ORIGINAL

The role of postoperative ultrasonography in the early detection of renal artery pseudoaneurysms after robot-assisted partial nephrectomy

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Abstract : INTRODUCTION : The presence of renal artery pseudoaneurysms, a complication after robot-assisted partial nephrectomy, was evaluated by abdominal ultrasonography. The incidence of renal artery pseudoaneurysms detected by abdominal ultrasonography and the usefulness of abdominal ultrasonography for evaluation after partial nephrectomy were also examined. METHODS : A total of 73 patients who underwent robot-assisted partial nephrectomy between September 2020 and June 2023 and who underwent abdominal ultrasonography on postoperative day 7 to screen for renal pseudoaneurysms were retrospectively reviewed. RESULTS : Ultrasonography after partial nephrectomy showed the presence of renal artery pseudoaneurysms in 3 of 73 patients (4.1%). One of the patients with a renal artery pseudoaneurysm was diagnosed with a large, 15-mm renal artery pseudoaneurysm on postoperative day 7, followed by hematuria with blood clot on postoperative day 10, but the bleeding was stopped by vascular embolization, and the patient had a good course. Two other patients were diagnosed with 20-mm and 16-mm renal artery pseudoaneurysms on postoperative day 7 ; they were carefully monitored, and the pseudoaneurysms disappeared and regressed by CT or ultrasonography. One of the 73 patients in this study had an intravesical hemorrhage on the 8th postoperative day and underwent emergency embolization. The results of this study showed that renal artery pseudoaneurysms as small as 15 mm in diameter can be identified. CONCLUSION : The present results suggest that screening ultrasonography is useful in identifying renal pseudoaneurysms in the early postoperative period after partial nephrectomy. J. Med. Invest. 73 : 106-110, February, 2026

Keywords **:** *renal artery pseudoaneurysm, robot-assisted partial nephrectomy, abdominal ultrasonography, early detection*

INTRODUCTION

Partial nephrectomy is recommended for small-diameter renal tumors because the cancer-control performance of partial nephrectomy is comparable to that of nephrectomy, and nephrectomy is associated with a worse prognosis for patients due to complications from renal dysfunction (1, 2). Recent guidelines also recommend partial nephrectomy for T1a tumors 4 cm or smaller when possible, and partial nephrectomy for T1b tumors 4 to 7 cm in size when possible (3). However, there is a risk of postoperative bleeding and urine leak as complications of partial nephrectomy. The incidence of postoperative renal pseudoaneurysm in partial nephrectomy is approximately 1-3%, and it usually occurs within the first 14 days after surgery (4). The most common cause of postoperative bleeding is considered to be a renal pseudoaneurysm, but arteriovenous fistulas have also been reported (5). We actively perform robot-assisted partial nephrectomy (RAPN) and use ultrasonography to evaluate postoperative complications. Ultrasonography is less invasive and can evaluate blood flow information including pseudoaneurysms and arteriovenous fistulas without the use of contrast media. This study retrospectively investigated the incidence of pseudoaneurysms in 73 patients who underwent robot-assisted partial nephrectomy (RAPN) at our hospital between September 2020 and June 2023, and evaluated the usefulness of ultrasonography in detecting renal pseudoaneurysms.

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METHODS

Patient Background

Seventy-three patients who underwent RAPN at Tokushima University Hospital between September 2020 and June 2023 were included. All patients underwent ultrasonography one week after surgery, and they were evaluated for abnormal findings including renal pseudoaneurysms.

Ultrasonography

In this study, all examinations were carried out by ultrasound technicians who have specialist qualifications in ultrasound examinations for urological disorders. The ultrasonography system was a GE LogiqE10 C1-6 convex probe or L2-9 linear probe (GE Healthcare, Chicago, IL, USA). Color Doppler and pulsed Doppler methods were used to determine the presence of renal pseudoaneurysms. A pseudoaneurysm was diagnosed when B-mode ultrasound showed a non-echoic area close to the renal parenchyma, and color Doppler showed mosaic blood flow in the same area.

