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Evaluation of the Renal Arteries of 2,144 Living Kidney Donors Using Computed Tomography Angiography and Comparison with Intraoperative Findings

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Keywords

Renal transplantation · Donor candidates · Renal artery · Computed tomography angiography

Abstract

Objectives: A carefully chosen and suitably prepared kidney donor is essential in living-donor kidney transplantation. Computed tomography angiography (CTA) is an effective imaging method for evaluating the renovascular morphology of donor candidates. The aim of this study was to evaluate renal artery variations in kidney donors using CTA and compare the findings with the number of arteries detected during laparoscopic donor nephrectomy. ***Materials and Methods:*** The study included 2,144 living donors who underwent pretransplant renovascular assessment using CTA and laparoscopic donor nephrectomy in our center between August 2012 and October 2018. The number of renal arteries to the donor kidney detected on CTA was compared with the number of arteries discovered intraoperatively. ***Results:*** The mean age of the 2,144 living kidney donors included in the study was 47.19 ± 13.3 (18–87) years. According to CTA findings, 81.1% (n = 1,738) had a single renal artery, 17.2% (n = 369) had double renal arteries, 1.6% (n = 35) had triple renal arteries, and 0.1% (n = 2) had quadruple renal arteries. The same number of renal arteries were detected by CTA and in laparoscopic donor nephrectomy in 97.9% (n = 2,099) of the donors. In the other 2.1% (n = 45), fewer renal arteries were detected intraoperatively compared to their CTA findings. None of the donors included in the study had a greater number of renal arteries discovered during nephrectomy than by CTA. ***Conclusion:*** CTA is a highly accurate method for the evaluation of renovascular variations in donor candidates for living-donor kidney transplantation. However, it must be kept in mind that double or multiple renal artery variations may be detected on CTA in 18.9% of donor candidates.

Introduction

Based on outcome, kidney transplantation is the most effective method for the treatment of end-stage renal disease [1]. Due to a shortage of cadaveric organs, living-donor kidney transplantation is becoming more common [2]. As the success of organ transplantation depends on

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the quality of the graft organ, preoperative radiological evaluation of living donors is critical. This requires accurate visualization of the renal anatomy, collecting system, and renovascular structures in the potential donor. Spiral computed tomography angiography (CTA) is a rapid, safe, minimally invasive, and widely accepted method for preoperative assessment of the renal vasculature [3]. An accurate and detailed demonstration of renal artery variations in the preoperative assessment is particularly important to avoid unwanted complications, such as venous and/or ureteral injury during donor nephrectomy [4]. The aim of this retrospective study was to evaluate renal artery variations according to pretransplant CTA in comparison with intraoperative findings in a large series of living kidney donors.

Methods

After obtaining institutional review board approval (IRB approval No, 2019/004), we retrospectively evaluated records pertaining to 2,165 living-donor kidney transplantations performed between August 2012 and October 2018 in the Department of Transplantation of the Medical Park Hospital of Antalya. Of these transplantations, 2,144 living donors who underwent preoperative renovascular assessment using CTA were included in the study. For all donors, data on age, sex, number of renal arteries detected in CTA, and the planned nephrectomy side were recorded. The number of renal arteries detected by CTA was compared with intraoperative findings during laparoscopic donor nephrectomy. No oral contrast agent was used during imaging. Nonenhanced, arterial phase, and 2-min delayed-phase thin-section imaging was performed with 2-mm, axial, multiplanar reformation; maximum intensity projection; and volume-rendered angiographic reconstructions. Images were acquired from both the abdomen and pelvis, with nonenhanced imaging included to enable visualization of calcifications in the aortoiliac system, which may be obscured in contrast-enhanced images. CTA was performed using a 16-row multidetector CT device (General Electric Company Healthcare, USA) after administration of a mean of 90 (60–100) mL of iohexol 350 (Omnipaque™, General Electric Company Healthcare, USA) intravenous contrast material. The contrast material was administered via a 20-gauge intravenous catheter placed in an antecubital vein at a rate of 4–5 mL/s using a pump injector unit (Angiomat™, Mallinckrodt, USA). The number of renal arteries entering the kidney was determined based on the acquired images. After determining the appropriate side for donor nephrectomy, all living donors underwent laparoscopic nephrectomy. Intraoperative renovascular findings were noted.

