Chapter 6

# Angiography for Renal Artery Diseases

Daniel Emilio Dalledone Siqueira and
Ana Terezinha Guillaumon

Additional information is available at the end of the chapter

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**Abstract**

Renal Artery disease is one of the main causes of systemic arterial hypertension. Among its etiologies are atherosclerosis, fibromuscular dysplasia, Takayasu arteritis, among others. These diseases may evolve into stenosis, occlusion or aneurysms of the renal arteries. In the last decades, technological advances in both imaging diagnosis and treatment, have improved prognosis of patients, leading to earlier medical interventions. For the identification of renal vascular diseases, the adequate angiography technique as well as the capture of quality images are of utter importance. This chapter aims to address the main aspects of the renal artery diseases and their arteriographic findings.

**Keywords:** angiography, renal, atherosclerosis, nephropathy, fibromuscular dysplasia, renal aneurysm, Takayasu arteritis, kidney transplantation, diagnostic catheter

## 1. Introduction

The correct identification of renal vascular diseases by means of imaging techniques, among them the renal angiography, enables physicians to perform an appropriate morphological study and an efficient treatment [1]. Currently, new diagnostic and therapeutic methods have been developed and employed in the treatment of patients with renal vascular disease [2–4].

The present chapter is divided into three sections. The first section introduces the renal vascular anatomy, anatomical variations, renal angiography and its techniques. The second section examines the renal vascular diseases and their imaging findings. The third section presents other methods for the diagnosis of the renal vascular disease.

## 2. Renal angiographic morfology

### 2.1. Renal angiography

Renal angiography, despite the technological advances of the imaging methods, is still considered the final diagnostic method of the renal artery diseases. This method provides an anatomical visibility of the renal arteries when correct techniques are applied. Moreover, treatment decisions are made based on the lesion morphological aspects at arteriography. Another relevant aspect is that arteriography can provide images for immediate diagnostic and endovascular treatment during the procedure. A correct optimization of the arteriographic images provides an adequate assessment of the renal arteries, as well as of their segmental and subsegmental branches.

### 2.2. The renal angiography technique

Arterial access is obtained by inserting a 5F or 6F sheath into the femoral or brachial artery, using the modified Seldinger technique [5]. Ultrasound-guided arterial puncture can also be performed. A 5F catheter is positioned inside the aorta using the femoral or brachial artery access. Renal arteriography must start with the aortography, which aims to identify ostial stenosis of the renal arteries (**Figure 1**). Contrast material is injected manually or by means of an automatic injection pump, providing the sequence of images. The contrast volume, infusion speed, as well as the acquisition characteristics of the images, depend on each patient. Usual parameters include a 10–20 mL/K injection of contrast agent for 2 seconds. Images are usually registered for 3–5 seconds, about 1–2 images per second. However, this procedure may be extended for 3–5 additional seconds, depending on the images of interest, providing assessment of the intra-parenchymatous and venous arterial phases.

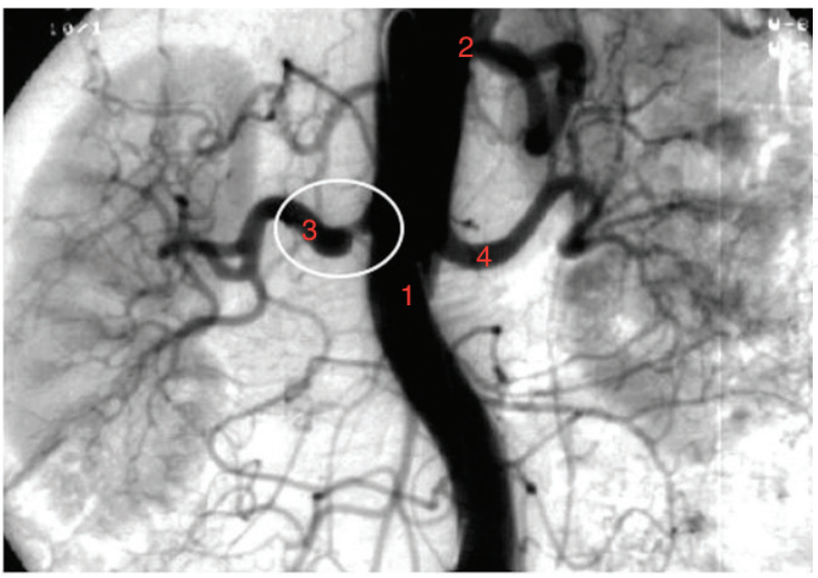


**Figure 1.** Aortography showing – (1) abdominal aorta; (2) superior mesenteric artery; (3) right renal artery, with atherosclerotic ostial stenosis; (4) left renal artery.

