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REVIEW ARTICLE

Outcomes of kidney autotransplantation technique in the treatment of different vascular disorders: an updated narrative review

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ABSTRACT

INTRODUCTION: Kidney autotransplantation (KAT) is a versatile surgical technique used to treat multiple diseases affecting the kidney. This procedure allows the reconstruction of the renal artery or vein with optimal surgical exposure reducing warm ischemia time compared to open direct repair. Although infrequently reported nowadays and despite the growing use of endovascular treatments, KAT still has a place in treating complex kidney vascular conditions.

METHODS: We performed a literature review using the MEDLINE®, SCOPUS, and Web of Science databases with the combination of the terms: "kidney autotransplantation," "renal artery," "renal vein," "aorta," "aneurysm," and "nutcracker syndrome." All relevant English-language studies published between January 1990 and June 2022 reporting the outcomes of the KAT technique in vascular disorders were included.

RESULTS: A total of 32 articles were included. Ex-vivo repair and KAT is widely described in treating renal artery aneurysms (RAA), with a reported technical success rate of 99.9%, a complication rate ranging from 6.9 to 9.4%, and a graft loss rate of up to 4.1%. The use of the laparoscopic technique for harvesting the kidney was variable throughout the series published, and heterotopic KAT was performed in most treated patients. Ex-vivo repair and KAT was successfully used after failed endovascular therapy and is a viable option in women of childbearing age with bilateral complex RAA.

Concerning renal artery stenosis associated with different etiologies (fibromuscular dysplasia, Takayasu's arteritis, and neurofibromatosis type 1), significant reduction of blood pressure and the number of anti-hypertensive drugs have been reported in most patients after KAT. Results of arterial hypertension improvement associated with RAA after KAT are more variable.

The use of KAT in treating nutcracker syndrome is reported with good results, even after left renal vein transposition or venous stenting failure. Other reports exist on the successful use of KAT for treating renal vein aneurysms and as an adjunct in open surgical or hybrid aortic reconstructions.

CONCLUSION: Renal autotransplantation is a useful technique in the treatment of kidney vascular disorders with good overall results reported in the literature. It may be an essential adjunct in open surgical or hybrid treatments for abdominal and thoracoabdominal aortic diseases. Defining the patients who would benefit from this technique as a preferential treatment choice in different renal vessel disorders would be necessary.

Keywords: Kidney autotransplantation; Renal Artery Aneurysms; Renovascular hypertension; Nutcracker syndrome; Renal vein Aneurysm.

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INTRODUCTION

Kidney autotransplantation (KAT) was first described in 1962 to correct a high ureteral injury.[1] Since then, multiple studies have reported using KAT to treat complex urethral, renovascular, or malignant diseases, allowing the preservation of the functioning parenchyma.[2] It remains a versatile surgical technique usually used as a last-option therapy when other treatments have failed or are inappropriate.

With this technique, the kidney is removed from its original location, and the renal parenchyma is immediately protected by a cold infusion of a preservation solution and hypothermia; the repair is performed *ex-vivo* on a back table under direct visualization. This way, it is possible to optimize the surgical exposure and proceed with the repair without concerns about warm ischemia times, reducing the risk of ischemic kidney injury.[3] Regarding renovascular diseases, KAT can be used to treat multiple conditions affecting the renal artery or vein. Although favorable outcomes have been published, this technique has been poorly reported in the last few years, probably due to the advances in endovascular therapy and the low familiarity of most vascular centers with kidney transplantation.

The present study aims to give an updated overview of the results of KAT surgery in different renal artery and vein disorders, highlighting the strengths and limitations of this technique.

METHODS

A literature search was performed in the MEDLINE, SCOPUS, and Web of Science databases with a combination of the terms: "kidney autotransplantation," "renal artery," "renal vein," "aorta," "aneurysm," and "nutcracker syndrome."

We include papers published from January 1990 to June 2022, only written in English. Subsequently, a review of the references of the selected articles was carried out, and those considered relevant by the authors were retrieved.

Inclusion and exclusion criteria

The selection of articles for the review was the responsibility of the two first authors. All relevant studies reporting the renal autotransplantation technique results in vascular disorders were included. Systematic reviews, clinical trials, observational studies, small series, and case reports providing adequate evidence of the outcomes and follow-up of the KAT technique have been used in this review. We excluded narrative reviews. Papers referring to the use of this technique in disorders of the ureter, renal pelvis, and other urologic diseases were not included in the study. Whenever we used data from a systematic review, we did not include any referenced study to avoid data duplication.