Surgical technique of RAPN

All partial nephrectomies were performed using the da Vinci Xi robotic platform (Intuitive Surgical, Inc., Sunnyvale, CA, USA). Five ports were placed, four for the da Vinci Xi and one for the assistant. All surgical procedures were performed by a team of three surgeons (a lead surgeon and two assistants) who are certified in the the da Vinci Xi robotic platform. The approach was selected according to tumor location, with the transperitoneal approach usually used for anteriorly located lesions and the retroperitoneal approach for posteriorly located lesions. A ureteral catheter was used in cases where the collecting system was expected to be open preoperatively. In robot-assisted surgery, the renal hilum was first dissected to allow clamping of individual renal arteries. An intraoperative ultrasound probe (L43K : Hitachi, Tokyo, Japan) was used to identify the tumor margins. The clamping technique involved either total or partial clamping of the renal artery. After ultrasonography confirmed that blood flow to the kidney was reduced, the renal tumor was resected through an incision with a margin around the tumor. The blood vessels entering the tumor were managed by an assistant using a Hem-o-lok clip ML. For renal parenchymal suture (suture of the inner and outer layers), the tumor bed was sutured with 15 cm of 3-0 V-Loc 180 CV23 (Covidien, New Haven, CT, USA). After the inner suture, the outer layer was sutured with 30 cm of 2-0 V-Loc 180 GS21 (Covidien). The clamp on the renal artery was removed to check for bleeding. Factor XIII with fibrinogen was applied to the surface after hemostasis was completed.

Statistical analysis

Intraoperative blood loss was recorded at the end of the procedure. Tumor complexity was defined by the RENAL nephrometry score. All statistical analyses were performed using SPSS® Statistics Grad Pack 29.0 software (SPSS Inc., Chicago, IL, USA). Quantitative parameters were evaluated using Mann-Whitney's U test, and P values less than 0.05 were considered significant.

RESULTS

Table 1 shows the characteristics of the patients in the entire cohort. The mean age of patients at surgery was 64 years, and the gender ratio was 72.6% male and 27.4% female. The mean preoperative eGFR was 71.5 mL/min/m^2 (range 61.0-82.0 mL/min/m^2). The distribution of the RENAL nephrometry score was 40% low, 54% medium, and 6% high. Tumors >4 cm in diameter were included in 11% of the cases. The distance between the tumor and the urinary tract and renal sinus was less than 4 mm in 58% of cases, and the tumor was located in the middle of the kidney in 27% of cases. A total of 66 patients (90%) were diagnosed with malignant tumors.

Screening ultrasonography performed one week after surgery showed a pseudoaneurysm in 3 of 73 patients (4.1%). In one other patient, a pseudoaneurysm could not be detected by abdominal ultrasonography on the seventh postoperative day, and it was subsequently diagnosed on closer examination.

Table 1. Patient characteristics and surgical outcomes

Number of patients	73
Pseudoaneurysm, n (%)	4 (6)
Mean age, y (median, range)	64 (67, 36-84)
Mean body mass index, kg/m^2 (median, range)	25 (24, 17-42)
Sex, n (%)	
Male	53 (72.6)
Female	20 (27.4)
Mean preoperative eGFR, ml/min/m^2 (median, range)	71.5 (71.0, 31.0-133.0)
Mean eGFR before discharge, ml/min/m^2 (median, range)	64.1 (63.0, 30.0-110.0)
Mean eGFR after one month, ml/min/m^2 (median, range)	64.8 (65.0, 30.0-146.0)
ASA score, n (%)	
1	8 (11)
2	63 (86)
3	2 (3)
RENAL score, n (%)	
4-6	30 (41)
7-9	39 (53)
10-12	4 (6)
Mean surgery time, min (median, range)	261 (243, 119-449)
Mean total ischemia time, min (median, range)	27 (26, 9-66)
Surgical approach, n (%)	
Transversal	39 (53)
Retroperitoneum	34 (47)
Length of stay, days (Median, range)	12 (11, 8-23)
Pathological, n (%)	
Renal cell carcinoma	66 (90)
Benign lesion	7 (10)

