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Case Report

Kidney Autotransplantation for Renal Artery Aneurysm: Case Series and a Systematic Review

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Abstract: Objectives: Renal artery aneurysm (RAA) is a rare vascular disease. Kidney autotransplantation (KAT) is the treatment option when endovascular approach is not available. However, the evidence on KAT for RAA is mostly limited to small case series or reports. Here, we describe our 2 center experience of KAT for RAA, and provide the results of our systematic literature review to evaluate the outcomes.

Methods: A retrospective 2 center study was conducted in patients undergoing KAT for RAA between 2010 and 2018. Moreover, a systematic review was performed on medical databases to evaluate the outcomes of KAT for RAA.

Results: Nine patients were surgically treated at our institutions: eight with laparoscopic nephrectomy (LN), and 1 with open followed heterotopic KAT. All RAAs were ex-vivo reconstructed, and in 3 cases a vein graft was used for reconstruction. There were 2 postoperative major complications including 1 graft loss. In the systematic review, 102 studies with 355 patients were included. In 35 patients (9.9%) a minimal invasive approach was performed. The incidence of postoperative major complications and graft loss was 9.4% and 4.1%.

Conclusions: Our experiences showed that laparoscopic approach for nephrectomy followed heterotopic KAT was feasible with good postoperative outcomes. KAT is an effective treatment for RAA when endovascular approach is not feasible for interpretation of the outcomes, the quality and sample size of the evidence should be taken into consideration.

Renal artery aneurysm (RAA) is a rare vascular disease with an incidence of 0.1% in general population and a rate between 0.3% and 2.5% reported by angiographic and computed tomography studies.[1] In addition, the natural course of RAA shows slow to zero growth of aneurysm.[1] Typically, RAA presents in women, in the sixth decade and afflicts more right sided kidneys rather than the left side probably due to high incidence of fibromuscular dysplasia.[2] The diagnosis is performed mostly by computed tomography showing a saccular, calcified lesion accompanied with or without thromboembolism.[1] Indications for treatment of RAA include diameter > 2 cm, female gender within childbearing age, symptoms as pain, hematuria, hypertension refractory to medications, renal artery stenosis, thromboembolism, dissection or rupture that occurs in 2-5% of known aneurysms.[3,4]

The Authors have no conflict of interest to disclose.

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Ann Vasc Surg 2021; 77: 349.e349–349.e14
https://doi.org/10.1016/j.avsg.2021.05.039

Manuscript received: November 12, 2020; manuscript revised: April 10, 2021; manuscript accepted: May 4, 2021; published online: 23 August 2021

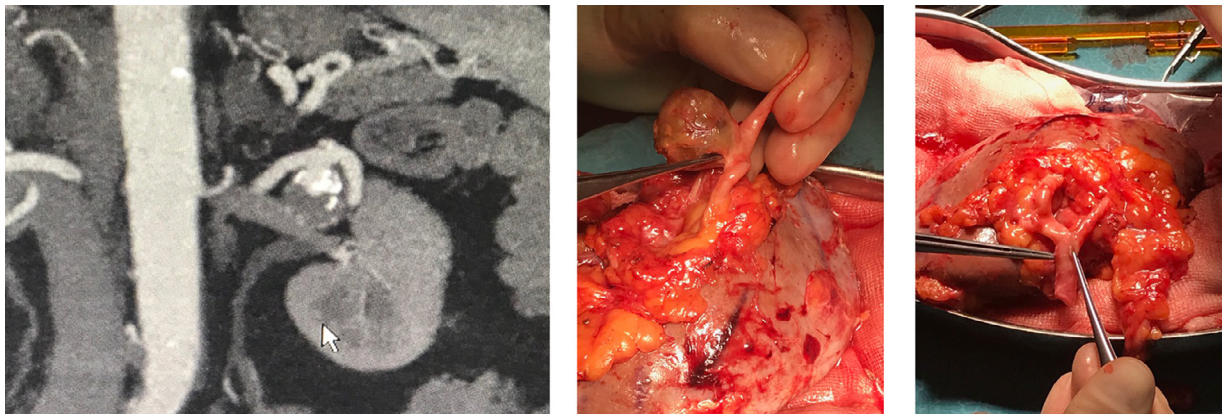

Fig. 1. A case of 68 year-old male with renal artery aneurysm (Case 8). (A) Computed tomography image shows a 3 cm saccular renal artery aneurysm partly thrombosed at the first bifurcation of the left kidney. (B) After laparoscopic nephrectomy of the left kidney, renal artery aneurysm was identified and prepared for ex-vivo renal artery reconstruction on the bench table. (C) After resecting the aneurysm, an end-to-end anastomosis was performed.