RESULTS

A total of 30 articles were included in our review. Two other papers were later retrieved after revising the references of the included articles. We found papers reporting KAT results in treating renal artery aneurysms,[4-14] renal artery stenosis and renovascular hypertension,[15-21] nutcracker syndrome,[22-29] renal vein aneurysms,[30] and as a complementary technique for aortic reconstructions.[31-35]

Renal Artery aneurysms

Renal artery aneurysms (RAA) are rare, with an incidence of 2.5% in the general population, and are usually incidental findings in imaging studies.[36] Indications for treatment include aneurysms greater than 2.5cm or regardless of size in women of childbearing age and with refractory arterial hypertension (AHT), considering the high rupture risk in these cases.[37] RAA can be classified according to the location in angiographic studies: type I are aneurysms located in the main renal artery; type II are aneurysms located in the renal hilus after the first bifurcation; type III are intraparenchymal RAA.[38] Classically, RAA were corrected by conventional surgery with *in-situ* vascular reconstruction. However, multiple endovascular alternatives emerged as covered stent exclusion, embolization of the aneurysmal sac or terminal branches, flow-diverting stents, and balloon-or stent-assisted embolization.[38] In the case of complex type II or III aneurysms not amenable for endovascular treatment, multiple branch aneurysms, or when an ischemia time of more than 30-40 minutes is expected with direct vascular reconstruction, KAT is recommended as the therapy of choice.[37]

Many publications have reported the successful use of KAT to repair RAA. A recent systematic review by *Ramouz et al.*, which included 199 patients submitted to KAT for RAA repair, reported technical success in 99.9% of cases. The main indication for treatment was AHT (70.4%), followed by an aneurysm diameter greater than 2cm (43.9%). Twelve patients had a previous failed endovascular treatment. With a median follow-up time of 12 months, postoperative complications were reported in 6.9% of patients with no deaths. Heterotopic KAT was done in 81% of patients, and only 14.4% were submitted to laparoscopic nephrectomy.[4] *Contarini et al.* reported nine patients with RAA surgically treated by *ex-vivo* repair and KAT (eight with laparoscopic nephrectomy). There were two major postoperative complications, including one graft loss with a mean follow-up of 15.7 months. In this author's systematic review including 355 patients, the incidence of postoperative significant complications and graft loss was 9.4% and 4.1%. A minimally invasive kidney harvest was performed in 9.9% of patients.[5]

Machado et al. reported 24 patients with RAA submitted to *ex-vivo* repair and heterotopic KAT, the majority (88,9%) with a minimally invasive laparoscopic harvesting. With a mean follow-up of 49.5 months, no deaths have been reported, and the kidney patency rate was 93%.6 In another case series, 3 of 11 patients with RAA were submitted to *ex-vivo* repair and KAT with a follow-up of 1, 5, and 26 months. One ureter anastomotic stenosis with acute kidney failure was observed and a surgical re-anastomosis of the ureter was necessary.[7]

Pomy et al. described a 41-year-old woman planning to become pregnant with bilateral renal artery aneurysms diagnosed in an ultrasound examination for AHT investigation. The patient was successfully submitted to bilateral KAT through laparoscopic harvesting, although she still needed antihypertensive drugs for blood pressure control in the follow-up.[7] A similar case was reported by *Mendes et al.* in a 35-year-old patient planning a pregnancy with multiple bilateral renal artery aneurysms; however, with complete AHT resolution after bilateral KAT.[9]

Other authors have described hilar and multiple RAA adequately managed by *ex-vivo* repair and KAT.[10-14]

