

# Prevalence of Renal Artery and Kidney Abnormalities by Computed Tomography among Healthy Adults

Elizabeth C. Lorenz,\* Terri J. Vrtiska,<sup>†</sup> John C. Lieske,\*<sup>‡</sup> John J. Dillon,\* Mark D. Stegall,<sup>§</sup> Xujian Li,<sup>||</sup> Eric J. Bergstralh,<sup>||</sup> and Andrew D. Rule\*<sup>¶</sup>

Divisions of \*Nephrology and Hypertension, <sup>§</sup>Transplantation Surgery, <sup>||</sup>Biomedical Statistics and Informatics, and <sup>¶</sup>Epidemiology, and the Departments of <sup>†</sup>Radiology and <sup>‡</sup>Laboratory Medicine and Pathology, Mayo Clinic, Rochester, Minnesota

**Background and objectives:** Management of incidental renal artery and kidney abnormalities in patients undergoing computed tomography scans is a clinical challenge because their frequency in healthy subjects has not been precisely estimated. Therefore, the prevalence and management of these abnormalities were determined among a large cohort of potential kidney donors undergoing protocol evaluations.

**Design, setting, participants, & measurements:** All patients at the Mayo Clinic who underwent computed tomographic angiography and urography as part of their kidney donor evaluation between 2000 and 2008 were identified. Radiographic reports were abstracted for abnormalities of the renal arteries and kidneys. The prevalence of radiographic abnormalities was stratified by age and gender, and the effect on approval for kidney donation was determined.

**Results:** Among 1957 potential kidney donors, the mean  $\pm$  SD age was 43  $\pm$  12 years, and 58% were women. The most common abnormalities were kidney stones (11%), focal scarring (3.6%), fibromuscular dysplasia (2.8%), and other renal artery narrowing or atherosclerosis (5.3%). Fibromuscular dysplasia, focal scarring, parenchymal atrophy, and upper tract dilation were more common in women. Renal artery narrowing, focal scarring, and indeterminate masses increased with age. Overall, 25% of potential donors had at least one abnormality. However, these incidental radiographic abnormalities contributed to exclusion from donation in only 6.7% of potential donors.

**Conclusions:** Incidental radiographic abnormalities of the renal arteries and kidneys are common. The majority of imaging findings are not perceived to be harmful enough to prevent kidney donation, but future studies are needed to determine their clinical relevance.

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Potential living kidney donors are a useful population in which to examine the prevalence and perceived significance of renal artery and kidney abnormalities in asymptomatic healthy adults because the donors undergo a rigorous evaluation for underlying disease that might preclude donation. Although the evaluation protocols vary between transplant centers, general guidelines have been developed (1). In addition to the standard history and examination, a laboratory evaluation is performed. Patients who have an abnormally low GFR, proteinuria, or significant risk factors for chronic kidney disease (*e.g.*, diabetes mellitus) are not approved for kidney donation (2). Protocol renal imaging has also become a component of the potential kidney donor evaluation. Imaging of the kidneys and renal vessels not only defines surgical anatomy but also detects occult pathology that might preclude donation (3). Prior studies examining the prevalence of radiographic kidney abnormalities in normal adults have been limited by small sample size (4–20). The purpose of this study is to

determine the variety and prevalence of incidental renal artery and kidney abnormalities present by computed tomographic (CT) angiography and urography among asymptomatic healthy adults. In addition, we assessed whether these abnormalities differed by age or gender, reviewed their clinical management, and assessed their effect on approval for donation.

## Materials and Methods

### Study Population

As part of a standardized protocol instituted in 2000, all potential kidney donors at the Mayo Clinic underwent CT angiography and urography to evaluate anatomy and identify abnormalities of the renal arteries and kidneys. Before the clinic visit and CT scan, all potential donors were prescreened. Based on a telephone interview with a transplant nurse, potential donors were excluded from further evaluation if they reported diabetes mellitus, use of more than one antihypertensive medication (two medications were permitted if one was a thiazide diuretic), severe obesity, active drug use, active psychiatric disorders, hepatitis, HIV, significant cardiovascular disease, or a history of urologic procedures that would preclude donation. Potential donors who reported a history of nephrolithiasis on the telephone interview were often asked to complete a 24-hour urine study for kidney stone risk factors and could be excluded if marked abnormalities were detected. The remaining potential donors underwent further evaluation at a clinic visit that included a prescheduled CT angiography and urogra-

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**Correspondence:** Dr. Andrew D. Rule, Mayo Clinic, 200 1st Street SW, Rochester, MN 55905. Phone: 507-284-8045; Fax: 507-284-1161; E-mail: [rule.andrew@mayo.edu](mailto:rule.andrew@mayo.edu)

phy of the kidneys. The serum creatinine level was reviewed by the radiologist before administration of contrast. All potential kidney donors that underwent a standardized CT scan between March 30, 2000, and July 23, 2008, and had research authorization in accordance with Minnesota State law were reviewed for clinical, laboratory, and radiographic findings.