Several therapeutic options are available for RAA although there is no consensus regarding standard operative treatment for this disease.[5] Endovascular approaches, including coil embolization, balloon-assisted coil embolization, and stent grafting, in selected cases are effective with successful rates of 73% to 100% reported in large series with variable rates of morbidity (13–60%).[6] Surgical approaches for RAA, reserved for more complex lesions, include in-situ repair, and ex-vivo reconstruction with kidney autotransplantation (KAT).[7] The first report of KAT was in 1961 performed by Shackman and Dempster due to a unilateral renal artery stenosis and 1 year later Hardy *et al.* performed the first KAT for a ureteral injury.[8] Afterwards the adoption of these techniques has increased with recently application of minimal invasive approach. The postoperative hospital stay, pain and time to return to full function decreased with the introduction of laparoscopy in living donor nephrectomy.[9] Pure laparoscopic, hand-assisted or retroperitoneoscopic procedures are reported as minimal invasive techniques suitable for KAT.[3,10] The first experience of laparoscopic KAT series for RAA was reported by Gallagher *et al.* in 2008: seven patients with RAA treated with laparoscopic nephrectomy (LN), ex-vivo repair and KAT using the same Gibson incision for kidney extraction in the iliac fossa.[4] Nevertheless, the current literatures are limited to case reports or small case series with lacking data in terms of outcomes and strategy concerning RAA treatment in large numbers. Furthermore, previous reviews on KAT have reported all different indications without any strict focus on RAA treatment, long-term outcomes or comparison between open and minimal invasive surgical approach.[11-16]

Here, we describe our 2 center experience of KAT for RAA, and provide the results of our systematic review to evaluate the outcomes of KAT for RAA.

METHODS

Study Design

A retrospective 2-center study was conducted in patients undergoing KAT for RAA at the Erasmus MC, Rotterdam, The Netherlands, and the Padua University Hospital, Padua, Italy, between January 2010 and December 2018. This study was approved by the Ethics Committee of the Erasmus MC, and written informed consent for this study was obtained from all patients at the Padua University Hospital. The present study was conducted in accordance with the tenets of the Declaration of Helsinki.

Clinical Data

The following demographic and clinical data of patients were collected: age, gender, comorbidity, symptom, the location of aneurysm, aneurysm diameter and morphology, the type of nephrectomy (laparoscopic or open), type of reconstruction, number of artery branches reconstructed, operative time, blood loss, postoperative complication (evaluated according to the Clavien-Dindo classification[17]), postoperative hospital stay, perioperative creatinine level, and graft survival. Postoperative major complication was defined as the Clavien-Dindo classification with grade III and IV. Graft loss was defined as graft failure with or without nephrectomy, or death. Graft survival was as time from KAT to last follow-up with

normal kidney function. All patients were routinely monitored by laboratory values such as serum creatinine and estimated glomerular filtration rate. If anomalies were found, ultrasound and computed tomography imaging were performed.

Surgical Technique

Patients from the Erasmus MC and the Padua University Hospital were treated with similar laparoscopic approach for nephrectomy, as described previously.[18] In brief during LN, the colon was mobilized and the renal capsule was opened using an ultrasonic device. After identification and dissection of the ureter, the renal artery, and the renal vein, a Pfannenstiel incision was made. The ureter was clipped distally and divided. The renal artery and vein were divided using an endoscopic stapler (EndoGia, US Surgical, Norwalk, USA). The kidney was placed in an endobag and extracted through the Pfannenstiel incision. Afterwards, the kidney was flushed with UW and preserved in static cold storage.

Regarding the ex-vivo aneurysm repair, the first option was an end-to-end anastomosis after resecting the aneurysm. Other options included the use of a venous patch or vein graft after the aneurysmectomy. Kidney implantation was performed in a heterotopic fashion as a standard kidney allotransplantation: through the same kidney extraction incision. The kidney was placed in iliac fossa and vascular anastomosis with iliac vessel was performed. The renal vein was connected to external iliac vein in an end to side fashion (with Prolene 5-0 running suture) and, renal artery was connected to external iliac artery or internal iliac artery respectively in an end-to-side or end-to-end anastomosis (with Prolene 6-0 running suture). Ureteroneocystostomy was arranged with Lich-Gregoir technique with a double J catheter formerly inserted and removed after 4 weeks. One case was treated with open approach, throughout a midline incision.

A SYSTEMATIC LITERATURE REVIEW

Registration

No ethical approval or informed consent statement was required for this review article. The research registration unique identifying number for our research is UMIN000039450.

Search Strategy

The present study was reported in accordance with the Preferred Reporting Items for Systematic Reviewers and Meta-Analyses (PRISMA) guidelines.[19] A systematic literature search of Embase, Medline Ovid, Web of science, Cochrane CENTRAL, and Google scholar was conducted on the May 13, 2019 using the key words of kidney autotransplantation and renal artery aneurysm (see Supplementary Table 1). The search was conducted without any limitations regarding languages and the year of publication.

