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Crossing Anatomic Barriers—Transplantation of a Kidney with 5 Arteries, Duplication of the Pyelocalyceal System, and Double Ureter

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Abstract

During the time of organ harvest, it is crucial for the kidney procurement team to consider significant vascular anatomical variations. Multiple renal arteries are not uncommon, and unintentional injury can result in an irreversibly damaged kidney graft that needs to be discarded. We present a kidney graft with 5 renal arteries and a single vein that was successfully procured and implanted with good graft function at discharge and at 4-yr follow-up. According to the literature, additional renal arteries can be found in about 33% of kidneys. This is the first study on a kidney with 5 arteries in the published literature, especially in the context of transplantation.

Keywords

renal anomalies, additional renal arteries, kidney transplantation, kidney procurement, warm ischemia time (WIT)

Introduction

Kidney transplantation has become the treatment of choice for patients with end-stage renal disease. It has been shown not only to decrease the mortality rate but also to improve life expectancy and the quality of patients' lives. Moreover, kidney transplantation is a more cost-efficient method when compared to dialysis. With an increasing number of patients with end-stage renal disease and a limited number of organs available, the wait time on the transplant list has become longer. One way to diminish this discrepancy between demand and supply in kidney transplantation is organ procurement from expanded criteria donors (ECD). Utilization of grafts with anatomical variations is another option, even though this may increase the complexity of transplantation itself. According to the literature, additional renal arteries are found in 33% of kidneys. This is a significant number in the total organ pool and leads to unavoidable exposure of organ procurement team members to kidney allografts with complex vascular anatomy. Awareness of arterial anomalies is essential for decreasing the rate of accidental injuries of additional arteries during kidney procurement. Transplantation of kidney grafts with multiple arteries is technically a more demanding procedure compared to kidney grafts with a single artery and may put recipients at higher risk of vascular complications due to kinking of the vessels and subsequent thrombosis. The longer time needed for vascular anastomoses directly contributes to elongation of the warm ischemia time (WIT), which is identified as a negative factor corresponding to ischemic insult to the graft and promoting delayed graft function occurrence. A lot of effort is put forth

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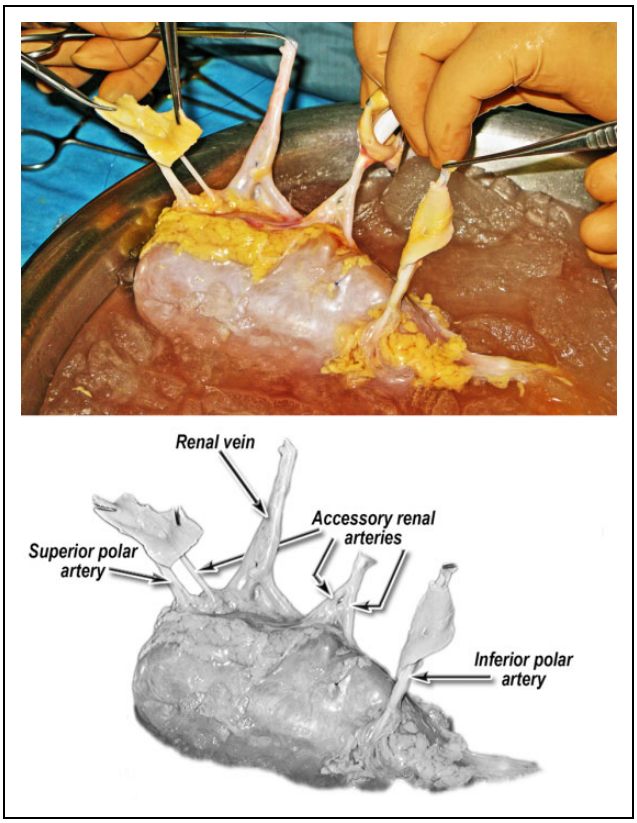

Fig. 1. Left kidney from deceased donor with 5 arteries and 1 vein—the back table graft preparation in hypothermic conditions (preservation fluid with ice at temperature of 4 °C, graft flushed through each artery with cold preservation fluid—Custodiol HTK).

to eliminate this negative factor in order to improve the overall success of kidney transplantation.

Materials and Methods

The material for this study was obtained from data gathered by the Kidney Procurement and Transplantation Team in the First Department of General, Oncological and Gastroenterological Surgery, Jagiellonian University Medical College, Krakow, Poland. The kidney presented in this study was a left kidney with 5 arteries, harvested from a brain-dead 21-yr-old male donor, procured in cold storage with a total cold ischemia time of 12 h, and subsequently transplanted to the 46-yr-old recipient with end-stage renal disease secondary to focal segmental glomerulosclerosis. The arteries were all identified and harvested along with aortic arterial patches, then transplanted using 3 Carrel patches. The end of the donor renal vein was anastomosed to the side of the wall circumference of the recipient right external iliac vein, and donor renal arteries on 3 Carrel patches were anastomosed to the side of the wall circumference of the recipient right external iliac artery. The kidney graft was photographed using a digital camera (Canon PowerShot G9, 12 MP). The obtained images were analyzed using Photoshop software (Adobe-Photoshop CS2, version 9.0.2) (Figs. 1 and 2).