### CT Scans

CT examinations were interpreted by radiologists with specialized interest in genitourinary imaging. From 2000 to 2005, all CT exams were acquired on the same modified four-channel multidetector CT scanner (Qxi; GE Medical Systems, Milwaukee, WI) with a modified tabletop, which permitted the acquisition of both axial CT images and traditional film-screen urograms (21). Precontrast axial CT scans were followed by a CT angiogram (standard prep delay of 15 to 18 seconds after intravenous contrast administration). A nephrographic-phase CT exam (obtained 55 seconds after intravenous contrast injection) was then performed. Ureteral compression balloons were inflated over the lower abdomen 2 minutes after intravenous contrast injection, and a traditional 8-minute overhead film-screen urogram was obtained. An excretory-phase CT scan and a 10-minute film-screen urogram could be obtained at the discretion of the radiologist.

Beginning in September of 2005, all renal donor CT evaluations were obtained on a 64-channel multidetector CT scanner (Sensation 64; Siemens Medical Solutions). A precontrast spiral CT scan was obtained followed by a CT angiogram acquisition using bolus-timing software. Nephrographic CT images were acquired 55 seconds after the start of the intravenous contrast injection. Ureteral compression balloons were inflated 2 minutes after the injection, and enhanced topographic images were obtained at 8 minutes and at 10 minutes. Excretory-phase CT imaging could be obtained at the request of the radiologist 10 minutes after the injection. Automated coronal reformatted images were obtained from all axial series acquisitions, and 3D volume rendered images were obtained at an independent workstation by dedicated 3D technologists.

CT scan reports were manually reviewed (E.C.L.). Initially, the 10 first, the 10 middle, and the 10 last reports were reviewed to determine renal artery and kidney findings that were being reported. An electronic database was created to abstract these and other typical imaging findings, with a "comment" field to capture any unexpected findings. Stones identified by the radiologist as being "tiny" were labeled as 0.5 mm in diameter. If the size of the largest stone or the number of stones was not specified in the report, the CT images were reviewed. Renal artery narrowing, atherosclerosis, and calcification were grouped together. Any mention of caliectasis, pyelectasis, or a generous, dilated, or prominent collecting system was identified as upper urinary tract dilation. Renal masses or cysts were identified as indeterminate if the radiologist described them as "indeterminate" or "suspicious" or if a renal ultrasound was pursued after the CT scan to further characterize the mass or cyst. Polycystic kidney disease was identified if the radiologist described findings consistent with polycystic kidney disease or if it was later diagnosed in the medical record. Reports of simple cysts or angiomyolipomas were not abstracted.

### Other Donor Characteristics

To characterize the population, all charts were manually reviewed for race, BP, body mass index, comorbidities (past symptomatic kidney stones, diabetes, hypertension, history of urinary tract infection, and history of symptomatic cardiovascular events (stroke, myocardial infarction, heart failure, or peripheral arterial disease)), and habits (alcohol use and cigarette smoking). Protocol laboratory studies were ob-

tained, including GFR (iothalamate clearance), 24-hour urinary albumin excretion, cholesterol, fasting glucose, serum uric acid, serum calcium, and serum phosphorus. The clinical notes of all potential donors with CT scan abnormalities who were not approved for kidney donation were further reviewed to determine whether the radiographic abnormality contributed to exclusion from donation. Further management for each radiographic abnormality was also noted. Abnormal radiographic findings were grouped into the following categories: absolute contraindication (always led to exclusion from donation), relative contraindication (sometimes led to exclusion from donation), and perceived clinically irrelevant (never led to exclusion from donation). Most approved donors underwent a left-sided, hand-assisted laparoscopic nephrectomy (right-sided if indicated based on abnormalities or renal artery variants).

### Statistical Analyses

The prevalence of each radiographic abnormality was estimated and compared by gender, age group (<30, 30 to 39, 40 to 49, 50 to 59, and  $\geq 60$  years), and between approved and not approved potential donors. Exact binomial confidence intervals are presented for the overall prevalence estimates. Logistic regression models compared the likelihood of each abnormality by gender with and without adjustment for age and by age with and without adjustment for gender. In subgroup analysis of kidney stones, the number of stones, the diameter of the largest stone, and the proportion with bilateral stones were compared between approved and not approved potential donors using rank sums test (continuous) or  $\chi^2$  test (categorical). All analyses were performed with SAS version 9.1.

## Results

### Prevalence of Radiographic Abnormalities

The study sample consisted of 1957 potential living kidney donors, who were 58% female and who had a mean age of 43 years (1130 women (44 years), 827 men (42.6 years),  $P = 0.0053$ ) (Table 1). Reported renal artery findings on CT scan included accessory renal arteries (43%), fibromuscular dysplasia (2.7%), atherosclerosis or narrowing or stenosis other than fibromuscular dysplasia (5.3%), and dilations or aneurysms (0.6%) (Table 2). Reported kidney parenchymal abnormalities on CT scan included tubular ectasia (medullary sponge kidney) (2.0%), focal scarring (3.6%), indeterminate masses (1.4%), parenchymal calcifications (1.1%), diffuse thinning or atrophy of either kidney (0.9%), polycystic kidney disease (0.3%), and chronic inflammatory changes (0.05%). Other abnormalities reported on CT scan were kidney stones (11%), upper urinary tract dilation (2.5%), malrotation (0.7%), congenital lobulation (0.5%), solitary or horseshoe or pelvic kidney (0.2%), and perinephric edema (0.05%).

