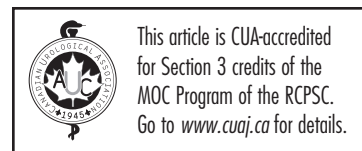


## Computed tomography identified factors that preclude living kidney donation

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### Abstract

**Introduction:** The purpose of this study was to determine the variety and prevalence of renal and non-renal abnormalities detected on multidetector computed tomography (MDCT) that precluded patients from donating a kidney.

**Methods:** Institutional review board approval was obtained and the requirement for informed consent was waived. A retrospective, single-centre review of 701 patients (444 female, 257 male; age range 18–86 years; mean age 43.2±11.9 years) that underwent renal donor protocol MDCT was conducted. A systematic review of the CT report, records from multidisciplinary renal transplantation rounds, and electronic medical records was performed to determine which patients were approved or declined as live renal donors. If declined as a donor, CT-identified reasons were categorized as abnormalities of renal vasculature, renal parenchyma, collecting system, or extra-renal.

**Results:** A total of 81 patients were excluded as renal donors on the basis of CT findings. Abnormalities of the collecting system accounted for the most frequent cause of exclusion (n=41), with asymptomatic renal calculi being detected in 39 patients. Complex vascular anatomy and vascular abnormalities resulted in the exclusion of 29 patients. Supernumerary arteries and early arterial branching resulted in the exclusion of 20 patients, while renal vein anomalies leading to exclusion were uncommon (n=2). Abnormalities of renal parenchyma resulted in the exclusion of nine patients. Three patients were diagnosed with autosomal dominant polycystic kidney disease, two patients had renal cell carcinoma, and two patients had areas of cortical scarring. A complex cystic lesion requiring surveillance imaging was encountered in one patient and a large area of renal infarction related to prior adrenalectomy was demonstrated in one patient. Extra-renal abnormalities leading to exclusion were limited to two patients with pulmonary nodules.

**Conclusions:** MDCT plays a critical role in the preoperative assessment of potential renal donors by identifying contraindications to donor nephrectomy and providing accurate vascular mapping. This study is anticipated to be informative for those involved in

the workup of potential living renal donors by quantifying the incidence and reasons for donor exclusion identified on CT.

### Introduction

Chronic kidney disease (CKD) is a common condition across the developed world,<sup>1</sup> with a prevalence of 12.5% in the adult Canadian population.<sup>2</sup> The prevalence of CKD continues to rise as a result of increasing rates of diabetes, hypertension, obesity, and an aging population.<sup>3</sup> Kidney transplantation has been recognized as the preferred long-term treatment for end-stage kidney disease (ESKD). When compared to dialysis, kidney transplantation results in improved quality of life,<sup>4</sup> prolonged patient survival,<sup>5</sup> and long-term health system cost savings.<sup>6</sup> With a growing ESKD population and limited supply of cadaveric kidneys, living donor kidney transplantation plays an increasingly important role in the management of these patients by potentially increasing the pool of available kidneys. Apart from improved graft survival and recipient outcomes,<sup>7</sup> the overall outcomes for donors are similar to the general population in terms of survival and the risk of developing ESKD.<sup>8</sup> The benefits of living kidney donation have led to it becoming the preferred surgical option in many centres.

Laparoscopic donor nephrectomy (LDN) is the preferred surgical procedure for kidney procurement due to less post-operative pain, faster recovery times, and improved quality of life when compared to open nephrectomy.<sup>9</sup> Living donor transplantation is a high-stakes procedure that requires careful patient and kidney selection and meticulous preoperative planning. Multidetector computed tomography (MDCT) is well-established as an accurate imaging modality for the anatomic assessment of renal vasculature, parenchyma, and collecting system.<sup>10</sup> In addition to assessing the kidneys, MDCT is able to detect other contraindications to pursuing donor nephrectomy. The purpose of this study was to determine the variety and prevalence of renal and non-renal abnormalities detected on MDCT that ultimately preclude patients from donating a kidney.

## Methods

This retrospective, single-centre study was approved by our institutional review board with a waiver for informed consent. Our radiology information system (syngo, Siemens Medical Solutions USA, Inc., Malvern, PA, U.S.) was searched using Montage Search and Analytics (Montage Healthcare Solutions, Philadelphia, PA, U.S.) for renal donor protocol CT examinations performed between January 1, 2005 and December 31, 2014.

A systematic review of the CT report, records from multidisciplinary renal transplantation rounds, and electronic medical records was performed to determine which patients were declined as live kidney donors on the basis of CT-identified reasons. CT-identified reasons were categorized as abnormalities of renal vasculature, renal parenchyma, collecting system, or extra-renal.