Some technical details must be considered for the correct visibility of the renal parenchyma images. The side holes of the catheter must be positioned at the L1–L2 level. The correct positioning is necessary to prevent the contrast agent from filling the superior mesenteric artery, causing overlapping of images.

### 2.3. Selective catheterization of renal arteries

In some cases, depending on the quality of the images captured during aortography, it is necessary to perform selective catheterization of the renal arteries in order to better visualize the ostium and the distal branches, without the overlapping of the aorta and the branches. Selective catheterization must be performed with a preformed catheter such as Cobra, Renal Double Curved (RDC), Omni Selective, Simmons, among others. The renal intravenous contrast may be administered manually or with an injection pump. Volume of contrast agent is usually 3–6 mL/s, administered for 1–2 minutes.

Renal selective catheterization presents advantages in relation to aortography, as a smaller amount of contrast material is necessary to capture renal vessel images. Additionally, it offers the possibility to carry out a hemodynamic study of the stenosis by measuring the blood pressure before and after the lesion. Pressure gradient values cannot be obtained with other non-invasive diagnostic methods.

### 2.4. Registration methods of the angiographic images

Renal angiography may be performed by means of films or digital subtraction. In film-based angiography, X-ray images are recorded after the intravenous contrast injection. On the other hand, in digital subtraction angiography (DSA), the fluoroscopic images are produced in a sequence by means of an image intensifier (**Figure 2**). The captured images are electronically filed in digital format. The initial image, produced before contrast medium injection, is subtracted, generating a mask. All subsequent images are subtracted from this mask image, and only the contrast medium is visualized.

**Figure 2.** Hemodynamic room – School of Medical Sciences at Universidade Estadual de Campinas – UNICAMP.

### 2.5. Normal anatomy

The kidneys are a pair of retroperitoneal organs, located parallel to the spinal column, on the psoas major muscle, generally between L1 and L4 vertebrae level, in an orthostatic position. There may be a change in the position of both kidneys during the respiratory cycle, that is, during the inhalation and exhalation processes. This breathing variation may represent from 1 to 7 cm in the cranial-caudal position. In the supine position, the kidneys generally lie at the T12-L13 spinal segment level. The right kidney may be found slightly more caudal than the left kidney, due to the liver location. Both kidneys represent 0.4% of the total body weight and are approximately 11–13 cm long, the left kidney slightly longer than the right one.

Kidneys are related with the suprarenal gland, located above them, encapsulated by the renal fascia. Posteriorly situated are the diaphragm muscle, psoas major and quadratus lumborum muscles, the branches of the lumbar plexus, the 12 costal arch and the lateral edge of the erector spinae muscle. Anteriorly, they are covered by the peritoneum, the right kidney related to the posterior border of the liver and small intestine, whereas the left kidney is related to the stomach, spleen and small intestine.

At the medial border of the kidneys is a vertical fissure, called renal hilus, through which the renal vessels, nerves and ureter pass. Each kidney is structurally divided into cortex and medulla.

Renal arteries branch off the aorta, at the lateral side, right below the superior mesenteric artery, next to the L1–L2 vertebrae level [6, 7]. The right renal artery passes behind the inferior cava vein. Renal arteries are single in approximately 65% of the population and multiple in 35%. They are subdivided into segmental, interlobar and arcuate arteries.

Venous drainage takes place in the renal vessels, located anteriorly to the ipsilateral renal artery. Both veins drain into the inferior cava vein. Left renal vein is longer and receives tributary veins such as left gonadal vein, suprarenal vein, phrenic vein, among others. Right renal vein, on the other hand, is shorter, and generally does not receive tributaries.

### 2.6. Anatomical variations

Accessory renal arteries may be present in one or in both kidneys, corresponding to 25–35% of the general population [8]. Most accessory renal arteries supply the inferior pole of the kidney, arising from the suprarenal aorta to iliac arteries. Kidney anatomical alterations, such as ectopia, fusion and rotation, are associated with vascular alterations related to variations in origin and the number of renal arteries. In the horseshoe kidney, arterial irrigation is generally provided by three or more arteries, arising from the aorta or the iliac, or from both [9, 10].