Men were more likely than women to have accessory renal arteries, whereas women were more likely to have fibromuscular dysplasia, focal scarring, atrophy of either kidney, or upper urinary tract dilation. Likelihood of kidney stones did not vary by age or gender. Older age was associated with fibromuscular dysplasia, other renal artery narrowing or atherosclerosis, focal scarring, parenchymal calcifications, and indeterminate masses, whereas polycystic kidney disease and congenital abnormalities had borderline associations with younger age (Table 3). Notably, four of six potential donors

**Table 1.** Characteristics of 1957 potential kidney donors at the Mayo Clinic between 2000 and 2008

Potential Donor Characteristic	Mean $\pm$ SD (Range) or n (%)
Age, y	43 $\pm$ 12 (18 to 76)
Gender, female	1130 (58)
Race, white	1707 (92)
Ethnicity, Hispanic	31 (1.7)
Body mass index, kg/m <sup>2</sup>	28 $\pm$ 5 (18 to 59)
Systolic BP, mmHg	125 $\pm$ 16 (80 to 198)
Diastolic BP, mmHg	75 $\pm$ 10 (25 to 122)
Diabetes mellitus	6 (0.2)
History of cardiovascular events	7 (0.4)
Hypertension	286 (14.6)
History of urinary tract infection	131 (6.7)
Daily alcohol use	119 (6.1)
Current smoker	415 (21)
Past smoker	429 (22)
GFR, ml/min per 1.73 m <sup>2</sup>	101 $\pm$ 19 (57 to 177)
24-h urine albumin excretion, mg	8.2 $\pm$ 18 (0 to 458)
Total cholesterol, mg/dl	198 $\pm$ 38 (84 to 437)
Fasting glucose, mg/dl	96 $\pm$ 10 (51 to 146)
Uric acid, mg/dl	5.3 $\pm$ 1.4 (1.3 to 11)
Calcium, mg/dl	9.6 $\pm$ 0.3 (8.4 to 11)
Phosphorus, mg/dl	3.5 $\pm$ 0.5 (1.8 to 6.2)

with polycystic kidney disease were related to a potential recipient with this disease.

### Management of Radiographic Abnormalities

The majority (75%;  $n = 1469$ ) of potential kidney donors had no radiographic abnormalities on CT scan (Figure 1), including individuals with accessory renal arteries and congenital lobulation because these findings were never considered harmful such that they precluded donation. Radiographic abnormalities that were absolute contraindications to donation were found in 0.5% ( $n = 10$ ) of potential donors and included polycystic kidney disease, solitary or horseshoe kidney, and pelvic kidney. All other abnormalities were considered relative contraindications and occurred in 24% ( $n = 478$ ) of potential donors. Of all persons with radiographic abnormalities of the renal arteries or kidneys ( $n = 488$ ), the abnormalities contributed to exclusion from donation in 27% ( $n = 132$ ). Figure 2 depicts the percentage of persons for each radiographic abnormality that were excluded from donation because of the abnormality. Kidney stones were the most common radiographic abnormality that contributed to exclusion from donation, followed by parenchymal abnormalities and renal artery abnormalities (Figure 3).

The management of incidental renal artery abnormalities varied. Renal artery narrowing or stenosis or atherosclerosis ( $n = 103$ ) contributed to 21 patients not being approved for kidney donation. Of these, four were started on either new or

additional antihypertensive medications for concurrent hypertension, and none underwent revascularization procedures. Fibromuscular dysplasia ( $n = 54$ ) contributed to 17 patients not being approved for kidney donation. Of these, two were started on either new or additional antihypertensive medications for concurrent hypertension, and none underwent revascularization procedures. Renal artery dilation ( $n = 12$ ) contributed to six patients not being approved for kidney donation, where the dilation was interpreted as an aneurysm. Five of these six patients were advised to follow up with vascular surgery or undergo repeat imaging. One patient was also started on an antihypertensive medication for concurrent hypertension.

For most parenchymal abnormalities, there were no interventions other than monitoring, and the severity of the abnormality influenced exclusion from kidney donation (Figure 2). One potential donor was excluded for suspected chronic inflammatory changes in the right kidney parenchyma. Another potential donor had minimal diffuse perinephric soft tissue edema or thickening bilaterally, and these findings did not lead to exclusion from donation. Indeterminate or suspicious renal masses ( $n = 27$ ) on CT scan were further evaluated with ultrasound and were found to be benign in 11 patients and considered benign on rereview of the CT scan images for two patients. Of the remaining 14 patients in which the mass contributed to donor exclusion, four underwent surgical resection (three renal cell cancers and one papillary adenoma on gross pathology) and 10 were advised to undergo surgical resection or follow-up imaging at other institutions.

