Ultrasound as a first line screening tool for the detection of Renal Artery Stenosis: a comprehensive review

Themistoklis N. Spyridopoulos¹,², Katerina Kaziani³, Alexia P. Balanika⁴, Mariana Kalokairinou-Motogna⁵, Vasiliki Bizimi⁶, Iovana Paianidi⁶, Christos S. Baltas⁶

¹ 2nd Department of Radiology, University General Hospital of Athens “Attikon”, Athens, Greece
² Department of Hygiene, Epidemiology and Medical Statistics, Athens University Medical School, Athens, Greece
³ 2nd Critical Care Department, University General Hospital of Athens “Attikon”, Athens, Greece
⁴ Computed Tomography Department, General Hospital of Athens “Asklepieio Voulas”, Athens, Greece
⁵ Radiology Imaging Department, General Hospital Sotiria, Athens, Greece
⁶ Radiology Imaging Department, General Hospital of Athens “G. Gennimatas”, Athens, Greece

Received 15.04.2010 Accepted 02.05.2010
Med Ultrason
2010, Vol. 12, No 3, 228-232
Address for correspondence: Mariana Kalokairinou-Motogna
Terpsiheas 42, 15341
Athens, Greece
Email: motogna@hotmail.com

Introduction
Renal artery stenosis (RAS) is the most common cause of potentially curable secondary hypertension [1]. Its prevalence varies, depending on the study sample; it accounts for about 5% of all hypertensions and reaches up to 30% in populations selected with a clinical ap-
Atherosclerosis in older patients and fibromuscular dysplasia (FMD) in younger patients accounts for approximately 90% of the cases of RAS, with an increasing frequency because of demographic changes in population development.

The gold standard technique for RAS diagnosis is selective arteriography; however, it remains unsuitable for RAS screening because it is an invasive and expensive method [3]. Magnetic resonance angiography (MRA) and computed tomography angiography (CTA) are promising alternative techniques, which are also expensive and not widely available; moreover, these methods only provide anatomical information about RAS and cannot document whether a stenosis is severe enough to cause a pressure gradient, trigger renin release and subsequent renovascular hypertension (RVH) [4]. Less invasive screening tools, such as intravenous pyelography and radionuclide scans, are abnormal in the majority of patients with RVH, but have false positive rates of 11% and 25%, respectively [5,6].

Color Doppler ultrasound (CDUS) has been applied for RAS evaluation. Although it is highly operator-dependent, it is a noninvasive, suitable for outpatient use, low cost and widely available method, which may be used as an alternative first line screening tool for RAS. Two methods are used in CDUS evaluation of RAS: a direct and an indirect approach. A combination of these methods is recommended to optimize results [7]. We will present a concrete review of the CDUS parameters currently used for establishing RAS (fig 1-7).

**Fig 1.** Color flow US image in an asymptomatic 45 years old male demonstrates a normal left renal artery.

**Fig 2.** Color flow Doppler sonography in the left renal artery of a 38 years old female patient, shows strong blood flow in the vessel without any local acceleration.

**Fig 3.** Color flow US image at the middle segment of left renal artery, translumbar approach, in a 54 year old man, shows lumen constriction and aliasing, findings that indicate increased PSV a high grade stenosis.

**Fig 4.** The same patient as in fig 3. Doppler frequency spectrum documents high systolic flow velocity of 213cm/sec in the jet of high grade stenosis of middle segment of left renal artery.
Gray scale ultrasound (B-mode) exam begins with imaging of both kidneys. Each kidney’s length is measured and compared to the contralateral one. A length difference > 2cm is suggestive of RAS on the side of smaller kidney. The renal parenchyma is also evaluated in terms of thickness (>1cm) and echogenicity (equal or slightly less than the normal liver parenchyma).

Direct parameters’ evaluation includes the entire length of the main renal artery, including any accessory renal arteries. Using CDUS with proper technique (angle adaptation <60°, a 2-3 MHz Doppler frequency, increase the system pulse repetition frequency (PRF) whenever aliasing is encountered, updating the image after probe manipulation) we measure the following parameters: a) highest peak systolic (PSV), b) end-diastolic velocity (EDV) in the renal trunk, c) the velocity of abdominal aorta at the level of renal arteries in order to calculate the renal/aortic ratio (RAR) and d) the renal/renal ratio (RRR): the rate between PSV at the proximal or mid segment of the renal artery and PSV measured at the distal segment of the renal artery, proposed by Chain et al [8].