### MDCT technique and image analysis

All renal donor CT examinations were performed on a 64 slice MDCT scanner (LightSpeed 64 or Optima 64, General Electric Medical Systems, Milwaukee, WI, U.S.). Our protocol includes an unenhanced phase, late arterial phase, and delayed scout topogram. The unenhanced and late arterial phases of imaging were acquired from the level of the dome of the liver to the pelvic brim. The following parameters were used for the unenhanced phase: 120 kVP, 100–500 mA, 0.5 second rotation time, pitch of 1.375:1, noise index of 26, and reconstructed images with a standard soft tissue algorithm at 2.5 mm. The late arterial phase was acquired using an intravenous injection of 80 cc Visipaque 320 (GE Healthcare, Waukesha, WI, U.S.) at a rate of 4 cc/second with a power injector. Smart Prep bolus tracking (General Electric Medical Systems, Milwaukee, WI, U.S.) was used with the region of interest positioned over the abdominal aorta at the level of the kidneys. The following parameters were used for the late arterial phase: 140 kVP, 200–750 mA, 0.5 second rotation time, pitch of 0.969:1, noise index of 21, and reconstructed images with a standard soft tissue algorithm at 1.25 mm. A delayed scout topogram was acquired supine at a six-minute delay and following the patient sitting upright for one minute to encourage contrast passage into the ureters. Coronal and oblique maximum intensity projection (MIP) reconstructions were generated from source data.

Each examination was reported by a subspecialty-trained, board-certified radiologist on a picture archiving and communication system (PACS) workstation (eFilm, Merge eFilm Inc., Chicago, IL or Carestream PACS, Carestream Health, Rochester, NY, U.S.). Special attention was made to describing renal size, arterial and venous anatomy, nephrolithiasis, cortical scarring, focal renal lesions, collecting system configuration, and significant extra-renal findings. Every CT

examination was reviewed a second time during our multidisciplinary renal transplantation rounds, which included radiologists, urologists, transplant nephrologists, allied health disciplines, and transplant team coordinators. The workup of potential renal donors at our institution has been reported previously.<sup>11</sup>

## Results

A total of 773 patients underwent renal donor protocol CT as part of their workup. Thirty-six patients were excluded from this study on the basis of incomplete medical records. Recipient factors resulted in the exclusion of 16 potential donors due to a rejected recipient (n=6), the recipient receiving a kidney through an alternate or deceased donor (n=6), and recipient death (n=4). Ten patients withdrew their offer to donate a kidney. Psychosocial issues accounted for the exclusion of seven patients, while other unspecified factors resulted in the exclusion of three patients. The remaining 701 patients (444 female, 257 male; age range 18–86 years; mean age 43.2±11.9 years) were reviewed in detail at multidisciplinary rounds and either accepted or declined for donation. CT findings resulted in the exclusion of 81 patients and 67 patients were excluded due to medical reasons that were discovered after the CT was performed (Table 1). Donor nephrectomy was ultimately performed in 388 of the 553 approved patients.

**Table 1. Computed tomography (CT) abnormalities leading to CT-initiated exclusion from kidney donation in 81 patients**

	n
Collecting system	41
Renal calculi	39
Ureteropelvic junction obstruction due to crossing vessels	2
Renal vasculature	29
Supernumerary arteries and/or early arterial branching	20
Renal arterial aneurysms	2
Renal vein anomalies	2
Atherosclerotic plaque at the renal arterial ostium	1
Duplicated IVC	1
Fibromuscular dysplasia	1
Polyarteritis nodosa	1
Renal arterio-venous malformation	1
Renal parenchyma	9
Autosomal dominant polycystic kidney disease	3
Renal cell carcinoma	2
Renal scarring	2
Complex renal cyst	1
Segmental renal infarction	1
Extra-renal	2
Pulmonary nodule	2

Abnormalities of the collecting system accounted for the most frequent cause of CT-initiated donor exclusion ( $n=41$ ). Asymptomatic renal calculi were detected in 39 of these patients. Medullary sponge kidney was present in five patients, five patients had bilateral nephrolithiasis, and 29 patients had unilateral nephrolithiasis. Of the 29 patients with unilateral nephrolithiasis, 20 had a solitary calculus (mean size  $0.3 \pm 0.3$  cm, median 0.2 cm, range 0.1–1.3 cm), six patients had two calculi, and three patients had three or more calculi. Unilateral ureteropelvic junction obstruction due to crossing vessels was demonstrated in two patients.

