Computed Tomograpy Angiography of the Renal Circulation

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KEYWORDS

• Computed tomography angiography • Renal artery stenosis • Atherosclerotic stenosis
• Fibromuscular dysplasia • Curved planar reformat • Three-dimensional volume-rendered display
• Dual energy computed tomography • Renal cell carcinoma

KEY POINTS

- There are 4 distinct phases of enhancement of the kidneys: arterial, cortical, medullary, and excretory/pyelographic phases.
- Using various reformatted displays of the renal circulation aids in accurate depiction of the vessels and degree of arterial stenosis.
- It is not always possible to distinguish acute renal arterial occlusion because of dissection versus thromboembolic disease; therefore, adequate angiographic phase acquisition of the aorta and mesenteric vasculature may provide a full picture of the pathology.
- Acute occlusion of the renal artery can be a diagnostic challenge given significant overlap of disease clinical presentation, and complete imaging of the kidneys may aid timely diagnosis (ie, noncontrast, complete angionephrogram, and excretory phases).
- Dual energy computed tomography can eliminate additional radiation by providing virtual noncontrast imaging and may possibly be able to differentiate various subtypes of renal cell carcinoma.

INTRODUCTION

The kidneys are critical organs maintaining fluid and electrolyte balance and hormonal homeostasis. The arterial blood supply is critical to maintaining these homeostatic functions. Renal arterial blood flow may be compromised by a variety of pathologic conditions that affect the pediatric and adult population. These conditions may be clinically suspect or relatively occult.

Modern medicine has produced substantial literature on the indications for and clinical value of varying approaches to imaging the renal arterial circulation. Within the last 20 years, computed tomography (CT) angiography has evolved as the dominant imaging modality that provides high-resolution 2- and 3-dimensional imaging of the renal arterial circulation together with 3-dimensional display of the renal parenchyma and imaging of the renal veins.[1] Doppler renal sonography, more particularly in pediatric and young adult populations, serves a role as an initial screening modality.[2] Magnetic resonance (MR) angiography has also developed into a high-resolution 2- and 3-dimensional imaging process, but spatial resolution is still inferior to that of CT angiography. MR angiography is of most benefit when used in the pediatric population as a nonionizing imaging modality or in adults with renal dysfunction in whom intravenous iodinated contrast material is relatively contraindicated.[3] However, MR in the adult population with renal dysfunction less than an estimated

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glomerular filtration rate value of 30 also runs the potential risk of nephrogenic systemic fibrosis.

In this article, the clinical indications, techniques, and findings associated with the appropriate use of CT angiography are described.

COMPUTED TOMOGRAPHY ANGIOGRAPHY: TECHNIQUE

In the resting state, renal arterial flow constitutes 25% of cardiac output. This flow is distributed most prominently to the renal cortex, which receives 90% of the renal arterial flow input and also constitutes the most rapid flow component with a renal arteriovenous circulation time of 6 seconds. Flow to the renal medulla and renal sinus tissues occurs at a considerably lower rate and smaller volume flow rate component.

After contrast material delivery into the renal circulation, an initial cortical angionephrogram effect is observed reflecting the fast flow rate and volume flow component to the renal cortex. In a healthy young adult, the cortical angionephrogram effect is observed with diminishing cortical to medullary contrast observed up to 80 seconds after injection. In the timeframe of 80 to 120 seconds, renal medullary enhancement increases secondary to glomerular filtration of contrast material resulting in a uniform nephrogram, which is usually observed up to 180 seconds after injection. At that stage, the excretory phase begins with calyceal excretion of contrast material.[4]

On imaging studies, the renal flow physiology results in the sequential appearance of an arterial and venous flow imaging phase with a cortical angionephrogram, a uniform nephrogram phase, and an excretory phase. CT angiography for depiction of the renal arteries preferably uses first circulation contrast bolus with an accompanying well-defined cortical angionephrogram. Concurrent imaging of the main renal vein is caused by the rapid parenchymal contrast circulation from the renal arteries to renal veins.[4]

Appropriate acquisition timing depends on either preliminary mini bolus or bolus tracking software.

High-resolution CT angiographic images are provided by 64-channel and above detector arrays with submillimeter isotropic volume acquisition. The more modern CT platforms use either a wide detector approach with 256-channel or greater acquisition or a dual source system in a high-pitch mode resulting in rapid acquisition and high temporal resolution.

Contrast material injection and acquisition parameters are critical elements in the production of high-resolution CT angiographic, cortical angiographic, and uniform nephrographic phase display.

Contrast material concentration of 300 mg of iodine per milliliter or greater with an injection rate of 4 to 6 mL/s and contrast volume appropriate for increasing the attenuation of the abdominal aorta and renal arteries by 300 to 400 Hounsfield units is a relatively standard acquisition approach. The volume of contrast material depends on both the duration of acquisition and the patient weight (**Table 1**). In our practice, the standard interval for contrast medium injection is equal to a delay time between the arrival of contrast material in the abdominal aorta and the beginning of acquisition plus the acquisition interval is used (**Fig. 1**). Using preliminary mini bolus technique, the arrival time of contrast material is determined by the time to peak in the abdominal aorta at the level of renal arteries. Only 12 to 15 mL of contrast is needed for this determination. A 4- to 6-second delay between arrival and the beginning of acquisition is used so that imaging is performed during peak aortic enhancement. With an acquisition interval equal to 4 seconds (determined by beam width, pitch, and rotation speed) and a delay time between bolus arrival in the aorta and beginning of scan acquisition equal to 6 seconds, a total contrast material injection interval of 10 seconds is chosen. With an injection rate of 6 mL/s, this results in a total contrast volume of 60 mL.

A sliding scale of total contrast material volume versus patient weight is also used, as larger body weight correlates with higher circulating arterial blood volume, resulting in relative dilution of contrast material bolus. Thus, in patients with larger body weights, a longer contrast medium injection duration and a longer delay between bolus arrival in the aorta and the beginning of scan acquisition are used (**Fig. 2**).

In patients with suspected renal artery stenosis or aneurysm or in patients studied after intravascular

Table 1
Weight/velocity compensated CT Angiography

Patient weight (lbs)	<150	151–200	201–250	251–300	>300
Peak plus delay (s)	4–7	7	11	14	14
Contrast volume (mL)	60–80	80–100	100–125	125–140	140–160