Kidney stones were detected in 210 potential donors. These stones specifically contributed to 51 persons not being approved for donation, whereas another 39 with stones were excluded from donation for other reasons. Characteristics associated with exclusion *versus* approval for kidney donation were the mean number of stones (3.0 *versus* 1.9;  $P = 0.0053$ ), bilateral stones (36% *versus* 18%;  $P = 0.0034$ ), and mean diameter of largest stone (2.8 *versus* 1.4 mm;  $P = 0.0005$ ). The one patient with a staghorn calculus was excluded from kidney donation. One patient underwent ureteroscopy with laser lithotripsy before donation, and another underwent unsuccessful attempted ureteroscopic stone removal before donation. Nine patients were started on medical therapy (potassium citrate in two and thiazide diuretic in seven). Five of these medically treated stone patients were accepted as donors. Upper tract dilation ( $n = 49$ ) contributed to two patients not being approved for donation. Both patients had dilation extending from the renal pelvis into the ureter, but without evidence of an obstructing lesion. Malrotation of a kidney ( $n = 14$ ) contributed to donor exclusion in one patient who had severe malrotation of the middle and lower segments of her right kidney.

### Discussion

Incidental renal artery and kidney abnormalities were commonly present on CT angiography/urography of potential kidney donors, affecting 25% of these ostensibly healthy adults. The most common findings were kidney stones (10.7%), renal artery narrowing or atherosclerosis (5.3%), focal scarring (3.6%), fibromuscular dysplasia (2.8%), and upper urinary tract

Table 2. CT scan findings overall and by gender among 1957 potential kidney donors at the Mayo Clinic between 2000 and 2008

CT Findings of the Kidneys and Renal Arteries	Overall, <i>n</i> (%) [95% CI]	Men, <i>n</i> (%)	Women, <i>n</i> (%)	<i>P</i>	
				Unadjusted	Age-Adjusted
<i>n</i>	1957	827	1130		
Renal artery variants					
>1 left renal artery	565 (29 [27,31])	266 (32)	299 (27)	0.0060	0.0062
>1 right renal artery	528 (27 [25,29])	238 (29)	290 (26)	0.12	0.12
>1 renal artery on either side	845 (43 [41,45])	384 (46)	461 (41)	0.013	0.013
>1 renal artery on both sides	248 (13 [11,14])	120 (15)	128 (11)	0.037	0.037
Renal artery abnormalities					
fibromuscular dysplasia	54 (2.8 [2.1,3.6])	10 (1.2)	44 (3.9)	0.0007	0.0015
other renal artery narrowing or atherosclerosis	103 (5.3 [4.3,6.4])	48 (5.8)	55 (4.9)	0.36	0.080
renal artery dilatation	12 (0.6 [0.3,1.1])	5 (0.6)	7 (0.6)	0.97	0.96
Parenchymal abnormalities					
medullary sponge kidney	40 (2.0 [1.5,2.8])	13 (1.6)	27 (2.4)	0.2101	0.24
focal scarring	70 (3.6 [2.8,4.5])	15 (1.8)	55 (4.9)	0.0006	0.0011
diffuse thinning or atrophy of either kidney	17 (0.9 [0.5,1.4])	2 (0.2)	15 (1.3)	0.023	0.023
parenchymal calcification	21 (1.1 [0.7,1.6])	13 (1.6)	8 (0.7)	0.074	0.058
indeterminate mass	27 (1.4 [0.9,2.0])	11 (1.3)	16 (1.4)	0.87	0.97
polycystic kidney disease	6 (0.3 [0.1,0.7])	2 (0.2)	4 (0.4)	0.66	0.61
other parenchymal abnormality	2 (0.1 [0.0,0.4])	1 (0.1)	1 (0.1)	0.83	0.70
Kidney stones	210 (11 [9.4,12])	87 (11)	123 (11)	0.80	0.84
Upper urinary tract dilatation	49 (2.5 [1.9,3.3])	7 (0.9)	42 (3.7)	0.0002	0.0002
Any congenital abnormality	26 (1.3 [0.9,1.9])	8 (1.0)	18 (1.6)	0.22	0.20
solitary or horseshoe or pelvic kidney	4 (0.2 [0.1,0.5])	1 (0.1)	3 (0.3)	0.47	0.51
malrotation of either kidney	14 (0.7 [0.4,1.2])	4 (0.5)	10 (0.9)	0.31	0.27
congenital lobulation	9 (0.5 [0.2,0.9])	3 (0.4)	6 (0.5)	0.59	0.56

95% CI, 95% confidence interval.

dilatation (2.5%). Fibromuscular dysplasia, focal scarring, parenchymal atrophy, and upper urinary tract dilation were more common in women than men. Renal artery narrowing or atherosclerosis, focal scarring, and indeterminate masses increased with age. Most radiographic abnormalities were not perceived to be harmful enough to prevent kidney donation and only contributed to exclusion from donation in 6.7% of all potential donors. Even when these incidental abnormalities contributed to donor exclusion, there were usually no specific interventions recommended other than monitoring. These findings highlight the need for outcome studies to inform the clinical significance of incidental renal artery and kidney abnormalities detected by CT angiography/urography.