Complex vascular anatomy and vascular abnormalities were the second most frequent cause of CT-initiated donor exclusion ( $n=29$ ). Two hundred fifty-five patients had at least one kidney with two or more arteries. Supernumerary arteries and/or early arterial branching resulted in the exclusion of 20 patients. Ten patients were deemed to require difficult vascular reconstruction during our multidisciplinary rounds due to the number of arteries, close origin of the arteries, and early branching. Five patients had left-sided supernumerary arteries where the accessory artery was distant from the main artery. A further four patients had bilateral supernumerary arteries where the accessory arteries were distant from the main arteries on both sides. Another patient was excluded due to four right and three left renal arteries. Renal vein anomalies leading to exclusion were uncommon ( $n=2$ ). Less frequent causes of exclusion included arterial aneurysms ( $n=2$ ), fibromuscular dysplasia ( $n=1$ ), atherosclerotic plaque at renal arterial ostium ( $n=1$ ), multiple renal artery aneurysms suggesting polyarteritis nodosa ( $n=1$ ), arterio-venous malformation ( $n=1$ ), and duplicated inferior vena cava ( $n=1$ ).

Abnormalities of renal parenchyma were the third most frequent cause of CT-initiated donor exclusion ( $n=9$ ). Three patients were diagnosed with autosomal dominant polycystic kidney disease (ADPKD), two patients had solid lesions that were excised and confirmed to represent clear-cell renal cell carcinoma, and two patients had areas of significant cortical scarring. A complex cystic lesion requiring surveillance imaging was encountered in one patient and a large area of renal infarction related to prior adrenalectomy was demonstrated in one patient.

Extra-renal abnormalities leading to exclusion were limited to two patients with incidental pulmonary nodules that required surveillance imaging.

## Discussion

Imaging plays a critical role in helping select appropriate patients for donor nephrectomy and as part of preoperative planning. MDCT is the imaging modality of choice in many transplant centres, as it offers a comprehensive assessment of renal vasculature, parenchyma, and collecting systems in a single examination. It provides an accurate depiction

of vascular anatomy and is able to depict contraindications to donor nephrectomy. Imaging findings resulted in the exclusion of 11.6% of our donors, which is comparable to 4.1–16% in prior studies.<sup>12–15</sup>

Incidental nephrolithiasis was the most common cause of renal donor exclusion in our study. We found the prevalence of nephrolithiasis in our study population was similar to that encountered at other institutions.<sup>12,13</sup> Nephrolithiasis has traditionally been considered a contraindication to renal donation due to the risk of stone recurrence in the donor and complications of “gifted calculi” in recipients. However, the shortage of available kidneys and plateauing rates of kidney donation<sup>16</sup> has led some centres to reconsider nephrolithiasis as an absolute contradiction.<sup>17</sup> If incidental nephrolithiasis without an associated significant metabolic abnormality becomes widely accepted under extended criteria, it is logical to expect nephrolithiasis to become a less frequent reason for potential donor exclusion in the future.

Variations of renal vascular anatomy were the second most common cause of donor exclusion. Despite accessory renal arteries<sup>13</sup> and prehilum branching<sup>18</sup> being relatively common, they represented the cause of exclusion in only 2.9% of patients. Multidisciplinary rounds deemed these patients as requiring more extensive surgical reconstruction, higher operative risks, or necessitating sacrifice of accessory vessels that could compromise graft function. Less frequent causes of donor exclusion on the basis of vascular abnormalities included arterial aneurysms, atherosclerosis, and an arterio-venous malformation. All patients with fibromuscular dysplasia were excluded as donors. Patients with bilateral ostial calcification that resulted in luminal narrowing were excluded as donors. However, patients with ostial calcification only on the side of the proposed donor nephrectomy were considered as potential donors. Patients were excluded if there was ostial calcification affecting what would become a solitary kidney following donor nephrectomy.

Solid renal masses were noted in 0.3% of patients, which is lower than the 0.6% prevalence of incidental renal masses seen in trauma patients.<sup>19</sup> Three patients were newly diagnosed with ADPKD following CT. Congenital abnormalities, such as a horseshoe kidney, pelvic kidney, and cross-fused renal ectopia, were not encountered in our study population.

This retrospective study had several limitations. First, a bias may have been introduced, as some patients were excluded during their medical workup and before CT imaging could be performed. All potential donors underwent a pre-CT screening ultrasound. If the screening ultrasound detected a significant abnormality, such as ADPKD or renal cell carcinoma, patients did not proceed in the donation process, nor undergo a renal donor CT. Second, there were different urologists, transplant nephrologists, and radiologists involved in the decision-making process during multidisciplinary rounds over our 10-year study period. Furthermore,

attitudes towards which patient factors and imaging findings constituted an absolute contraindication to donor nephrectomy have evolved over this 10-year period. Third, there may be inter-institutional differences in exclusion criteria for potential renal donors.

## Conclusion

MDCT plays a critical role in the preoperative assessment of potential renal donors by identifying contraindications to donor nephrectomy and providing accurate vascular mapping. This study will be informative for those involved in the workup of potential living kidney donors by quantifying the incidence and reasons for donor exclusion identified on CT.

**Competing interests:** The authors report no competing personal or financial interests

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