Inclusion and Exclusion Criteria

The present study included articles reporting data, operative findings and outcomes in patients undergoing KAT for RAA. In cases when multiple studies were published from the same institution, only the study including largest sample sizes with available data was included. Review articles, articles without sufficient data, conference abstracts, comments and animal studies were excluded.

Data Extraction

After removing duplicate records, abstracts were screened independently by 2 investigators (EC and KT) determining papers eligibility for analysis. The full-text articles were subsequently screened to meet the criteria for review. The extracted data included year of study publication, number of cases, patient information (age, gender, symptoms, comorbidity, presence of solitary kidney), operative findings (location, morphology, diameter, etiology of the aneurysm, number of renal branches reconstructed, prior endovascular treatment, nephrectomy and implantation approach, operative time, blood loss, ischemia time, and type of reconstruction) and outcomes (postoperative complications, graft loss, and postoperative hospital stay).

Quality Assessment

The methodological quality and synthesis of case series and case reports were used to evaluate the quality of the included studies.[20]

Statistical Analysis

Data are presented as mean with standard deviation and median with the interquartile range (IQR) for continuous variables. The outcomes between open and LN were compared. Categorical data are represented as proportions. Differences between groups were examined by Fisher's exact test or Chi-square test for categorical variables and the Mann-Whitney U test for continuous variables. JMP (version 11, SAS Institute, Cary, NC) was used for the analysis.

RESULTS

Patients

In total, 9 patients with RAA were surgically treated at each institution from 2010 to 2018. All 9 patients underwent KAT for RAA. The demographic characteristics of 9 patients undergoing KAT for RAA are demonstrated in Table I. Seven patients were treated with pure LN, 1 was with hand-assisted nephrectomy and 1 was with midline laparotomy. The mean age was 60 ± 8 (median 60, IQR 52–66.5) years, 5 patients had hypertension, 2 patients were symptomatic with abdominal pain and in 7 patients the diagnosis was incidental. All aneurysms had a saccular morphology, in 7 patients RAA was located on the left side and 2 on the right side with a mean diameter of 3.6 ± 1.6 (median 3.1, IQR 2.6–4.3) cm. In 1 case, multiple aneurysms were present. No patients had previous history of endovascular procedures for RAA.

In six cases, after resecting the aneurysm, an end-to-end arterial anastomosis was performed, as described in Figure 1. In 3 cases, a vein graft (gonadal or saphenous vein) was used as venous interponate. In a case 3, the gonadal vein was used to replace resected artery between the main renal artery and the branch. In case 4 and 5, the saphenous vein patch was used to cover the removed artery wall. Regarding the implantation of the kidney, an end-to-end anastomosis between renal artery and hypogastric artery was performed in 5 cases, and an end-to-side anastomosis between renal artery and iliac artery was in 4 cases.

Mean operative time was 348 ± 133 (median 370, IQR 203–455) minutes. Five patients had complications: 3 minor complication (wound dehiscence, hydrocele and bowel obstruction) and 2 major complications (acute flogosis of inguinal hernia and vein thrombosis) with 1 graft loss. Mean postoperative hospital stay was 7.4 ± 1.6 (median 8, IQR 6–8.5) days. Mean preoperative creatinine level was 71.1 ± 11.9 (median 67, IQR 64–85) μmol/L, and the creatinine level after a mean follow-up of 15.7 months was 76.7 ± 13.5 (median 79, IQR 65–87) μmol/L. Out of 9 patients, 1 patient was lost to follow-up.

A SYSTEMATIC LITERATURE REVIEW

Search Results and Study Characteristics

A systematic search of the literature identified 706 articles of which 102 articles met our inclusion criteria (Fig. 2). The summary of all included studies and our experiences is represented in Table II. Out of 102 papers, 67 (66%) were single case reports and 5 articles[3,56,68,104,106] were case series with more 10 patients reported. Forty-two papers were published before year 2000. Seventeen articles reported laparoscopic approach for nephrectomy, with the largest laparoscopic series of 7 patients published in 2008[4].

Study Quality Assessment

The methodological quality of included case series is shown in Table II and supplementary Table 2. The mean total score of the included studies was 3 (range 0–5).

Patient Characteristics

There were a total of 355 patients including our cases who underwent KAT for RAA. The study population consisted of 132 (37.2%) males, 171 (48.2%) females, and 52 (14.6%) cases with unavailable data. The mean age was 42.7 years. Open approach for nephrectomy was performed in 320 (90.1%) patients, via a midline, para-median or lumbotomy approach. In contrast, minimal invasive approach was observed in 35 (9.9%) patients with pure laparoscopic, hand-assisted or retroperitoneoscopic technique.

Aneurysm Characteristics

Saccular aneurysm was most frequently observed with a mean diameter of 2.5 cm. The location of aneurysm in 355 patients was as follows: main trunk ($n = 13$, 3.7%), first bifurcation ($n = 113$, 31.8%), first branch, second branch, or intraparenchymal aneurysm ($n = 35$, 9.9%), multiple ($n = 21$, 5.9%), and unknown ($n = 173$, 48.7%).