In general, the prevalence of renal artery abnormalities in our study was comparable to that found in other studies. Accessory renal arteries involved 29% of left kidneys and 27% of right kidneys, similar to the previously reported prevalence of 16% to 32% in left kidneys and 22% to 39% in right kidneys (15,16,22–25). Renal artery narrowing or atherosclerosis was strongly associated with age, consistent with the progression of atherosclerotic plaques with aging. The prevalence of renal artery narrowing or atherosclerosis in our study (5.3%) is much lower than the 29% prevalence of incidental renal artery calcification seen in another

study involving older individuals undergoing CT scans for various medical reasons (26). Other reports of fibromuscular dysplasia in potential donors identified a prevalence of 3.8% to 4.4% using conventional angiography, with 75% being women (27,28), compared with the 2.7% prevalence by CT angiography in our study (with 81% being women). The 0.6% prevalence of renal artery dilation in our study compares with 1.3% in another study of potential kidney donors (29).

An indeterminate mass was detected in 1.4% of potential donors, higher than the 0.4% prevalence in another study involving potential donors (30) and the 0.6% prevalence in trauma patients undergoing abdominal CT imaging (31). Our study also found a much higher prevalence of kidney stones (11%) than prior studies that used CT scans in asymptomatic healthy adults (3.2% to 6.1%) (11,32,33). The higher prevalence is likely related to interval advances in CT technology, including improved spatial resolution as well as dedicated assessment of the kidneys in kidney donor evaluations compared with other settings. Medullary sponge kidney has been identified in 0.5% to 1.0% of patients undergoing conventional urography for clinical indications (34,35). In our study, we found a higher prevalence of 2.0%, suggesting that CT urography may be more sensitive for detecting this abnormality. Upper urinary

Table 3. CT scan findings by age group among 1957 potential kidney donors at the Mayo Clinic between 2000 and 2008

CT Findings of the Kidneys and Renal Arteries	Age <30 y, n (%)	Age 30 to 39 y, n (%)	Age 40 to 49 y, n (%)	Age 50 to 59 y, n (%)	Age ≥60 y, n (%)	P (Trend Test)	
						Unadjusted	Gender-Adjusted
<i>n</i>	259	495	596	412	195		
<b>Renal artery variants</b>							
>1 left renal artery	67 (26)	161 (33)	173 (29)	107 (26)	57 (29)	0.46	0.59
>1 right renal artery	70 (27)	133 (27)	165 (28)	107 (26)	53 (27)	0.88	0.99
>1 renal artery on either side	110 (43)	222 (45)	260 (44)	169 (41)	84 (43)	0.54	0.66
>1 renal artery on both sides	27 (10)	72 (15)	78 (13)	45 (11)	26 (13)	0.78	0.92
<b>Renal artery abnormalities</b>							
fibromuscular dysplasia	1 (0.4)	5 (1)	15 (2.5)	19 (4.6)	14 (7.2)	<0.0001	<0.0001
other renal artery narrowing or atherosclerosis	1 (0.4)	2 (0.4)	13 (2.2)	39 (9.5)	48 (24.6)	<0.0001	<0.0001
renal artery dilatation	0 (0)	3 (0.6)	3 (0.5)	3 (0.7)	3 (1.5)	0.085	0.087
<b>Parenchymal abnormalities</b>							
medullary sponge kidney	4 (1.5)	4 (0.8)	19 (3.2)	5 (1.2)	4 (2.1)	0.48	0.41
focal scarring	4 (1.5)	12 (2.4)	14 (2.3)	24 (5.8)	16 (8.2)	<0.0001	<0.0001
diffuse thinning or atrophy of either kidney	2 (0.8)	5 (1)	5 (0.8)	4 (1)	1 (0.5)	0.83	0.70
parenchymal calcification	0 (0)	6 (1.2)	4 (0.7)	8 (1.9)	3 (1.5)	0.066	0.049
indeterminate mass	0 (0)	5 (1)	6 (1)	8 (1.9)	8 (4.1)	0.0003	0.0004
polycystic kidney disease	2 (0.8)	3 (0.6)	0 (0)	1 (0.2)	0 (0)	0.054	0.051
<b>Kidney stones</b>	20 (7.7)	60 (12)	58 (9.7)	45 (11)	27 (14)	0.24	0.26
<b>Upper urinary tract dilatation</b>	7 (2.7)	17 (3.4)	11 (1.8)	9 (2.2)	5 (2.6)	0.34	0.21
<b>Any congenital abnormality</b>	4 (1.5)	12 (2.4)	6 (1.0)	1 (0.24)	3 (1.5)	0.052	0.058

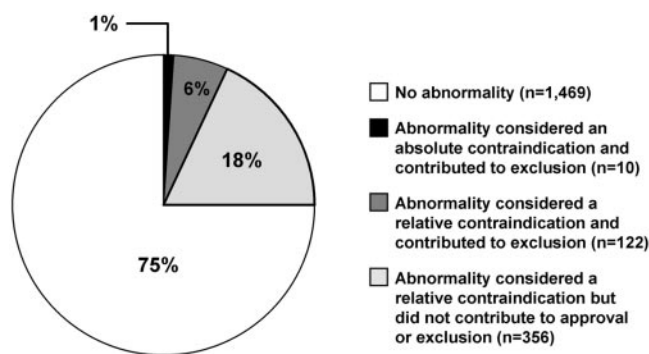


Figure 1. CT scan findings of the renal arteries and kidneys among 1957 potential kidney donors and the impact on exclusion from donation.