Renovascular hypertension

Fibromuscular dysplasia, renal artery dissections, segmental arterial mediolysis, and vasculitis are non-atherosclerotic conditions that can affect the renal artery leading to changes in flow and causing AHT and kidney dysfunction. *Van Rooyen et al.* describe a series of 15 patients with spontaneous renal artery dissection associated with fibromuscular dysplasia in 93% of the cases and manifested as AHT or renal dysfunction. *Ex-vivo* reconstruction and KAT were performed in 17 kidneys without operative deaths or significant morbidity. With a follow-up ranging from 1 to 8 years, 79% had satisfactory blood pressure control, and all patients had normal renal function.[15] Similarly, in a pediatric study that included 16 patients with renovascular hypertension, KAT showed complete resolution of AHT in 61.5% and an improvement in 38.5% of the cases with a median follow-up of 53.4 months.[16] A similar observational study with five patients with renal artery stenosis demonstrated a significant reduction in mean AHT from 204mmHg to 129mmHg and a reduction in antihypertensive drugs from 3.4 to 0.2 after surgery with a mean follow-up of 3.4 years.[17] A study with five patients with renal artery disease also found a reduction in mean systolic blood pressure from 168mmHg to 128mmHg with a mean follow-up of 9.8 years post-kidney transplantation.[18] The cause of renal artery stenosis in these studies included fibromuscular dysplasia, Takayasu's arteritis, mid-aortic syndrome, and Neurofibromatosis type 1.[16-18]

A case report showed similar successful use of KAT for managing resistant hypertension in a young male with Takayasu's arteritis and renal artery stenosis of a solitary kidney.[19]

In the case of the AHT associated with RAA, the systematic review of *Ramouz et al.* demonstrated that AHT was cured in 37.5% and improved in 18.8% of patients after KAT.[4] A case series of patients with RAA reported improvement of AHT in 23,5% of patients and cure in 35,3%.[6] In contrast, in the series of 10 patients with RAA reported by *Dezfouli et al.*, AHT was not resolved after aneurysm repair in patients with preoperative AHT.[7]

Midaortic syndrome is a narrowing of the aorta in the thoracoabdominal transition, that can be associated with Takayasu's arteritis, neurofibromatosis, and fibromuscular dysplasia. This syndrome can cause renovascular AHT due to low flow to the renal arteries. Some authors treated this condition with KAT and aortic bypass, achieving AHT improvement within one and two years of follow-up."[20,21]

Nutcracker syndrome

Nutcracker syndrome (NCS) describes the clinical symptoms associated with the anatomical compression of the left renal vein (LRV), which may result in an impaired venous outflow to the inferior vena cava.[39] Two main types of NCS have been described. Anterior NCS is the most common and consists of a compression of the LRV between the aorta and superior mesenteric artery (SMA). In the sagittal view, an aorto-mesenteric angle inferior to 35° is required for the diagnosis.[40] Posterior NCS is an anatomical variant in which the retroaortic LRV is compressed between the aorta and the vertebral body.[39] Renal autotransplantation, by altering the native site of the kidney, eliminates this point of compression and even corrects kidney ptosis if present.

Some small series have reported the successful treatment of anterior NCS with full symptomatic resolution (hematuria and pain) after KAT (table 1).[22-26] *Bath et al.* reported three patients treated for loin pain-hematuria syndrome attributed to NCS after unsuccessful LRV transposition, relapsing debilitating pain. Two of these patients underwent KAT with complete resolution of symptoms, having 6 and 9 months of follow-up.[27] Similarly, *Miro et al.*[26] described a pediatric patient submitted to LRV transposition for NCS treatment. However, due to a torpid evolution, kidney autotransplantation was performed later resolving all the symptoms. *Harkrader et al.* reported a robotic-assisted KAT with *ex-vivo* reconstruction to treat a NCS with excruciating pain. Complete resolution of symptoms occurred after the surgery, and the patient was still asymptomatic at eight months of follow-up.[28] In 18 patients submitted to venous stenting for treating NCS, *Avgerinos et al.*[29] reported two patients with symptomatic recurrence requiring KAT because of debilitating symptoms despite patent stents. After the surgery, symptoms partially improved in one patient but remained unchanged in the other.

Table 1. Summary of the studies reporting the use of kidney autotransplantation technique for nutcracker syndrome treatment.