Type of Aneurysm Repair

Several techniques regarding aneurysm repair were reported.[3,4,23-25] Out of 355 patients, data on type of aneurysm repair were available in 267 patients including 215 with an autologous graft or a synthetic patch. An autologous graft was often used as a patch graft: hypogastric artery, superficial femoral artery, renal artery, saphenous vein, gonadal vein, or ovarian vein. In only 3 cases, a synthetic patch was used.[12,30,73] Aneurysm repair without graft patch was observed in approximately 20% of cases.

Postoperative Outcomes

Data regarding postoperative major complication (Clavien Dindo III or IV) was available in 95 studies

Table I. The demographic characteristics of patients undergoing kidney autotransplantation for renal artery aneurysm at the Erasmus MC and the Padova University Hospital between 2010 and 2018

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
Age/Gender	65/M	49/F	60/F	63/F	58/M	73/M	51/F	68/M	53/F
Comorbidities	NA	NA	Hypertension	Hypertension	Liver hemangioma	Atrial fibrillation, Hypertension	Hypertension	Parkinson, Aortic valve replacement	Nephrolithiasis
Symptoms	Incidental	Incidental	Incidental	Incidental	Incidental	Abdominal pain	Abdominal pain	Incidental	Incidental
Location of aneurysm	Left, First bifurcation	Right, First bifurcation	Left, First bifurcation	Left, First bifurcation	Right, First bifurcation	Left, First bifurcation	Left, Multiple aneurysm	Left, First bifurcation	Left, First bifurcation
Aneurysm diameter (cm)	2.3	2.2	3.3	5	2.8	3.1	7.4	3	3.5
Nephrectomy	Laparoscopic	Open	Laparoscopic	Laparoscopic	Laparoscopic hand assisted	Laparoscopic	Laparoscopic	Laparoscopic	Laparoscopic
Aneurysm repair	Aneurysm resection	Aneurysm resection	Vein graft (gonadal vein)	Vein patch (saphenous vein)	Vein patch (saphenous vein)	Aneurysm resection	Aneurysm resection	Aneurysm resection	Aneurysm resection
Number of branches	NA	2	3	1	1	1	2	2	2
Operative time (min)	270	420	555	465	445	370	202	201	203
Blood loss (ml)	NA	NA	NA	NA	NA	NA	50	200	150
Cold ischemic time (minutes)	NA	NA	NA	NA	NA	NA	65	67	91
Manipulation time (minutes)	NA	NA	NA	NA	NA	NA	34	40	48
Complication*	0	Wound dehiscence (II)	Renal vein thrombosis, Graft loss (IVa)	0	Hydrocele (I)	Inguinal hernia (IIIb)	0	0	Gastrointestinal (II)
Length of stay (days)	6	9	7	10	8	8	5	6	8
Preoperative creatinine (μmol/L)	NA	63	67	66	88	67	87	77	54
Creatinine at last follow-up (μmol/L)	90	70	96	60	79	73	83	84	55
Graft survival (months)	NA	60	0	3	14	12	19	10	17

M, male; F, female; and NA, not available.
*Evaluated according to the Clavien-Dindo Classifications.