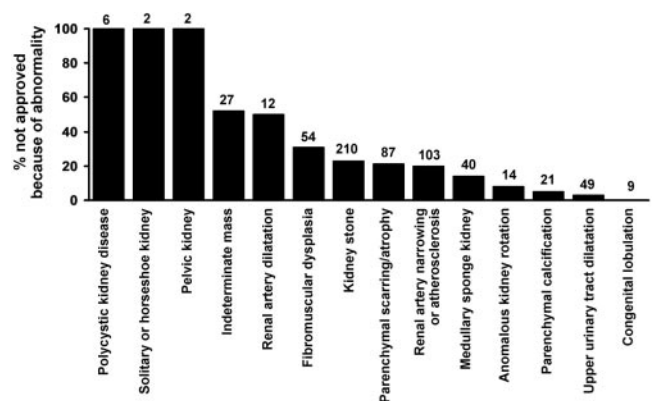


Figure 2. Proportion excluded from kidney donation for each CT scan abnormality of the renal arteries and kidneys.

tract dilation in the absence of an obstructing lesion occurred in 2.5% of our potential donors. It was generally mild, more common in women and, unless there was ureterectasis, did not lead to exclusion from donation. Prior pregnancies (36,37) or prior stone passage may explain this finding. The prevalence of focal scarring (3.6%) in our study was comparable to another

study that reported focal areas of renal volume loss in 8 (6%) of 126 potential donors by CT scan (16).

Congenital abnormalities were generally uncommon. Previous studies have estimated the prevalence of horseshoe kidneys to be approximately 0.2% (38,39), similar to the one patient

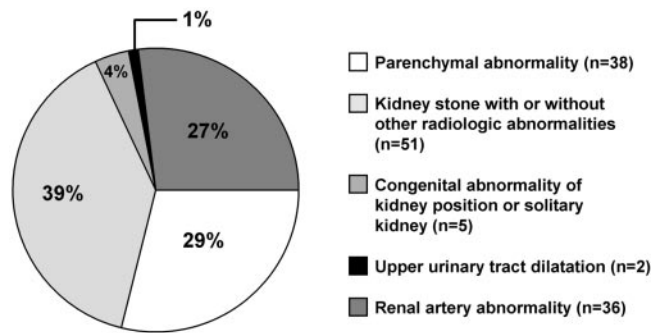


Figure 3. The primary radiographic abnormality of the renal arteries or kidneys that contributed to exclusion from donation for 132 potential kidney donors.

(0.1%) we report. Pelvic kidney is felt to occur in 1 of 500 to 1200 live births (40), also consistent with the 2 of 1957 potential donors in our study. Isolated malrotation (0.7%), which occurs when the kidney fails to rotate normally along its vertical axis, and congenital lobulation (0.5%), a remnant of normal renal development (41), were both slightly more common than other congenital abnormalities. These findings generally had little effect on donor selection except for severe malrotation.

The perception that radiographic abnormalities of the renal arteries and kidneys are harmful, such that the potential donor should be excluded from donation, varies between transplant centers. Risk stratification based on most radiographic findings is largely opinion-based and may be influenced by the type of imaging modality used (42). We found that 132 (6.7%) of 1957 of our potential donors had radiographic abnormalities of the renal arteries or kidneys that were perceived as contraindications for kidney donation, compared with 38 (11%) of 333 (42), 5 (4.0%) of 126 (16), and 3 (1.9%) of 159 (43) in other studies that used CT angiography/urography. This discrepancy between centers suggests a need for further research on the clinical relevance of these abnormalities. Unlike serum creatinine and urine albumin, there is a paucity of data on the risk of end-stage renal disease or mortality with these radiographic abnormalities. The 25% prevalence of these abnormalities also raises the possibility that CT angiography/urography could potentially improve risk stratification in patients with early chronic kidney disease.

There are several potential limitations and strengths to this study. Potential kidney donors undergo prescreening with a telephone interview and have a lower burden of comorbidities (particularly diabetes and past cardiovascular events) compared with the general population. Thus, the true prevalence of radiographic abnormalities of the renal arteries and kidneys is likely higher in the general population than in potential kidney donors selected on health. To our knowledge, there are no general population studies with CT angiography/urography assessment of the renal arteries and kidneys. Although many centers exclude potential donors based on history, exam, and laboratory tests before undergoing CT scans, the potential donors in this study underwent CT scans as part of the initial evaluation, which limited some of the selection bias. The CT scan technology changed over the 9-year study period, but this

did not lead to substantive changes in prevalence estimates of abnormalities (data not shown).

In conclusion, incidental radiographic abnormalities of the renal arteries and kidneys are common, some increase with age, and some differ by gender. Most are not perceived to be harmful enough to prevent kidney donation. Future studies are needed to establish the clinical relevance of these abnormalities by relating them to other markers of kidney injury and to clinical outcomes, particularly progressive chronic kidney disease and end-stage renal disease.