Two of 29 patients (7%) with a low RENAL nephrometry score (4-6 points) and 2 of 39 patients (5%) with a medium score (7-9 points) were diagnosed as having a renal pseudoaneurysm. Four patients with a high score (10-12 points) did not develop renal pseudoaneurysms. In the four patients diagnosed with renal pseudoaneurysms in the present study (Table 2), in Case 1, a renal pseudoaneurysm could not be identified on postoperative day 7 by ultrasound examination. However, on the eighth postoperative day, the patient complained of macroscopic hematuria, and an angiogram performed for detailed examination showed a renal pseudoaneurysm, and embolization was performed (Figure 1). In Case 2, a renal pseudoaneurysm was diagnosed by ultrasonography on the seventh postoperative day, but the patient was asymptomatic and was followed up for observation. However, hematuria was observed on the 10th postoperative day, and vascular embolization was performed (Figure 2). Cases 3 and 4 were diagnosed as renal pseudoaneurysms by ultrasonography on the seventh postoperative day, but they were asymptomatic and were followed up for observation. Subsequent ultrasonography and contrast-enhanced computed tomography (CECT) confirmed the disappearance of the pseudoaneurysms.

Table 3 shows comparison of patient background and surgical factors according to the presence (n=4) or absence (n=69) of pseudoaneurysms. The analyzed factors such as patient age, BMI, renal function, RENAL score, operative time, blood loss, and ischemia time were not significantly different between the two groups.

DISCUSSION

A pseudoaneurysm after partial nephrectomy is a rare but potentially fatal complication. In a previous report, the incidence of pseudoaneurysm after partial nephrectomy was reported to be 1-5% (6-11). Netsch *et al*. reported that the incidence of pseudoaneurysm after partial nephrectomy was 1.4% (4 of 289) after

Table 2. Patient background and treatment methods for patients with pseudoaneurysm

Patient	Age (y)	Sex	Laterality	Aneurysm size (mm)	Tumor size (mm)	Nephrometry score					Symptom	Treatment
						Total	R	E	N	L		
1	79	Male	Left	1.5	17	5	1	1	1	2	Hematuria	TAE
2	51	Male	Right	15	23	8	1	2	2	3	Hematuria	TAE
3	61	Male	Left	20	15	7	1	3	2	1	No	Observation
4	69	Male	Right	16	15	4	1	1	1	1	No	Observation

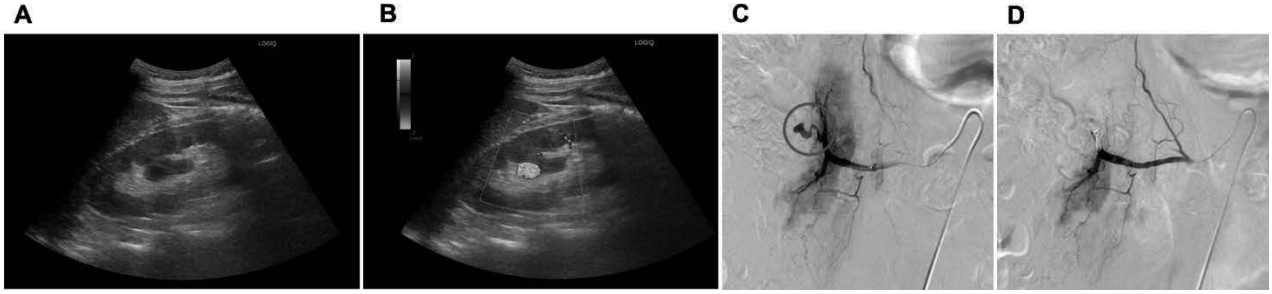

Figure 1. Renal artery pseudoaneurysm identified by screening with ultrasound examination (patient 2). (A) On postoperative day 7, a 15 mm anechoic area was observed within the kidney using the B-mode method in ultrasonography. (B) The same area exhibited a mosaic blood flow pattern on color Doppler imaging. (C) On postoperative day 10, an angiographic examination revealed an abnormal blood flow with saccular dilation, leading to a diagnosis of renal artery pseudoaneurysm. (D) Coil embolization was performed, and the disappearance of the abnormal blood flow was confirmed.