Alterations in renal veins are usual. It is possible to observe the circumaortic left renal vein with retroaortic and pre-aortic segments, draining into the inferior cava vein. Additionally, multiple renal veins to the right, the retroaortic left renal vein and the right gonadal vein are observed, draining into the right renal vein [11, 12].

### 2.7. Renal collateral circulation

Renal arteries, despite being described as terminal branches of the abdominal aorta, present systems of collateralization, in cases of stenosis or occlusion. Intra-renal blood flow is provided by

three collateral arterial systems, capsular, peripelvic and periureteral, which are supplied by lumbar arteries, abdominal aorta, internal iliac arteries, inferior adrenal arteries and other vessels [13].

In renal vein occlusion, blood flow is provided through ureteric, gonadal, adrenal, ascending lumbar and capsular veins [13].

## 3. Renal diseases and arteriographic morphology

### 3.1. Renal occlusive disease

Stenosis of the renal arteries may be defined as a multifactorial disease, of several etiologies, which affects the renal artery vasculature, at unilateral or bilateral level, determining various stenosis degrees, from its origin to the renal hilum [1, 14]. Clinically, it is presented as a renovascular hypertension and a renal ischemic disease and is associated with a higher cardiovascular risk and an increase in the mortality rate [15–18]. For research and treatment purposes, several authors suggest that renal artery stenosis is critical when it is greater than 60–70% [19].

The natural history of the renal atherosclerotic disease is still to be fully clarified. However, it is known that there is a progressive stenosis, associated with a decrease in the arterial flow, leading to an ultimate kidney failure, directly related to the stenosis degree of the renal artery [20, 21]. It is estimated that renovascular disease induces kidney failure in 5–15% of dialysis patients every year [22].

Prevalence of renal artery stenosis is controversial, as few population-based studies have been conducted to relate the disease to race, age and gender. Nevertheless, some research studies have demonstrated that renal artery stenosis affects 1–5% of patients with systemic arterial hypertension, representing the main cause of the secondary hypertension [1]. The disease is believed to account for 1% of the cases of mild to moderate hypertension and for 10–40% of the acute, severe and refractory hypertension cases [3]. Additionally, some population-based studies suggest that prevalence of the disease in patients older than 65 years of age is higher than 7% [1]. Random autopsy studies conducted in patients whose death was caused by other etiologies reveal that 4–50% of these patients presented renal arterial stenosis, 40% with no history of a systemic arterial hypertension [23].

Renal artery stenosis may present several etiologies, among them atherosclerosis, fibromuscular dysplasia (FMD) and Takayasu's arteritis (TAK) [24].

#### *3.1.1. Renal occlusive disease: atherosclerosis*

Atherosclerotic renal artery occlusion is more frequent and accounts for 70–80% of the cases. It is more prevalent in men, over 40 years of age, induces stenosis in the proximal segments of the renal arteries and is characterized by the presence of stenotic lesions at the proximal third of the renal arteries [25]. Morphologically, a renal artery atherosclerotic disease resembles eccentric atherosclerotic plaques, evolving towards the arterial lumen, with no precise aortic boundaries (**Figure 3**). It may affect the renal arteries at unilateral or bilateral levels, as well as the polar renal arteries, when they are present. Progression of the disease is observed in 50% of the cases, which may lead to bilateral stenosis, arterial occlusion, with or without renal infarction [20, 21].