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## Disclosures

None.

## References

1. Kasiske BL, Ravenscraft M, Ramos EL, Gaston RS, Bia MJ, Danovitch GM: The evaluation of living renal transplant donors: Clinical practice guidelines. Ad Hoc Clinical Practice Guidelines Subcommittee of the Patient Care and Education Committee of the American Society of Transplant Physicians. *J Am Soc Nephrol* 7: 2288–2313, 1996
2. Bia MJ, Ramos EL, Danovitch GM, Gaston RS, Harmon WE, Leichtman AB, Lundin PA, Neylan J, Kasiske BL: Evaluation of living renal donors. The current practice of US transplant centers. *Transplantation* 60: 322–327, 1995
3. Namasivayam S, Kalra MK, Small WC, Torres WE, Mittal PK: Multidetector row computed tomography evaluation of potential living laparoscopic renal donors: The story so far. *Curr Probl Diagn Radiol* 35: 102–114, 2006
4. Cochran ST, Krasny RM, Danovitch GM, Rajfer J, Barbaric ZM, Wilkinson A, Rosenthal JT: Helical CT angiography for examination of living renal donors. *AJR Am J Roentgenol* 168: 1569–1573, 1997
5. Del Pizzo JJ, Sklar GN, You-Cheong JW, Levin B, Krebs T, Jacobs SC: Helical computerized tomography arteriography for evaluation of live renal donors undergoing laparoscopic nephrectomy. *J Urol* 162: 31–34, 1999
6. Johnson JE, Loveday EJ, Archer LJ, Lear P, Thornton MJ: Preoperative evaluation of live renal donors using multislice CT angiography. *Clin Radiol* 60: 771–777, 2005
7. Kawamoto S, Montgomery RA, Lawler LP, Horton KM, Fishman EK: Multidetector CT angiography for preoperative evaluation of living laparoscopic kidney donors. *AJR Am J Roentgenol* 180: 1633–1638, 2003
8. Kawamoto S, Montgomery RA, Lawler LP, Horton KM, Fishman EK: Multi-detector row CT evaluation of living renal donors prior to laparoscopic nephrectomy. *RadioGraphics* 24: 453–466, 2004
9. Kim JK, Park SY, Kim HJ, Kim CS, Ahn HJ, Ahn TY, Cho KS: Living donor kidneys: Usefulness of multi-detector row CT for comprehensive evaluation. *Radiology* 229: 869–876, 2003