Table II. Summary of a systematic literature review

Study	Year	Language	Cases (*n*)	Age (mean)	Gender (M/F)	Location of aneurysm	Nephrectomy	Implantation	Complications	Graft loss (*n*)	Follow-up(months)	Quality
Lawson *et al.*[21]	1974	English	3	34	2/1	2MT/FB	Open	2E/O	1xIVa	1	NA	4
Belzer *et al.*[22]	1975	English	2	44	0/2	FB/L	Open	E/O	0	0	NA	3
Gaylis *et al.*[23]	1975	English	1	58	0/1	FB	Open	E	0	0	12	3
Gelin *et al.*[24]	1975	English	4	42	NA	FB/3NA	Open	4E	1xI	0	NA	5
Archimbaud *et al.*[25]	1975	French	1	48	0/1	FB	Open	E	0	0	1	2
McLoughlin *et al.*[26]	1976	English	2	64	0/2	2FB	Open	2E	1xI/1xII	0	NA	2
Faidutti *et al.*[27]	1976	French	2	31	1/1	2FB	Open	2E	0	0	NA	2
Boijsen *et al.*[28]	1977	English	1	39	0/1	FB	Open	E	0	0	NA	1
Gough *et al.*[29]	1977	English	1	44	0/1	FB	Open	E	0	0	6	4
Javadpour *et al.*[30]	1977	English	1	32	1/0	MT	Open	E	0	0	16	4
McLoughlin *et al.*[31]	1977	English	3	NA	NA	3L	Open	3E	0	NA	NA	2
Hidai *et al.*[32]	1977	Japanese	1	40	0/1	L	Open	E	0	NA	NA	3
Rampal *et al.*[33]	1977	French	1	33	0/1	L	Open	E	Sepsis	NA	NA	3
Salvatierra *et al.*[34]	1978	English	2	38	0/2	FB/L	Open	2E	NA	NA	NA	1
Stoney *et al.*[35]	1978	English	2	37	0/2	2MT	Open	2O	0	0	48	5
Foulon *et al.*[36]	1978	French	1	43	1/0	FB	Open	E	0	0	3	1
Munda *et al.*[37]	1981	English	1	51	0/1	FB	Open	E	0	0	NA	1
Novick *et al.*[38]	1981	English	1	47	0/1	FB	Open	E	0	0	NA	2
Yoshioka *et al.*[39]	1981	Japanese	1	27	0/1	FB	Open	E	0	0	21	4
Mc Donald *et al.*[40]	1983	English	1	36	1/0	FB	Open	E	0	0	51	3
Bugge *et al.*[41]	1984	English	9	35	1/8	5MT/4NA	Open	9E	0	0	31	5
Takaha *et al.*[42]	1984	Japanese	2	NA	NA	2FB	Open	2E	NA	0	NA	4
Takahashi *et al.*[43]	1984	Japanese	1	46	0/1	FB	Open	E	0	0	1	3
Jordan *et al.*[44]	1985	English	2	7.5	1/1	NA	Open	2E	NA	NA	NA	1
Pereversew *et al.*[45]	1988	Germany	4	NA	NA	4FB	Open	4E	NA	NA	NA	3
Haddad *et al.*[46]	1989	English	7	39.2	4/3	7FB	Open	7E	1xIIIb	0	15	5
Martin *et al.*[47]	1989	English	5	37.6	2/3	2L/ 3NA	Open	NA	1xI/1xIIIb	0	84	5
Dayton *et al.*[48]	1990	English	1	18	0/1	FB	Open	E	0	0	NA	2
Van Damme *et al.*[49]	1990	English	1	37	0/1	FB	Open	E	0	NA	NA	2
Creemers *et al.*[50]	1990	French	1	37	0/1	FB	Open	E	0	0	2	3
Aebert *et al.*[51]	1992	Germany	1	53	0/1	MT	Open	E	0	0	3	3
Nakahara *et al.*[52]	1992	Japanese	2	56	2/0	2FB	Open	2E	0	0	12.5	5
Nishimura *et al.*[53]	1992	Japanese	1	47	1/0	FB	Open	E	0	NA	NA	3
Rodríguez *et al.*[54]	1992	Spanish	1	23	1/0	FB	Open	E	0	0	1	4
Shoskes *et al.*[55]	1995	English	1	8	0/1	FB	Open	E	0	0	5	2
Lacombe[56]	1995	French	32	NA	NA	NA	Open	NA	NA	NA	NA	4
Petritsch *et al.*[57]	1995	Germany	2	44	0/2	2FB	Open	2E	0	0	NA	4

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Table II (*continued*)