The indirect evaluation for renal artery stenosis adds another layer of information to that already obtained from the direct method. Normal intrarenal segmental and interlobar arteries display an early systolic peak (ESP) at the beginning of systole and is best seen at Doppler angles 0-30º and Doppler frequencies of ≥3 MHz. The ESP is absent in case of >60% stenosis of the main renal artery. It is necessary to obtain Doppler samplings at the upper, mid and lower pole of the kidney; otherwise, RVH due to stenosis of an accessory renal artery could be missed. A significant RAS, delays the systolic rise in arteries immediately distal to it, resulting in a waveform termed “tardus parvus”. Bilateral “tardus parvus” waveforms could potentially be the result of a proximal stenosis in the aorta or aortic aneurysm rather than bilateral RAS. Other limitations associated with indirect evaluation for RAS include the inability to differentiate between severe stenosis and occlusion of the main renal artery. Collateral flow to the kidney in renal artery occlusion can produce an intrarenal Doppler presentation similar to that seen with severe RAS. We should keep in mind that it takes an even greater amount of stenosis before
the acceleration time becomes abnormal and a “tardus parvus” waveform develops.

The indirect parameters measured by Doppler wave curves from intrarenal segmental arteries are a) intrarenal resistance index (RI= PSV - EDV: PSV) and b) the acceleration time (AT). The RI value is calculated as the mean value of at least three measurements obtained at different areas in the renal parenchyma; this index should not be taken into account in patients with arrhythmias. Distal to a relevant stenosis the increase of systolic flow velocity to peak velocity is delayed; this time interval is called acceleration time or time-to-maximum systole. The normal value of AT is defined as 0.07 sec. Every increase in the AT is suspicious for a severe proximal stenosis.

**Evaluation of direct CDUS-RAS parameters**

A PSV >200 cm/sec with the presence of post-stenotic turbulence is the most frequently used parameter in determining relevant RAS (>60% in renal arteriography) and has a relatively high sensitivity (71-98%) and specificity (62-98%) [7]. An EDV >150 cm/sec has been reported to be associated with significant RAS (> 80%) if there is no underlying kidney structural disease (RI <0.7). In patients with a RI >0.7, EDV was not elevated >150 cm/sec even in the presence of significant stenosis [9]. Zeller et al correlated a RAR >3.5 (side-to-side RI difference ≤0.05) with an angiographic 70% RAS. This study reported that RAR is an index with high sensitivity (100%) and relatively low specificity (6%), attributed to the fact that this parameter was initially defined to detect less significant RAS [10]. RAR is not reliable in the presence of an aortic aneurysm and an aortic peak flow velocity greater than 40 cm/sec. Finally, a RAR >2.7 is suggestive of RAS >50% with comparably high sensitivity and specificity to the ones of PSV [8].

**Evaluation of indirect CDUS-RAS parameters**

A side-to-side difference of the RI of >0.05 has been the detection of at least 70% RAS has a specificity of 99% and a sensitivity of 77% [10]. Of note is that the absolute value of the RI is of no relevance in terms of detecting RAS. The RI increases physiologically with age, in bradycardia, and pathologically increased in aortic valve insufficiency and any type of parenchymal renal disease such as diabetic kidney disease, hypertensive kidney disease, and other tubulo-interstitial kidney diseases [11,12]. Motew et al evaluated the correlation of an AT with a threshold of 100 ms and an angiographic >60% RAS. The sensitivity was only 32%, however, the specificity 100% [13].

**Evaluation of combined direct and indirect CDUS-RAS parameters**

The combination of a PSV >200 cm/sec and the side-to-side difference in RI has been reported to detect a >70% RAS with a sensitivity of 89% and a specificity of 92% [14]. Another study showed that the combination of the RAR >3.5 with the side-to-side difference of the RI can detect a ≥70% RAS, with high specificity (97%) and a relatively low sensitivity (76%), which was explained by the fact that about ¼ of the study sample had bilateral severe RAS affecting negatively the predictive value of the side-to-side difference of the RI, since the RI was decreased in both kidneys [10]. Finally, Mollo et al reported a sensitivity and specificity of a combined use of an elevated PSV and extended AT in detecting severe RAS of 75 and 100%, respectively [15].

**Conclusion**

It is absolutely mandatory to use strict color Doppler criteria in diagnosing a severe RAS. The most reliable approach to detect severe RAS is the combined use of a direct parameter such as a PSV >200 cm/sec or the RAR >3.5 and an indirect parameter, most likely the side-to-side difference of the RI. Based on the previous evidence Zeller et al proposed an algorithm of how to use CDUS for the detection of severe RAS [7]. First, measure PSV at the origin of renal artery and abdominal aorta velocity at the same level. If PSV is >200 cm/sec or RAR >3.5, the diagnosis of RAS is obvious. In the case of unilateral stenosis, the measurement of RI provides evidence regarding its severity; if the dRI is >0.05, the stenosis is relevant and a revascularization should be considered. If the dRI is <0.05, the patient should be followed-up every 6 months, because of the risk of progression. As mentioned above, in the case of bilateral RAS, the dRI is a non-reliable diagnostic tool in detecting severe RAS. Additionally, AT should be measured; if AT is >0.07 seconds, stenosis is relevant and should be considered for percutaneous revascularization; otherwise, serial follow-up visits are indicated.

**Conflict of interest:** no conflict of interest

**References**