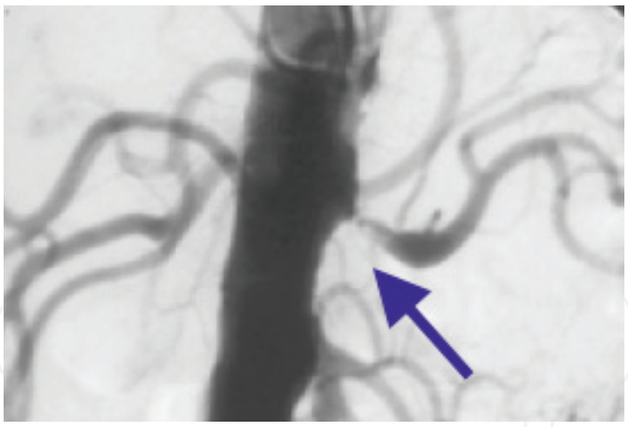

**Figure 3.** Atherosclerotic renal artery stenosis, located at the proximal third of the artery.

*3.1.2. Renal occlusive disease: fibromuscular dysplasia (FMD)*

Renal artery stenosis secondary to fibromuscular dysplasia accounts for 20–25% of the cases [26]. Fibromuscular dysplasia is a non-atherosclerotic and a non-inflammatory disease, which affects medium-sized arteries, rarely involving small-sized ones [27]. It is more prevalent in the Caucasian population, 15- to 50-year old women, affecting the more distal segments of the renal arteries and the intra-parenchymal segments. It may affect both renal arteries in 60% of the cases but is rarely observed in patients older than 60. Recent studies reveal that approximately 2% of renovascular hypertension are related to fibromuscular dysplasia [28].

Among the fibromuscular dysplasia types, the medial one is the most prevalent, the medial fibroplasia subtype accounting for 70–95% of dysplasia cases and 85% of the renovascular lesions [28]. Lesions predominantly affect the medial and distal third of the renal and polar arteries and their branches [26].

Arteriography may provide a high degree of diagnostic accuracy. The usual angiographic profile of medial fibroplasia resembles a string of bead (**Figure 4**). However, the gold standard procedure for the diagnosis of fibromuscular dysplasia is the histopathologic exam. The disease may evolve to renal artery stenosis or aneurysms and its diagnosis is usually an exam incidental finding, as fibromuscular dysplasia does not present alterations of inflammatory expressions such as hemosedimentation rate and C-reactive protein [29].

*3.1.3. Renal occlusive disease: Takayasu's arteritis (TAK)*

Takayasu's arteritis is a chronic, inflammatory and granulomatous disease, a vasculitis that affects large and middle-size arteries [30]. It is prevalent in women (80–90-% of the cases), starting between the age of 10 and 40 [31]. Initial symptoms are not specific, and include fever, general feeling of being unwell, weight loss and joint pains. There might be a vascular problem, which at the initial phase involves the thoracic and abdominal aorta and its main branches [32]. The inflammatory process induces the thickening of the arterial wall, leading to stenosis, occlusion or dilation of the affected arterial segments, at several stages [30]. In

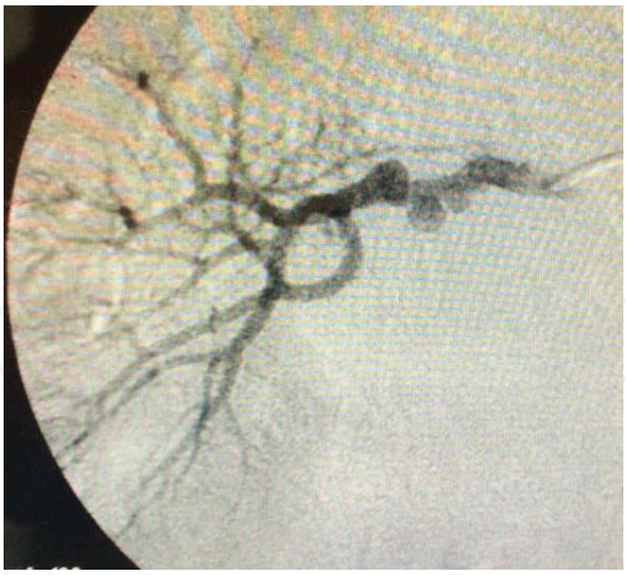

**Figure 4.** Morphological aspect of the fibromuscular dysplasia at selective angiography of the renal artery.

general, the clinical lab findings reveal elevated inflammatory markers, such as, C-reactive protein and hemosedimentation rate. Normocytic and normochromic anemia, and hypoalbuminemia reveal the chronic nature of the disease. Diagnostic criteria, defined by the American School of Rheumatology, include the development of signs and symptoms related to Takayasu's arteritis before the age of 40; claudication of the extremities, weakness; extremities discomfort and fatigue, more commonly in the upper limbs; decrease in the pulse rate amplitude in one or both brachial arteries; difference in the blood pressure of the upper limbs of at least 10 mmHg; murmur in one or both subclavian arteries; abdominal murmur; alterations in the arteriography: narrowing or occlusion of the aorta and /or its main branches or of the large proximal arteries in the lower and upper limbs, not caused by atherosclerosis or fibromuscular dysplasia. Three of the above criteria confirm the diagnosis, sensibility of 90.5% and specificity of 97.8%.