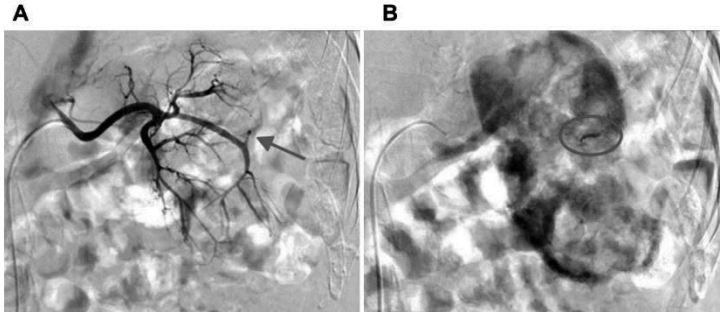

Figure 2. Renal artery pseudoaneurysm not identified by screening with ultrasound examination (patient 1). (A) On postoperative day 7, no obvious abnormalities were detected on the ultrasound examination. However, on postoperative day 8, following macroscopic hematuria, an angiographic examination revealed a 1.5 mm abnormal blood flow, leading to a diagnosis of renal artery pseudoaneurysm. (B) Coil embolization was performed, and the disappearance of the abnormal blood flow was confirmed.

Table 3. Comparison of patient background and surgical factors according to the presence or absence of pseudoaneurysms

Pseudoaneurysm	Without (n=69)	With (n=4)	p value
	Median (range)	Median (range)	
Age, y	63 (36-84)	56 (51-61)	0.875
Tumor size, mm	25 (9-61)	19 (15-23)	0.200
BMI, kg/m^2	25 (17-36)	25 (21-28)	0.923
Preoperative eGFR, ml/min/m^2	71 (35-133)	92 (89-94)	0.528
Pre-hospitalization eGFR, ml/min/m^2	65 (33-110)	64 (62-66)	0.326
One month after surgery eGFR, ml/min/m^2	65 (33-146)	74 (66-81)	0.956
Length of stay, days	11 (8-23)	12 (11-12)	0.087
ASA score	2 (1-3)	2 (2-2)	0.626
RENAL score	7 (4-10)	9 (8-9)	0.721
R	1 (1-2)	1 (1-1)	0.474
E	1 (1-3)	3 (2-3)	0.684
N	3 (1-3)	2 (3-3)	0.638
L	2 (1-3)	2 (1-3)	0.825
Surgery time, min	243 (119-449)	350 (302-397)	0.156
Ischemia time, min	25 (9-54)	52 (38-66)	0.116
Blood loss, mL	20 (0-90)	28 (5-50)	0.970

open resection and 10% (4 of 40) after laparoscopic resection (6). Similarly, Ghoneim *et al*. reported incidences of 0.6% (7 of 1160) after open resection and 2.6% (8 of 301) after laparoscopic resection (5). Gill *et al*. reported a 2 to 3-fold decrease in the incidence of pseudoaneurysms and postoperative bleeding with experience and procedural modifications, including the introduction of robotic technology (12, 13). In a study in which all patients underwent CECT on day 4 after partial nephrectomy with the aim of detecting renal pseudoaneurysms in the early postoperative period, 17 of 117 patients (14.5%) were found to have them (4).

In these reports, the diagnosis of pseudoaneurysm after partial nephrectomy was made by CECT or angiography. However, both CECT and angiography are highly invasive examinations because they require the use of contrast media and radiation exposure. In contrast, ultrasonography is highly versatile, has excellent real-time performance, and can evaluate pseudoaneurysms and arteriovenous fistulas without the use of contrast media. Furthermore, the resolution of ultrasonography has improved with the development of equipment, and even small lesions can be detected more frequently. Previous reports have not investigated the use of ultrasonography for screening after partial nephrectomy. We believe that ultrasonography may be sufficient to evaluate pseudoaneurysms after RAPN, and we are evaluating the use of ultrasonography for screening imaging of pseudoaneurysms after RAPN.