Study	Year	Language	Cases (*n*)	Age (mean)	Gender (M/F)	Location of aneurysm	Nephrectomy	Implantation	Complications	Graft loss (*n*)	Follow-up(months)	Quality
Toshino *et al.*[58]	1996	English	8	55	4/4	8FB	Open	8E	0	0	NA	4
Watano *et al.*[59]	1996	English	1	25	0/1	Multiple	Open	E	0	0	NA	3
Seki *et al.*[60]	1997	English	9	54	2/7	4FB/4L/Multiple	Open	9E	2xI/ 1xIIIb	0	NA	4
Reiher *et al.*[61]	1998	Germany	4	NA	NA	NA	Open	4E	NA	NA	NA	4
Lee *et al.*[62]	1999	Japanese	1	73	0/1	L	Open	O	0	0	NA	3
Cho *et al.*[63]	2001	English	2	50.5	0/2	2FB	Open	2E	1xIIIa	0	45	4
Lacroix *et al.*[64]	2001	English	1	28	0/1	FB	Open	E	0	0	NA	2
García-Fernández*et al.*[65]	2002	Spanish	1	49	0/1	FB	Open	O	0	0	1	3
Njinou *et al.*[66]	2002	French	1	70	1/0	FB	Open	E	0	0	1	2
El Tayar *et al.*[13]	2003	English	1	35	0/1	NA	Open	E	0	0	12	4
Ysa-Figueras *et al.*[67]	2003	Spanish	7	56	3/4	FB/5L/Multiple	Open	7E	1xII	0	23	5
Varetto *et al.*[68]	2004	English	38	37	20/18	NA	Open	NA	6xIII/1xIVa	2	89	3
Ishida *et al.*[69]	2004	Japanese	1	74	1/0	FB	Open	E	0	0	18	4
Beseth *et al.*[70]	2005	English	1	8	1/0	FB	Open	O	0	0	3	2
Han *et al.*[71]	2005	English	1	13	1/0	L	Open	E	I	0	16	4
Knobloch *et al.*[72]	2005	English	1	46	0/1	FB	Open	O	0	0	NA	3
Kostic *et al.*[73]	2005	English	1	75	1/0	FB	Open	E	0	0	NA	1
Sevmis *et al.*[74]	2006	English	1	48	1/0	L	Open	E	0	0	12	4
Thomas *et al.*[75]	2006	English	1	51	0/1	L	Open	E	0	0	3	3
Unno *et al.*[76]	2007	English	1	57	0/1	FB	LN	E	0	0	NA	2
Lavalle *et al.*[77]	2007	Spanish	1	NA	NA	FB	Open	E	0	0	NA	4
Zhang *et al.*[78]	2007	Chinese	1	53	1/0	FB	Open	E	0	0	0.5	3
Lim *et al.*[79]	2008	English	1	44	0/1	Multiple	Open	E	0	0	6	2
Park *et al.*[80]	2008	English	1	12	0/1	FB	Open	NA	0	0	NA	1
Gallagher *et al.*[4]	2008	English	7	60.7	3/4	NA	LN	7E	1xI/1xIIIb	NA	NA	4
Blanco *et al.*[81]	2008	Spanish	1	48	1/0	FB	LN	E	0	0	6	3
Guo *et al.*[82]	2008	Chinese	1	42	1/0	FB	LN (hand-assisted)	E	0	0	13	4
Ching *et al.*[83]	2010	English	1	64	1/0	L	Open	NA	0	0	NA	0
Øyen *et al.*[84]	2010	English	1	38	0/1	MT	LN	E	0	0	3	3
Shirodkar *et al.*[85]	2010	English	2	52.5	0/2	FB/L	LN	2E	1xI	0	NA	3
Guasch *et al.*[86]	2010	Spanish	1	55	0/1	FB	Open	E	0	0	6	3
Iaitskiĭ *et al.*[87]	2010	Russian	1	39	1/0	FB	Open	NA	NA	NA	NA	3
Desai *et al.*[88]	2011	English	1	64	0/1	FB	LN	E	0	0	24	4
Iwahashi *et al.*[89]	2011	English	1	67	1/0	FB	Open	O	0	0	NA	2
Gabrielli *et al.*[15]	2011	Italian	3	33	1/2	3FB	Open	3E	0	0	1	4

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Table II (*continued*)

Study	Year	Language	Cases (*n*)	Age (mean)	Gender (M/F)	Location of aneurysm	Nephrectomy	Implantation	Complications	Graft loss (*n*)	Follow-up(months)	Quality
Morin *et al.*[90]	2012	English	6	46	1/5	NA	Open	NA	2xII/1xIIIb	0	65	5
Ogawa *et al.*[91]	2012	English	1	42	0/1	FB	LN	E	0	0	32	3
Prajapati *et al.*[92]	2012	English	1	15	1/0	FB	Open	E	I	NA	NA	2
Do Carmo *et al.*[93]	2012	Portuguese	1	61	0/1	FB	Open	O	0	0	NA	3
Batista –Garcia *et al.*[94]	2013	English	1	36	1/0	FB	LN	E	0	NA	NA	1
Forgacs *et al.*[95]	2013	English	3	44.6	0/3	2L/Multiple	Open	3E	1xII	0	72	5
Gutiérrez-Carreño *et al.*[96]	2013	Spanish	7	22-38	4/3	7NA	Open	7E	0	0	NA	2
Berloco *et al.*[12]	2014	English	1	41	0/1	L	Open	E	0	0	10	4
Genzini *et al.*[97]	2014	English	1	48	1/0	FB	Open	E	1xI	0	34	4
King *et al.*[98]	2014	English	1	58	0/1	FB	LN	E	0	0	1	3
Palcau *et al.*[99]	2014	English	1	22	0/1	L	Open	E	0	0	3	3
Sullivan *et al.*[100]	2014	English	1	35	0/1	FB	Open	E	0	0	10	2
Tozzi *et al.*[101]	2014	English	1	53	1/0	L	LN	E	0	0	6	4
Gui *et al.*[102]	2015	English	1	28	0/1	L	Open	O	0	0	8	2
Li *et al.*[103]	2015	English	1	57	1/0	FB	Open	O	NA	0	12	2
Laser *et al.*[104]	2015	English	14	54	4/10	NA	Open	14E	2xIVa	2	19	4
Chen *et al.*[105]	2016	English	1	58	0/1	FB	LN	E	0	0	12	4
Duprey *et al.*[106]	2016	English	65	NA	42/23	14Multiple/51NA	Open	NA	4xII/2xIII/6xIVa	6	108	5
Silski *et al.*[107]	2017	English	2	63	2/0	2L	LN	2E	1xI, 1xIIIa	NA	NA	4
Yoshioka *et al.*[10]	2017	English	1	32	1/0	L	LN	E	0	0	48	4
Adeyemi *et al.*[108]	2018	English	2	27.5	1/1	2FB	Open	E/O	1xIVa, 1xIIIa	0	48	5
Bourgi *et al.*[109]	2018	English	1	38	0/1	NA	Open	E	1xII	0	120	5
Favi *et al.*[110]	2018	English	1	41	0/1	FB	LN	E	0	0	36	4
Ivandaev *et al.*[111]	2018	English	1	36	0/1	FB	Open	O	0	0	9	3
Mead *et al.*[112]	2018	English	1	10	0/1	FB	Open	O	0	0	15	2
Gwon *et al.*[3]	2018	English	13	58	4/9	12FB/L	10 Open/3 LN	13E	1xI/1xII	0	28	4
Rana *et al.*[113]	2018	English	1	53	0/1	FB	LN	E	0	NA	NA	0
Sarwal *et al.*[114]	2018	English	1	21	1/0	MT	Open	O	0	0	3	2
Drucker *et al.*[115]	2019	English	1	18	0/1	FB	Open	E	1x II	NA	NA	1
Liu *et al.*[116]	2019	Chinese	2	NA	NA	FB/Multiple	Open	2E	0	0	NA	3
Our experiences	2020	English	9	60	4/5	7 FB/L/ Multiple	1 Open/8 LN	E	1xI/IIx2/1xIIIb/1xIVa	1	14	