Renal arteries play an important role in the development of the disease in 50–60% of the cases [30–32]. It is clinically characterized by the renal occlusive disease, inducing renovascular hypertension or kidney failure. Treatment of patients affected by renovascular hypertension has been proven difficult. Generally, arteriography is required to confirm the diagnosis of the disease, characterized by its location in the proximal aorta and its branches (**Figure 5**). Nevertheless, due to the method limitation, angiography does not provide the identification of the arterial wall thickening. Other imaging methods for clinical investigation, such as computed angiotomography or angioresonance, are recommended.

### 3.2. Renal aneurysmal disease

The renal aneurysmal disease is uncommon and asymptomatic in most cases. Population-based studies show an incidence of 0.1% of the total population, representing 25% of the visceral aneurysm cases [33]. The actual prevalence is unknown, considering that it is a multifactorial disease and depends on the hereditary aspects of the studied population. Its

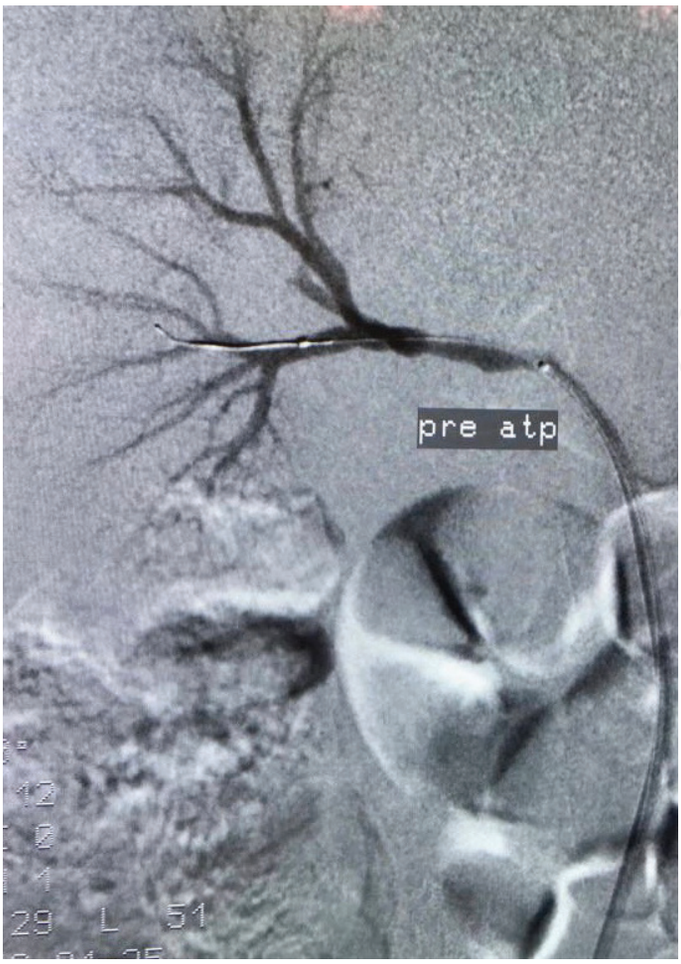


**Figure 5.** Aortography revealing renal artery occlusion induced by Takayasu's arteritis.

diagnosis usually represents an incidental finding during regular exams. It is more prevalent in women, in the right renal artery and rarely bilateral [34]. In most cases, they are solitary aneurysms, mostly saccular-shaped (**Figure 6**), accounting for 75% of the cases, but with some fusiform-shaped aneurysms as well, most often developed in the renal artery bifurcation, 90% of the cases extra-parenchymal and only 10% intra-parenchymal [35]. Among the various etiologies, the most prevalent is fibromuscular dysplasia. Other causes for the development of the renal aneurysmal disease include trauma, congenital diseases (Ehlers-Danlos syndrome and neurofibromatosis), inflammatory diseases, among others [35].

Renal arterial aneurysm presents low complication rates. Main complications are renovascular hypertension, renal artery thrombosis, renal infarction, distal embolization, formation of the arteriovenous fistula, dissection and rupture, the latter more common during pregnancy, mainly in the third trimester [36]. Maternal and fetal mortality rates associated with rupture during pregnancy are 55 and 85%, respectively [37].