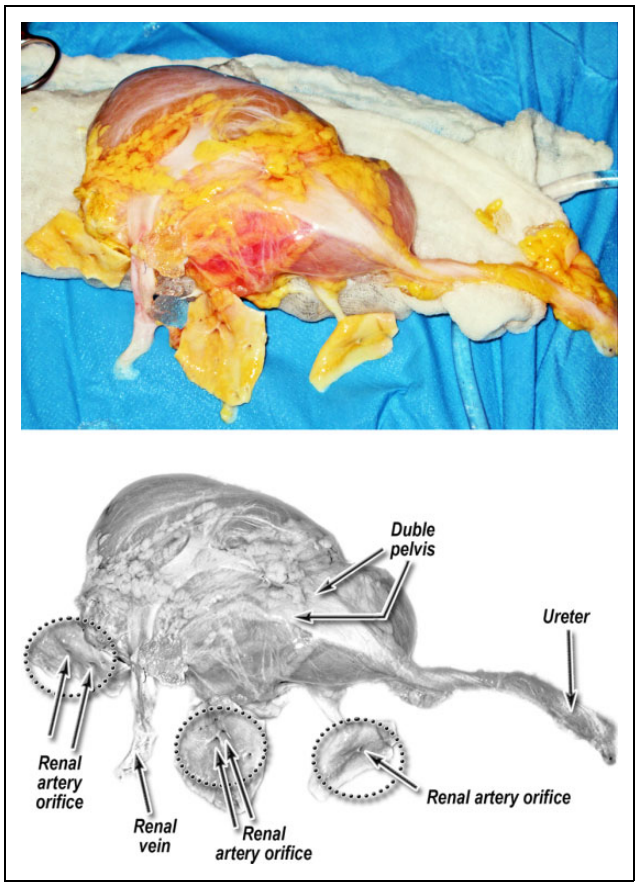

Fig. 2. Left kidney from deceased donor with 5 arteries and short ureter duplication—in dashed circles, 3 aorticarterial patches (Carrel patches), which after cut along the dashed lines and remove the parts of donors aorta wall (outside the dashed lines), were prepared to create anastomosis with recipient right external iliac artery.

Results

The anatomical findings during the harvest procedure included the aberrant lower location of the left kidney resulting from its failure to ascend completely during development. In addition, the kidney presented with 4 arteries originating separately from the abdominal aorta and 1 accessory artery arising from the left common iliac artery.

The time required to create the vascular anastomoses during transplantation (WIT) was 60 min (10 min for venous anastomosis and 50 min for arterial anastomosis). This WIT was significantly longer than the mean WIT in recipients of grafts with a single renal artery and vein (38.7 min according to our data, $P < 0.01$).[1] Postoperatively, there were no vascular complications and the ensuing delayed graft function was limited to 6 d. The patient was discharged from the hospital on postoperative day 19 in a clinically stable condition, with diuresis of 50 to 60 mL/h (320 to 384 mL/kg/h). The patient presented in good health at the 4-yr follow-up with creatinine of 1.4. The patient had an episode of humoral rejection that occurred 1.5 yr from transplantation, which was

Table 1. Articles Where Kidneys with Multiple Arteries Were Reported in the Transplant Context.

Author	Study	Number of Arteries	Conclusions
Rossi et al.[2]	Case report	Left kidney—4 arteries, right kidney—3 arteries	Evaluation of living kidney donor with MCTA
Sezer et al.[3]	Retrospective study of 249 kidney grafts	214 Grafts (85.9%)—1 artery, 31 grafts (12.5%)—2 arteries, 3 grafts (1.2%)—3 arteries, 1 graft (0.4%)—4 arteries	No adverse effects of multiple renal arteries on posttransplantation recipient or graft survival, urologic, and vascular complications
Orlando et al.[4]	Case report	Renal graft with 6 arteries and double pelvis	Good graft function in 90 days' follow-up
Hwang et al.[5]	Retrospective cohort study of 1,186 kidney grafts	890 Grafts (75%)—1 artery, 296 grafts (25%)—>1 artery (257 grafts—2 arteries, 32 grafts—3 arteries, 5 grafts—4 arteries, 2 grafts—5 arteries)	Multiplicity of renal graft arteries did not impact long-term posttransplant results. No significant differences in graft or patient survival or complication rates compared with single artery transplantation
Bozkurt et al.[6]	Retrospective study of 196 multiple arteries renal grafts recipients	182 Kidney grafts—2 arteries, 14 kidney grafts $\geq$3 arteries	Low postoperative complication rates and favorable outcomes of renal grafts with additional arteries
Kamali et al.[7]	Retrospective study of 718 kidney recipients	658 Kidney grafts—1 artery, 60 > 1 artery (49—2 arteries, 11— >2 arteries)	Reasonable complications and acceptable outcomes of renal allograft transplantation with multiple arteries

Abbreviation: MCTA, multidetector computed tomography angiography.

treated with steroids. Control ultrasonography at the 4-yr follow-up revealed homogenous blood flow in the graft.