Author	Number of patients	Gender/Age (years)	Symptoms/ signs	NCS type	Treatment	Technique	Previous treatment	Follow-up (months)	Outcome
Ali-El-Dein et al.[22]	11	- / mean 31.5	LP=9; GH=5; MH=3; Anemia=3	Ant.=6; Post.=5	KAT=6; LRVT=1; Other cx=1; Conservative=3	Heterotopic=5; Orthotopic=1	None	mean 56; 12-120	LP resolution=7/8; GH/ MH improvement=8/8; Kidney function preservation=all
Salehipour et al.[23]	4	3M 1F / mean 25.5 (23-28)	Gross hematuria=4	Ant.=4	KAT=4	Heterotopic=4	LRVT=2	4-24;	Complete symptomatic resolution=4
Bath et al.[27]	3	3F / 19, 19, 42	LP=2	Ant.	KAT=2; Nephrectomy=1	Heterotopic=2	LRVT=2	9, 23, 6	Complete symptomatic resolution=3
Xu et al.[24]	1	F / 21	GH	Ant.	KAT	Heterotopic	.	3	Complete symptomatic resolution
Decaestecker et al.[25]	1	M / 39	LP; GH; Recurrent left varicocele;	Ant.	Robot assisted KAT	Heterotopic	.	4	Complete symptomatic resolution
Harkrader et al.[28]	1	F / 22	LP, GH, GIS	Ant	KAT	Heterotopic	.	8	LP/GH resolution; GIS improvement

LP: Loin Pain; **GH**: Gross Hematuria; **MH:** Microscopic Hematuria; **LPHS:** loin pain-hematuria syndrome; **GIS:** Gastrointestinal symptoms; **Ant.:** Anterior nutcracker syndrome; **Post.:** Posterior nutcracker syndrome; **KAT:** Kidney autotransplantation; **LRVT:** Left renal vein transposition; **mo:** months

Renal Vein Aneurysms

Visceral venous aneurysms are sporadic, most commonly affecting the portal venous system. Complications include aneurysm thrombosis, thromboembolism, and even rupture, so treatment should be considered, especially in symptomatic patients or large expanding aneurysms.[41] A renal vein aneurysm reported by *Özyuksel et al.* in which the patient presented with recurrent pulmonary thromboembolism despite anticoagulation was treated by *ex-vivo* repair and KAT. With a follow-up of 9 months, the patient preserves a functional kidney with no postoperative complications.[30]

Adjunct technique for aortic reconstructions

Some authors report the successful use of KAT in hybrid treatments for aortic disorders (table 2), namely aortic dissections and thoracoabdominal aneurysms, allowing the exclusion of the renal artery with an endograft and preserving the functional kidney parenchyma.[31-33]

Min et al. argued that performing renal autotransplantation in complex open aortic reconstructions reduces the kidneys' warm ischemia injury, compared with open direct repair in which the ideal warm ischemia time of fewer than 30 minutes is hard-to-accomplish if aortic cross-clamping is needed. The author reports a case of a patient with a pararenal aneurysm who underwent bilateral KAT, followed by open aneurysm exclusion with a bifurcated graft.[34] Another case report refers to a patient with right renal artery occlusion after EVAR needing hemodialysis that was initially managed by endovascular therapy but ended up doing a successful right KAT avoiding kidney replacement therapy.[35]

Table 2. Summary of the reported cases regarding the use of kidney autotransplantation as an adjunct technique for complex aortic reconstructions.

Author (year)	Gender/Age (years)	Aortic disease	Kidney procedure	Aortic therapy	Pre to postoperative kidney function	Follow-up (months)	Outcome
Espinosa et al.[31]	F / 65	Type A aortic dissection - thoracoabdominal aortic aneurysm (post dissection)	Right KAT; Left kidney exclusion;	FEVAR (fenestrations to CT and SMA) fenestrations to CT and SMA)	SCr 0.7 mg/dL → 1.2 mg/dL	12	Aneurysm exclusion; Functional graft (single kidney)
Rana et al.[32]	F / 39	Saccular aneurysm of the abdominal aorta (zone 8) + occlusion of the CT and LRA	Right KAT;	Hybrid visceral debranching + EVAR	GFR 76.2 ml/min → 76 ml/min	12	Aneurysm exclusion; Functional graft (single kidney)
Min et al.[34]	M / 53	Pararenal AAA	Bilateral KAT;	Aneurysm resection and aortic-bi-iliac graft interposition	-	19	Aneurysm exclusion; Well-preserved renal function
Uehara et al.[35]	F / 76	RRA occlusion after EVAR (Atrophic left kidney)	Right KAT	-	SCr 1.0mg/dL → 1.03 mg/dL	24	Aneurysm exclusion; Functional graft (single kidney)
Gazzola et al.[33]	M / 73	Type A acute aortic dissection	Right KAT	FEVAR (fenestrations to CT, SMA and LRA)	-	12	Aneurysm exclusion; Well-preserved renal function