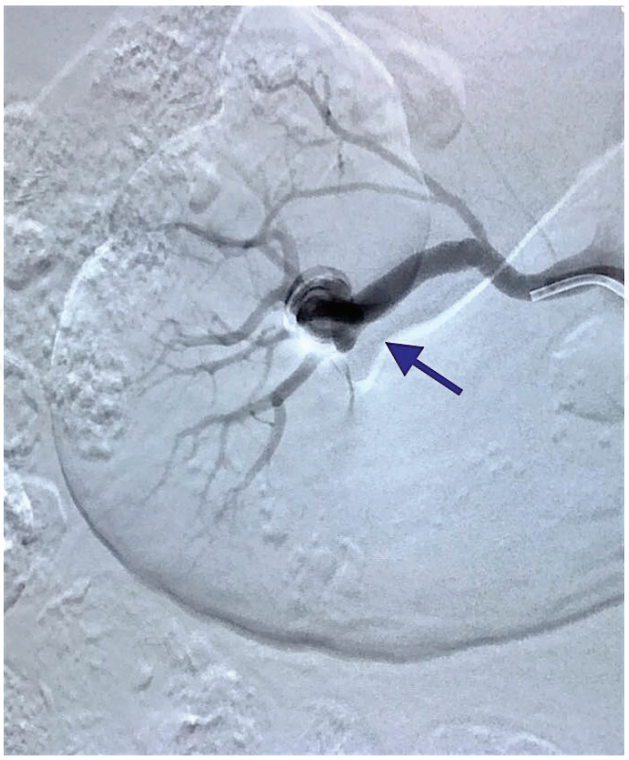

**Figure 6.** Selective arteriography of the renal artery revealing a saccular aneurysm.

Renal artery aneurysms may be classified according to their location: Type 1 in the main renal artery; Type 2 in the bifurcation and beginning of the segmental branches; Type 3 in the distal: intra-parenchymal artery.

Currently, several endovascular treatment methods have been developed to preserve renal function. Treatment indications reported by Henke et al., exhaustively revised, include: (1) renal artery aneurysms of over 1.0 cm in diameter, with a difficulty-to-control hypertension; (2) all renal artery aneurysms of over 2.0 cm in diameter; (3) most aneurysms of 1.5–2.0 cm in diameter. Some authors consider the possibility to treat all symptomatic renal artery aneurysms [35].

### 3.3. Kidney transplantation

Renal transplant represents a treatment option for the terminal renal disease. In this case, arteriography before and after the transplant provides better and thorough technical information.

Vascular complications are rare in renal transplants; however, they may lead to the loss of the transplanted kidney. Among the most common vascular complications are the renal artery stenosis (**Figure 7**), renal artery thrombosis, vascular lesions after biopsy, pseudoaneurysms and hematomas [38].

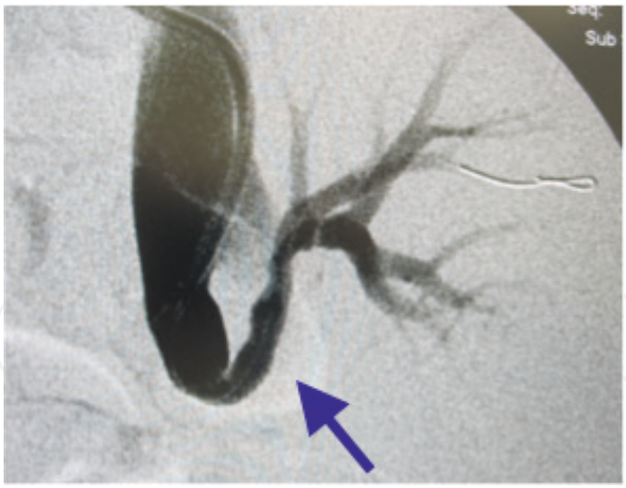

**Figure 7.** Selective arteriography of the transplanted kidney showing anastomotic stenosis.

## 4. Other diagnostic methods

The imaging study of the renal arteries may be performed by other diagnostic methods. In the last years, several imaging techniques have been developed in an attempt to precisely display the renal vascular anatomy, and obtain good quality of images, reproducibility and a lower rate of complications. Each method presents its advantages and disadvantages; however, in general, when compared, these exams are less invasive than renal angiography, considered a standard gold procedure [4].