MT, main trunk aneurysm; FB, first bifurcation aneurysm; L, first branch, second branch, or intraparenchymal aneurysm; Multiple, multiple renal artery aneurysm; LN, laparoscopic nephrectomy; E, Heterotopic; and O, Orthotop

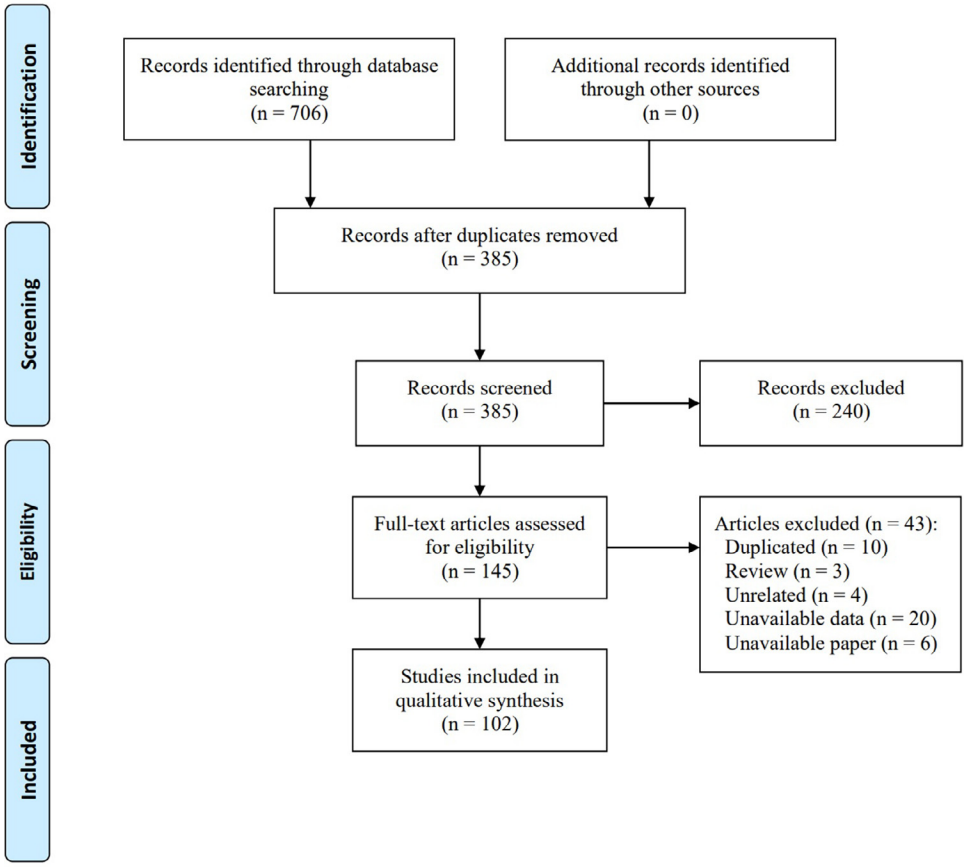

Fig. 2. PRISMA 2009 Flow Diagram.

($n = 307$) with the incidence of major complications of 9.4%. Mean postoperative hospital stay in large series was reported to be 8 to 11 days. No in-hospital mortality after KAT was identified.