KAT: Kidney autotransplantation; **CT:** Celiac artery; **SMA:** Superior mesenteric artery; **SCr:** Serum Creatinine; **GFR:** Glomerular Filtration Rate; **LRA:** Left Renal Artery; **AAA:** Abdominal Aortic Aneurysm; **RRA:** Right Renal Artery;

DISCUSSION

KAT is a long-time-used surgical technique most frequently indicated in treating complex renal vessel disorders, high ureteral stenosis, or tumors not amenable to direct open repair.[2] Other less frequent indications could include retroperitoneal fibrosis, loin-pain hematuria syndrome, and metabolic stone disease.[2,42] This procedure has shown promising results with a low mortality rate, despite being an invasive procedure with associated morbidity. Laparoscopic nephrectomy for KAT reduced the procedure's invasiveness.[43] Nowadays, the preferred technique uses the same Gibson incision for laparoscopic kidney removal and implantation of the graft in the iliac vessels.[44]

KAT can be heterotopic, in which the ureter is ligated and sectioned for posterior ureteroneocystostomy and the kidney is implanted in iliac vessels, or orthotopic, in which only the ligation and division of the renal artery and vein are performed, preserving the ureter and the vesicourethral junction and the anastomosis are made to the abdominal aorta and inferior vena cava. The advantages of the first are the possibility of performing the necessary surgical repair on a back table with better surgical exposure without clamping the abdominal aorta. However, orthotopic kidney autotransplantation reduces the risk of ureteral injury and avoids the possible higher atherosclerotic burden in the iliac vessels.[4,45] No studies directly compare these two techniques. Kidney function preservation with KAT was reported in 88 – 100% of patients.[4,19]

KAT in treating RAA has been widely reported with good overall results, low morbidity, and meager graft failure rates. It should be noted that this technique is almost exclusively used in complex aneurysms in the segmental or subsegmental renal artery branches (types II and III). However, published studies include small series or clinical cases with a short follow-up, and a publication bias may exist.

Regarding renovascular disease AHT, available data demonstrate favorable results in treating renal artery stenosis,

regardless of etiology. The outcomes are more variable in the case of AHT associated with RAA. This may be related to the mechanisms proposed for AHT in the case of renal artery aneurysms. Turbulent flow in the aneurysmal sac or the compression of adjacent arterial branches and veins can lead to reduced flow to the kidney, causing AHT. Additionally, aneurysmal sac thrombus embolization with cortical ischemia may also contribute and could not be reversed by KAT.[6,45]

Endovascular treatment for NCS has been growing in the last decade. There are still some cautions regarding the risk of stent migration. Surgical treatment usually consists of LRV transposition. Still, other possibilities exist, such as renal autotransplantation, gonadal vein transposition, and superior mesenteric artery transposition. KAT not only resolves the compression of the LRV but also corrects the position of the kidney in case of nephropexy. The studies used in this review showed several cases of KAT surgery as salvage therapy after LRV transposition or LRV stenting failure for treating persistent loin pain. This may happen since, in some patients with NCS, the origin of the pain may be a urethral spasm and not be directly related to LRV hypertension. KAT by denervating the kidney and ureter is an effective treatment.[27] This technique has also been reported with good mid-term results in treating renal vein aneurysms and as an adjunct to complex vascular reconstructions.

For different renal arterial or vein disorders, KAT is a surgical procedure with excellent results reported in the literature. It appears to have advantages in resolving NCS-associated loin pain, but LRV venous stenting and LRV transposition are used more frequently. Except for RAA, indications for this technique are not established.

CONCLUSION

Renal autotransplantation in treating renal artery and vein disorders is a versatile technique with good overall results reported in the literature. Most of the published studies refer to the use of this procedure in the treatment of RAA. Still, it can be used in different diseases affecting the renal artery or renal vein. It may also be an essential adjunct in open surgical or hybrid treatments for abdominal and thoracoabdominal aortic diseases. Defining the patients who would benefit from this technique as a preferential treatment choice in different conditions of the renal vessels would be necessary.

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