### 4.1. Eco-Doppler

Eco-Doppler of renal arteries and veins has been widely used as an initial method in the investigation of vascular diseases. It combines the visualization of B-mode images and the measurement of blood flow velocities of renal arteries and veins as well as of specific indexes [39, 40]. Moreover, Eco-Doppler provides information related to renal anatomy, intra-renal vasculature, and kidney size.

### 4.2. Magnetic angioresonance

Magnetic angioresonance (MAR) has been largely used to complement Eco-Doppler investigation of the renal arteries. It is a less invasive method than angiography and provides images of a quality similar to that obtained at angiography. However, it requires neither arterial puncture nor nephrotoxic contrast medium to capture images [4].

The images generated by means of an electromagnetic field are compiled as multiple thin slices, adjacent and transversal. Additionally, tri-dimensional data from the images captured through magnetic angioresonance may be projected in multiple levels, providing better and thorough anatomic understanding of the images.

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### 4.3. Computed tomography (CT scan)

Computed angiotomography of the aorta and its branches is performed by administering an iodine-based contrast dye injection into a peripheral vein [4]. After the administration of the contrast material and the time necessary for each type of study, several sequential images are captured with a rotation platform. The images of the renal arteries are obtained at axial level, in thin slices, and then processed and reconstructed at several other levels with specific software programs, providing a tridimensional view (**Figure 8**).

The advantages of computed angiotomography include the possibility to measure the renal dimensions, the cortical thickness, the renal perfusion and vascular alterations in the aorta and its branches. On the other hand, the use of iodinated contrast media, known to be nephrotoxic, represents a risk factor mainly to nephropathic patients. The contrast volume used at angiotomography is larger than the one at digital subtraction angiography, 120–150 and 10–20 mL, respectively.

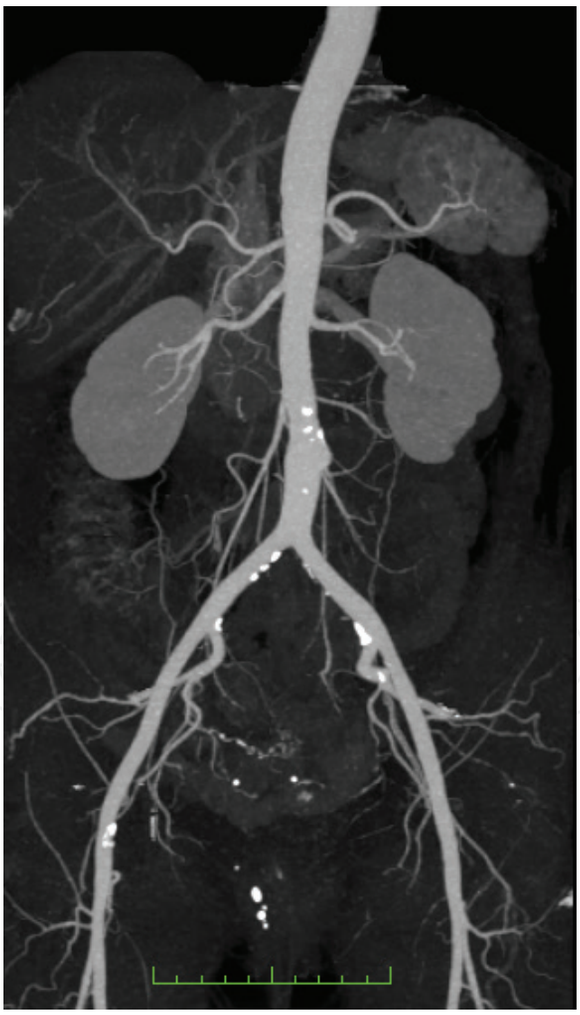

**Figure 8.** Computed angiotomography of the aorta and its branches, tridimensional view.

## Author details

Daniel Emilio Dalledone Siqueira[1,2]* and Ana Terezinha Guillaumon[1,3,4]

*Address all correspondence to: siq_daniel@yahoo.com.br

1 School of Medical Sciences, UNICAMP, Brazil

2 Brazilian Society of Vascular Surgery – SBACV, Curitiba, Brazil

3 Vascular and Endovascular Surgery at the Hospital de Clínicas, UNICAMP, Brazil

4 Brazilian Society of Vascular Surgery – SBACV, Campinas, Brazil

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