In a study using ultrasonography to screen for renal pseudoaneurysms after RAPN at our hospital, we were able to detect renal pseudoaneurysms by ultrasonography in 3 (4.1%) of 73 patients who underwent RAPN between September 2020 and June 2023. The detection rate of renal pseudoaneurysms by ultrasonography in the present study was comparable to that by CECT and angiography (1-5%) in the past. All three patients with renal pseudoaneurysms detected by ultrasonography were asymptomatic. The sizes of the aneurysms were φ15 mm, φ16 mm, and φ20 mm, respectively. In two of the three cases, the pseudoaneurysms disappeared after 2-3 months of follow-up ultrasonography and CECT. One of the three patients who had hematuria with blood clot 3 days after ultrasonography showed a renal pseudoaneurysm and underwent emergency vascular catheter embolization.

The detailed mechanism of pseudoaneurysm formation after partial nephrectomy is not known, but it is assumed that intraoperative resection and suture damage to the renal artery branches are the main causes of hematoma formation (4, 14). Risk factors for pseudoaneurysms after partial nephrectomy include high BMI and large tumor size as patient background factors (4), and renal artery occlusion time, prolonged operation time, and renal sinus exposure have been reported as intraoperative findings (15, 16). In the present study, there was no clear trend in cases with pseudoaneurysms (Table 3).

Pseudoaneurysms have been reported to cause fatal hemorrhage requiring emergency nephrectomy (17), and vascular embolization is the first choice of treatment when diagnosed. However, it has also been noted that pseudoaneurysms after partial nephrectomy may regress spontaneously. Morita *et al*. reported the possibility of bleeding in 28 asymptomatic patients with small pseudoaneurysms of 5 mm or less, two of which required embolization (18). If no clinical manifestations such as gross hematuria, lateral abdominal pain, or anemia are observed, the patient should be followed up with ultrasound or CECT without intervention, and if the pseudoaneurysm increases over time or symptoms appear, treatment such as vascular embolization should again be considered.

One limitation of the present study is the extent to which small pseudoaneurysms can be detected by ultrasonography. In the present study, the size of pseudoaneurysms detected by ultrasonography was approximately 1 to 2 cm. However, in one of the 73 patients, a pseudoaneurysm could not be detected by abdominal ultrasonography on the seventh postoperative day, and macroscopic hematuria occurred on the eighth postoperative day, resulting in emergency vascular embolization. Angiography showed that the size of the renal pseudoaneurysm was about 1.5 mm in diameter, a very small lesion. When detecting a postoperative pseudoaneurysm by ultrasonography, it is possible that a small lesion may be overlooked by B-mode alone. Therefore, we believe that the recognition of abnormal blood flow using not

only the B-mode method, but also by color Doppler and high-sensitivity blood flow evaluation methods is necessary to detect small pseudoaneurysms. After this case, we have been using not only the B-mode method, but also the color Doppler method and high-sensitivity blood flow evaluation method in combination, as well as a linear probe in addition to a convex probe to reduce the number of missed aneurysms.

CONCLUSION

Ultrasonography was performed one week after RAPN, and 3 of 73 patients (4.1%) had pseudoaneurysms, suggesting that screening ultrasonography in the early postoperative period after RAPN can also detect asymptomatic pseudoaneurysms.

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DECLARATIONS

Conflict of interest Rikizo Matsumoto, Kei Daizumoto, Keisuke Ozaki, Asami Yuasa, Susumu Nishio, Tetsuhito Yano, Mitsuki Nishiyama, Saki Kobayashi, Ryoei Minato, Yutaro Sasaki, Ryotaro Tomida, Yoshito Kusuhara, Tomoya Fukawa, Yasuyo Yamamoto, Kunihisa Yamaguchi, Masayuki Takahashi, Hisanori Uehara,Takayoshi Shinya, Hiroomi Kanayama, Junya Furukawa declare that they have no confict of interest.

Ethics approval The institutional review board approved this study (approval number 2400).

Consent to participate All patients provided informed consent

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