Statistical analyses were performed using the OpenEpi® version 3.01 (Atlanta, GA, USA) statistical program. Descriptive statistics were presented as frequency and percentage, and age was expressed as mean ± SD (range). Sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy were calculated within a 95% confidence interval.

Table 1. Distribution of donors according to the number or renal arteries detected by CTA and intraoperatively

	Arteries discovered intraoperatively			
	1	2	3	4
Arteries detected on CTA				
1	1,738			
2	32	337		
3	2	10	23	
4			1	1

Table 2. Comparison of CTA results with intraoperative findings according to the number of renal arteries

Parameter	Mean	95% CI
Sensitivity, %	100	98.95–100
Specificity, %	97.48	96.64–98.11
Positive predictive value, %	91.39	88.21–93.78
Negative predictive value, %	100	99.78–100
Diagnostic accuracy, %	97.9	97.2–98.43

CI, confidence interval.

Results

The 2,144 living kidney donors included in the study had a mean age of 47.19 ± 13.3 (18–87) years; 57.5% (n = 1,233) were female and 42.5% (n = 911) were male. Nephrectomy was performed on the left side in 90.6% (n = 1,942) and on the right side in 9.4% (n = 202) of the donors. According to CTA findings, 81.1% (n = 1,738) had a single renal artery, 17.2% (n = 369) had double renal arteries, 1.6% (n = 35) had triple renal arteries, and 0.1% (n = 2) had quadruple renal arteries (Table 1). The number of renal arteries found during laparoscopic donor nephrectomy was the same as detected by CTA in 97.9% (n = 2,099) of the patients. In the other 2.1% (n = 45), fewer renal arteries were detected intraoperatively compared to the CTA findings. None of the donors included in the study had a greater number of renal arteries discovered during nephrectomy than were detected by CTA (Table 2).

Discussion

Living-donor surgeries completely contradict the first rule of medicine, "*primum non nocere*." In these procedures, a healthy organ is surgically removed from a healthy individual. While organs removed due to malignancy or other pathological reasons are sent to pathology, the organ removed in donor surgeries is used in another individual. Therefore, it is crucially important that the organ to be transplanted is removed with minimal harm to the donor and the organ itself. Due to the shortage of cadaveric donor kidneys in Turkey, living-donor kidney transplantation is more common here than in the European Union or USA [5]. According to recent data, living-donor transplantations account for over 75% of all kidney transplantations performed in Turkey [6], whereas this percentage is only about 25% in the USA [7].

Both radiological and laboratory assessments are essential components of the preoperative evaluation of potential living donors. Intravenous pyelography and digital subtraction angiography have been successfully used for many years to visualize the anatomy of candidate donors' kidneys. However, both imaging methods involve exposing the donors to high levels of radiation and potentially nephrotoxic intravenous iodinated contrast medium. Moreover, digital subtraction angiography is a more invasive method than CTA, and donor candidates had to be hospitalized after the procedure. With technological advances, CTA replaced these 2 imaging methods and has been successfully used in the preoperative assessment of living donors for 2 decades [8].

In recent years, magnetic resonance angiography (MRA) has been introduced as an alternative imaging modality to CTA for preoperative renovascular assessment of living donors. Advantages of MRA over CTA include not exposing patients to radiation and avoiding the side effects of contrast agents. The main advantage of CT is that precontrast imaging enables the detection of asymptomatic kidney stones. Donor kidney stones are known to be a relative contraindication for transplantation [9]. Ultrasonography has a low sensitivity, especially in the detection of kidney stones <5 mm, and noncontrast CT is currently the gold standard for visualizing stones of this size [10].

