-Dindo Grade 1—2, n	Clavien-Dindo Grade 3—5, n
Fever after 3 days postoperative	3	0
Superficial incisional SSI	1	0
Upper arm pain	1	0
Respiratory failure	1	0
Cholecystitis	0	1
Urinary leakage	0	0
RAP	0	0

RAP, renal artery pseudoaneurysm; SSI, surgical site infection.

performed, it is important to establish a safer procedure that can avoid such complications.

RAP after PN occurred at mean 14.9 days [9], but since it may appear within 1—90 days, care should be taken up to about 3 months after surgery. Symptoms of RAP were reported in 97% of cases. The most common symptoms were gross hematuria (87.3%), and others were flank pain and anemia [9].

The etiology of RAP after PN is believed to be direct injury to a segmental branch of the renal artery [13]. Moreover, Singh and Gill [11] proposed two mechanisms for the occurrence of RAP. First, it is an inadvertent vascular injury that occurs during tumor resection, which particularly required resection of the deep parts of the tumor. Second, it is a vascular injury during parenchymal renorrhaphy. When patient activities increase a few days after surgery, blood flow to the surgical wound increases, and blood accumulates outside the blood vessels and then forms an aneurysm [14].

In general, parenchymal renorrhaphy is performed to prevent hemorrhage and urinary leakage, but it is ideal to omit parenchymal renorrhaphy to reduce the risk of RAP. At Kobe City Medical Center General Hospital, we performed LPN between 2002 and 2016. Of the 130 patients who underwent parenchymal renorrhaphy, six patients (4.6%) who developed symptomatic RAP underwent transarterial embolization. Consequently, we performed PN without parenchymal renorrhaphy and used soft-coagulation system for hemostasis of the resection bed. The safety and effectiveness of the soft-coagulation system for PN without parenchymal renorrhaphy was reported by Ota et al. [15]. The soft-coagulation system of VIO 300D was used with the effect level set at 7 and output of 80 W, using ball-type electrode to increase the contact area with the resection bed. Due to the high effect setting, the voltage rises and the electric current is quickly transmitted to the tissue, and the coagulation is completed at a shallow depth, so there is less damage to the normal parenchyma. Additionally, for hemostasis, TachoSil® was used as absorbable hemostats. TachoSil® was placed on the resection bed as dry as possible and pressed for 3—5 min after soft-coagulation.

The incidence rates of RAP requiring transarterial embolization after RAPN are 1.1% and 1.0% according to the studies of Tanagho et al. [16] and Scoll et al. [17], respectively. However, considering that the frequency of asymptomatic unruptured RAP is higher than expected (previous reported 15.0% [6] and 21.7% [7]), in the present study, we had no case of asymptomatic unruptured RAP. This is because parenchymal renorrhaphy was not performed, and blunt dissection was carried out as much as possible during tumor resection. PN without parenchymal renorrhaphy makes it possible to reduce the chances of vascular injury due to blind suture and further enables proper hemostasis of the resection bed after declamping. The following two aspects can be also considered merits of blunt dissection during tumor resection. First, blunt dissection results in a more flattened resection bed than in sharp incision with scissor forceps. As a result, it is easy to recognize the exposed blood vessels on the resection bed. Furthermore, the contact between the soft-coagulation electrode and resection bed is improved; thus, coagulation hemostasis can be effectively performed. Second, blunt dissection makes it possible to quickly identify and handle before damaging the tumor feeding vessels and to reduce the chance of unnecessary vascular injury.

In addition, in the present study, no urinary leakage was observed. Previous studies reported that the incidence rate of urinary leakage after RAPN is 1.1%—12.5% [16,17]. This finding is the reason that when the collecting system was opened, the inner suture was reliably performed because the opened urinary tract can be identified easily due to the flattened resection bed by blunt dissection and stereoscopic viewing with an expanded view of the robotic surgery. Furthermore, blunt dissection can prevent cutting of the urinary tract and further make it possible to handle the tumor and the urinary tract in layers that are prone to peeling. The urinary tract may be closed by soft coagulation of the resected bed in case of very small injury. If reliable hemostasis and reliable urinary tract closure can be performed, parenchymal renorrhaphy is unnecessary. Our procedure can make it possible.

In this study, PSM was found in four cases (6.6%). This rate was relatively higher than that in other reports [18,19]. PSM was defined as the presence of tumor at the specimen edge, diagnosed by pathologists in our institution. In two cases, which were our initial cases, the tumors were cut into incidentally during the enucleation because of early experience blunt dissection. One case was upgraded to pT3a, and another case was the cT1b case, which had an arteriovenous fistula around the tumor, and during the enucleation, due to poor vision by bleeding, this tumor was fractured by suppressing.

There were some issues with routine CE-CT. Radiation exposure owing to CE-CT could increase the risk of secondary malignancy. The required radiation dose for a multiphase abdominal and pelvic CT was 31 mSv [20], but it is hard to explain that secondary malignancy is induced by one additional CT session. The contrast medium could induce allergic reactions. Despite the aforementioned problems, the present study was a meaningful report showing that omitting parenchymal renorrhaphy may reduce the risk of asymptomatic unruptured RAP on postoperative routine CT after RAPN.

The present study had several limitations. First, it was an analysis conducted in a single center with a small number of cases. Second, whether the incidence of symptomatic RAP can be used to predict asymptomatic RAP was

unknown. Third, diagnosis of RAP was performed by a single radiologist, but no cutoff RAP size was set. Fourth, about unruptured RAP, it was not compared with RAPN with parenchymal renorrhaphy. Fifth, patients with renal impairment, patients allergic to contrast medium, or patients with asthma were excluded from the study.

5. Conclusion

RAP is a life-threatening complication depending on the degree of bleeding and should never be ignored. While RAPN is widely performed, it is important to establish a procedure that can avoid such complications. Our findings suggest that a surgical approach with blunt dissection and soft-coagulation system and without parenchymal renorrhaphy is feasible and reduces the incidence of RAP.

Author contributions

Study design: Yoichiro Tohi, Mutsushi Kawakita.
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Drafting of manuscript: Yoichiro Tohi.
Critical revision of the manuscript: Yoichiro Tohi, Mutsushi Kawakita.

Conflicts of interest

The authors declare no conflict of interest.

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