Long-term Outcomes

No study reported on aneurysm recurrence after KAT during follow-up. In only 1 case, the dilation of the gonadal vein patch after KAT was identified.[58] The overall incidence of graft loss was 4.1% including early or late graft loss (12 cases out of 290). However, there were only 29 studies ($n = 137$) showing outcomes after more than 1-year follow-up. The largest series by Duprey *et al.* reported that the primary and primary-assisted patency of KAT were 88% and 91%, and the overall patient survival rate was 100%, 98%, and 89% at 5, 10, 15 years.[106]

DISCUSSION

The present study reports our 2-center experiences of KAT for RAA as the largest laparoscopic case series published so far, showing surgical technique and outcomes. We found that laparoscopic approach for nephrectomy followed by heterotopic KAT was feasible. In addition, this systematic review identified 102 articles including 355 patients undergoing KAT for RAA, and demonstrated that KAT for RAA was an effective procedure with good outcomes.

With respect to strategy for RAA, there is no treatment guideline for RAA. Endovascular treatment for RAA would be the first option, owing to minimal invasiveness benefits, especially for simple aneurysms located at main artery, first branch or parenchymal RAAs.[1,6] Even in ruptured aneurysms, endovascular approach might play a rule with coil embolization or endovascular stenting in case of hemodynamic stability and favorable anatomy.[117] However, data with long-term follow-up is lacking in patients treated with endovascular procedure for RAA, and the fact that the persistence of residual flow accounted for 15% of cases should be recognized.[106]

When an endovascular approach is not feasible, surgical treatment should be considered as the second line treatment. There are 2 option regarding RAA repair: in-situ or ex-vivo repair.[3] In-situ repair is reserved for simple cases, and can be done

laparoscopically or robotically.[118] These approaches are not recommended for multiple or complex aneurysms, especially located in artery bifurcations, right mid renal artery or whence distal vascular control might be challenging and long ischemia time are required to perform anastomosis.[119] In challenging complex conditions such as multiple aneurysms, ex-vivo repair is the last option available to preserve renal function.[88] To date, no randomized controlled trial has been performed to compare outcomes between in-situ and ex-vivo RAA repair. However, superior patency rates in ex-vivo repair have been reported compared to those in in-situ repair.[120,121] Regarding the ureter management in KAT, there is more risk of leakage or stenosis when the ureter is divided. In contrast, the ureter needs to be long enough to take out the kidney and reconstruct the vessels in cases with non-divided technique of the ureter. This technique can be easier in cases with open approach for nephrectomy or non-obese cases.

The use of open or laparoscopic approach for nephrectomy in complex RAA requiring ex-vivo RAA repair depends on availability and experience. In the overall outcome of this complex surgery, the most decisive factor would be excellent outcomes in vascular reconstructive surgery. Currently, LN is widely described as the gold standard both in cancer patients and kidney donors since shorter hospital stay, less pain and decreased time to return to full function than open nephrectomy, and these benefits can also be applied to KAT.[122,123] In our experiences, LN with ex-vivo renal artery reconstruction followed heterotopic KAT was feasible for complex RAA. The present systematic review overviewed the current evidence regarding KAT for RAA, and demonstrated that the use of LN for RAA was still limited, without comparative studies assessing both techniques.

Finally, the primary nephrectomy would be another option especially in cases of previous endovascular treatment, repetitive and refractory renovascular hypertension, and multiple complex or ruptured RAA.[1,2] However kidneys should be preserved as much as possible in patients with bilateral RAA or in hemodynamically stable patients with ruptured RAA.

This systematic review has some limitations. Inherent to the low incidence of the condition, the study design was retrospective and covered mostly empirical evidence from case reports and small case series without proper control. Due to of its low incidence, 1 can assume that KAT for RAA is underdiagnosed and underreported, presenting a potential publication bias. Moreover, several data were unavailable, in particular long-term follow-up. Actually 47 studies out of 102 did not report on follow-up period because of focusing on surgical and short-term outcomes, and the rest demonstrated outcomes with a mean follow-up of 21 months. Therefore, we could not perform meta-analysis of long-term outcomes such as graft patency and graft survival by comparing open and LN. Accordingly, further well-designed studies with proper control as well as long-term follow-up should be conducted.

CONCLUSIONS

The present study demonstrated our experiences of KAT for RAA. Laparoscopic approach for nephrectomy was feasible with good postoperative outcomes. Despite the difficulty of interpreting the fragmented and empirical evidence on KAT for RAA and the limitations, our systematic review shows that KAT is an effective treatment for RAA when other therapeutic strategies are not available. The use of open or laparoscopic approach for nephrectomy could depend on availability and experience.

AUTHOR CONTRIBUTIONS

Concept and study design: EC, KT and RCM; acquisition of data: EC, KT, HJANK, LF, PR and RCM; Drafting of the manuscript: EC and KT; Critical revision of the manuscript for important intellectual content: HJANK, JNMI, LF, PR and RCM. All authors have approved the final version of the article.

FUNDING

None.

We thank Wichor M. Bramer (Biomedical Information Specialists) from the Medical Library in Erasmus MC, Erasmus University Medical Centre Rotterdam (Rotterdam, the Netherlands) for his assistance with the literature search.

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