Discussion

According to the literature, additional renal arteries can be found in up to 33% of patients,[2] 8% to 30% of kidneys unilaterally and 10% bilaterally.[3] This finding, however, depends on the specific population studied. In Table 1, we included the literature review where kidneys with additional arteries were evaluated in the context of transplantation.

The adachi study of arterial system variations in a Japanese population is still an invaluable reference of anatomic variations, despite its publication in 1928.[8] They studied a total of 338 kidneys. A single renal artery was described in 261 cases (77.2%) and additional renal arteries were described in 77 cases (22.8%). Among kidneys with additional arteries, 2 arteries in 68 cases and 3 arteries in 9 cases were reported. They did not find any kidneys with 4 and more renal arteries.[8]

Miclaus and Matusz reported a case of a 58-yr-old male with bilateral quadruple renal arteries that were incidentally discovered with multidetector computed tomography angiography (MCTA).[9] Although the kidney was not utilized as an allograft, the case emphasized the prevalence of bilateral multiple renal arteries. Bilateral double and triple renal arteries have been reported in the past, but this case was the first to report bilateral quadruple renal arteries.[9]

Rossi et al. reported a case of a 23-yr-old living donor candidate with 4 left renal arteries and 3 right renal arteries evaluated using MCTA.[2] The authors explained the common existence of vascular variations in kidneys by implementing the theory of early embryonic development of blood supply to urogenital structures. This is represented by a number of lateral intersegmental arteries of mesonephros, originating from the abdominal aorta and iliac arteries. During development and migration of the kidney, aortic renal branches vertically merge and usually develop into a single arterial system. In cases where kidney migration is disrupted, the early stage of vascular development persists, which results in additional renal arteries.[2]

Satyapal et al. state that as blood supply establishes according to the location of kidneys, aberrant positioning of the kidneys predisposes them to abnormal vascular supply.[10] This further supports our observations at the time of organ procurement that an abnormal inferior position of the harvested kidney can be an indirect indicator of multiple renal arteries in the graft.

Failure to anastomose renal arteries during transplantation is critical as it can lead to segmental ischemia in the renal allograft.[11] The longer WIT is inevitable as the number of renal arteries increases and the dimension of each artery decreases, making each anastomosis more difficult.[3] The most common vascular complication with transplantation is renal artery stenosis. The incidence varies from 3% to 23%, within the first 12 mo after the procedure.[3]

Orlando et al. reported a rare case of a renal graft with 6 arteries and a double pelvis. This is the greatest number of accessory renal arteries reported in the literature as well as the first case of a kidney with more than 4 arteries to be successfully transplanted.[4] We present a second kidney graft with more than 4 renal arteries. The results of the transplantation were successful with an uneventful postoperative course. Delayed graft function persevered for 9 days, at which time serum creatinine normalized to 1.1 mg/dL.[4] This case further supports our findings of successful transplantation in spite of the difficulties associated with having anatomical variation. Orlando et al. assert that variations in vascular or urinary tract anatomy should be included in

the definition of ECD. This recommendation is supported by the fact that the variations lead to longer WIT and, therefore, a higher risk of acute tubular necrosis, acute rejection, and delayed graft function.[4]

Utilizing kidneys with multiple renal arteries has become essential in transplantation, as the number of patients with end-stage renal disease continues to increase, despite the limited pool of kidney donors. Hwang et al. studied the long-term graft function and survival over an 18-yr period and found the outcomes to be comparable for a varying number of renal arteries or techniques applied for reconstruction and anastomosis.[5]

The impact of multiple renal arteries on the outcomes of transplantation remains controversial. Results of the study by Bozkurt et al. showed that only 2.1% of grafts ($n = 196$) were found to have complications of lymphocele and urinary leak, but none were related to the vasculature.[6]

Kamali et al., however, found an increased incidence of delayed graft function in recipients of kidneys with more than 2 renal arteries, when compared to kidneys with either a single or 2 renal arteries. Furthermore, multiple renal artery recipients experienced a higher incidence of renal artery stenosis.[7]

As the results of transplantation utilizing grafts multiple renal arteries vary in the success and rate of complications, it is crucial for surgeons to understand the anatomical variation prior to the operation to minimize the time and the complications that can arise during the operation. Despite the disputable findings that studies have shown, multiple arteries will continue to play a significant role in kidney transplantations, as the complications have been minimal and the outcomes have been acceptable.

Ethical Approval

This study was approved by the Jagiellonian University Medical College Bioethics Committee (registry no. KBET/189/B/2013).

Statement of Human and Animal Rights

This study adhered to the Declaration of Helsinki and its later amendments.

Statement of Informed Consent

Obtained verbally from the patient.

Declaration of Conflicting Interests

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