10. Patil UD, Ragavan A, Nadaraj, Murthy K, Shankar R, Bastani B, Ballal SH: Helical CT angiography in evaluation of live kidney donors. *Nephrol Dial Transplant* 16: 1900–1904, 2001
11. Platt JF, Ellis JH, Korobkin M, Reige K: Helical CT evaluation of potential kidney donors: Findings in 154 subjects. *AJR Am J Roentgenol* 169: 1325–1330, 1997
12. Platt JF, Ellis JH, Korobkin M, Reige KA, Konnak JW, Leichtman AB: Potential renal donors: Comparison of conventional imaging with helical CT. *Radiology* 198: 419–423, 1996
13. Pozniak MA, Balison DJ, Lee FT, Jr., Tambeaux RH, Uehling DT, Moon TD: CT angiography of potential renal transplant donors. *RadioGraphics* 18: 565–587, 1998
14. Rajamahanty S, Simon R, Edey M, Butt K, Eshghi M: Accuracy of three-dimensional CT angiography for preoperative vascular evaluation of laparoscopic living renal donors. *J Endourol* 19: 339–341, 2005
15. Raman SS, Pojchamarnwiputh S, Muangsomboon K, Schulam PG, Gritsch HA, Lu DS: Utility of 16-MDCT angiography for comprehensive preoperative vascular evaluation of laparoscopic renal donors. *AJR Am J Roentgenol* 186: 1630–1638, 2006
16. Raman SS, Pojchamarnwiputh S, Muangsomboon K, Schulam PG, Gritsch HA, Lu DS: Surgically relevant normal and variant renal parenchymal and vascular anatomy in preoperative 16-MDCT evaluation of potential laparoscopic renal donors. *AJR Am J Roentgenol* 188: 105–114, 2007
17. Rubin GD, Alfrey EJ, Dake MD, Semba CP, Sommer FG, Kuo PC, Dafoe DC, Waskerwitz JA, Bloch DA, Jeffrey RB: Assessment of living renal donors with spiral CT. *Radiology* 195: 457–462, 1995
18. Rydberg J, Kopecky KK, Tann M, Persohn SA, Leapman SB, Filo RS, Shalhav AL: Evaluation of prospective living renal donors for laparoscopic nephrectomy with multisection CT: The marriage of minimally invasive imaging with minimally invasive surgery. *RadioGraphics* 21 Spec No: S223–S236, 2001
19. Sahani DV, Rastogi N, Greenfield AC, Kalva SP, Ko D, Saini S, Harris G, Mueller PR: Multi-detector row CT in evaluation of 94 living renal donors by readers with varied experience. *Radiology* 235: 905–910, 2005
20. Smith PA, Ratner LE, Lynch FC, Corl FM, Fishman EK: Role of CT angiography in the preoperative evaluation for laparoscopic nephrectomy. *RadioGraphics* 18: 589–601, 1998
21. Kawashima A, Vrtiska TJ, LeRoy AJ, Hartman RP, McCollough CH, King, BF, Jr.: CT urography. *RadioGraphics* 24[Suppl 1]: S35–S54; discussion S55–S58, 2004
22. Baniel J, Foster RS, Donohue JP: Surgical anatomy of the lumbar vessels: Implications for retroperitoneal surgery. *J Urol* 153: 1422–1425, 1995
23. Pollack R, Prusak BF, Mozes MF: Anatomic abnormalities of cadaver kidneys procured for purposes of transplantation. *Am Surg* 52: 233–235, 1986
24. Ratner LE, Kavoussi LR, Schulam PG, Bender JS, Magnuson TH, Montgomery R: Comparison of laparoscopic live donor nephrectomy versus the standard open approach. *Transplant Proc* 29: 138–139, 1997
25. Satyapal KS, Haffejee AA, Singh B, Ramsaroop L, Robbs JV, Kalideen JM: Additional renal arteries: Incidence and morphometry. *Surg Radiol Anat* 23: 33–38, 2001
26. Tolkin L, Bursztyn M, Ben-Dov IZ, Simanovsky N, Hiller N: Incidental renal artery calcifications: A study of 350 consecutive abdominal computed tomography scans. *Nephrol Dial Transplant* 24: 2170–2175, 2009
27. Andreoni KA, Weeks SM, Gerber DA, Fair JH, Mauro MA, McCoy L, Scott L, Johnson MW: Incidence of donor renal fibromuscular dysplasia: Does it justify routine angiography? *Transplantation* 73: 1112–1116, 2002
28. Cragg AH, Smith TP, Thompson BH, Maroney TP, Stanson AW, Shaw GT, Hunter DW, Cochran ST: Incidental fibromuscular dysplasia in potential renal donors: Long-term clinical follow-up. *Radiology* 172: 145–147, 1989
29. Petridis A, Papachristodoulou A, Geroukis T, Fouzas I, Papanikolaou V, Palladas P: Preoperative evaluation of living kidney donors with multidetector computed tomography angiography. *Transplant Proc* 40: 3137–3141, 2008
30. Sener A, Uberoi V, Bartlett ST, Kramer AC, Phelan, MW: Living-donor renal transplantation of grafts with incidental renal masses after ex-vivo partial nephrectomy. *BJU Int* 2009
31. Ekeh AP, Walusimbi M, Brigham E, Woods RJ, McCarthy MC: The prevalence of incidental findings on abdominal computed tomography scans of trauma patients. *J Emerg Med* February 19, 2009 [epub ahead of print]
32. Chin M, Mendelson R, Edwards J, Foster N, Forbes G: Computed tomographic colonography: Prevalence, nature, and clinical significance of extracolonic findings in a community screening program. *Am J Gastroenterol* 100: 2771–2776, 2005
33. Flicker MS, Tsoukas AT, Hazra A, Dachman AH: Economic impact of extracolonic findings at computed tomographic colonography. *J Comput Assisted Tomogr* 32: 497–503, 2008
34. Mayall GF: The incidence of medullary sponge kidney. *Clin Radiol* 21: 171–174, 1970
35. Palubinskas AJ: Renal pyramidal structure opacification in excretory urography and its relation to medullary sponge kidney. *Radiology* 81: 963–970, 1963
36. Beydoun SN: Morphologic changes in the renal tract in pregnancy. *Clin Obstet Gynecol* 28: 249–256, 1985
37. Schulman A, Herlinger H: Urinary tract dilatation in pregnancy. *Br J Radiol* 48: 638–645, 1975
38. Decter RM: Renal duplication and fusion anomalies. *Pediatr Clin North Am* 44: 1323–1341, 1997
39. Weizer AZ, Silverstein AD, Auge BK, Delvecchio FC, Raj G, Albala DM, Leder R, Preminger GM: Determining the incidence of horseshoe kidney from radiographic data at a single institution. *J Urol* 170: 1722–1726, 2003
40. Dunnick NR, McCallum RW, Sandler CM: *Congenital Anomalies. Textbook of Uroradiology*, Baltimore, Williams & Wilkins, 1991
41. Williams H: Renal revision: From lobulation to duplication—What is normal? *Arch Intern Med Educ Pract Ed* 92: ep152–ep158, 2007
42. Strang AM, Lockhart ME, Kenney PJ, Amling CL, Urban DA, El-Galley R, Burns JR, Colli JL, Hammontree LN, Kolettis PN: Computerized tomographic angiography for renal donor evaluation leads to a higher exclusion rate. *J Urol* 177: 1826–1829, 2007
43. Laugharne M, Haslam E, Archer L, Jones L, Mitchell D, Loveday E, Lear P, Thornton M: Multidetector CT angiography in live donor renal transplantation: Experience from 156 consecutive cases at a single centre. *Transpl Int* 20: 156–166, 2007