There are numerous known anatomical variations in the renal vasculature. CTA is superior to MRA in imaging the renal venous system, which includes the adrenal vein, gonadal vein, and lumbar branches [11]. Another advantage of CTA is that it is less expensive than MRA. However, there are many publications in the literature which compare CTA and MRA in terms of the evaluation of renovascular structures in candidate donors. Some studies showed that CT was superior, especially when its correlation with intraoperative findings were analyzed [12, 13], while others demonstrated equal effectiveness [14]. Some researchers, however, emphasized that MRA should be the only imaging method used for renal assessment of candidate donors due to its high sensitivity and specificity [15, 16], and recommended that CTA only be considered as an alternative imaging method in patients who are ineligible for MRA. As a result, there is still no consensus regarding the optimal evaluation method for potential living donors.

In our study, renal artery imaging by CTA had 97.9% diagnostic accuracy for the number of arteries when compared with intraoperative findings. Similarly, Çıra et al. [3] reported a 97% accuracy rate with CTA in their study of 286 living donors. In this situation, false-negative results are of greater importance for the surgery than false-positive results. It must be kept in mind that a vein or veins not detected before donor nephrectomy may cause unwanted complications during the operation. In our study, more arteries were detected by CTA than during surgery in only 2.1% of 2,144 patients, which can be considered false-positive results. None of the donors included in the study actually had more renal arteries (discovered during laparoscopic donor nephrectomy) than were detected in CTA, which would be a false-negative result.

Our study, in which CTA was used to evaluate renal arteries in over 2,000 kidney transplantations, is – to the best of our knowledge – the largest series in the literature. An important point in this series is that CTA revealed 2 or more renal arteries in 18.9% of the donors. We believe that this finding is especially valuable in terms of providing an initial idea to the surgical team that will perform the donor nephrectomy. The prevalence of accessory renal arteries varies widely by region [17], and multiple renal arteries are not a desirable factor in transplant surgery. In fact, the number of renal arteries has a more significant negative predictive value than renal vein length [8].

Laparoscopic donor nephrectomy has been performed as a minimally invasive, standard method for living-donor kidney transplantation for nearly 2 decades due to its advantages, which include shorter hospital stay, mild postoperative pain, low morbidity, and cosmetic superiority [18, 19]. The main difference between donor nephrectomy and other nephrectomies is that the removed organ will be used in another patient. Before laparoscopic donor nephrectomy, the renovascular anatomy and collecting system must be carefully and accurately assessed. Loss of tactile sensation and/or limited field of view in the laparoscopic approach might cause an important limitation compared to classical open surgery [20]. Complex renovascular structures in particular may have consequences that can directly impact the surgical outcome [4]. Although small accessory arteries do not affect graft function, lower pole renal arteries are critically important as they may also have a role in supplying both the renal pelvis and upper portion of the ureter [21]. The surgical team must be prepared for such variations. The other key point is to protect the donor from postoperative morbidity and mortality.

A limitation of this study is that only the number of renal arteries in the donor kidney was evaluated. The venous structures and other renovascular variations in the donor kidney were not included in the study.

Conclusion

CTA is highly accurate compared to intraoperative findings, and it is an effective method for assessing donor candidates for living-donor kidney transplantation and identifying renovascular variations. However, it must be kept in mind that 2 or more renal arteries may be detected in 18.9% of candidate donors in CTA assessment.

Statement of Ethics

The study was approved by the local ethics committee (approval No. 2019/004), and written informed consent was obtained from all participants. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki.

Disclosure Statement

The authors declare to have no conflict of interest.

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Author Contributions

M.S.: writing and concept, M.C.: data collection, Y.Y.: literature Search, E.D.: critical review, and M.E.: analysis.

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