

Key words: renovascular hypertension; renal artery stenosis; duplex ultrasonography; contrast tomography angiography; magnetic resonance angiography; renography; intra-arterial angiography

Renovascular hypertension 2: Imaging techniques

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Abstract

Renovascular hypertension (RVHT) is hypertension caused by renal artery stenosis (RAS). For patients identified from clinical assessment as being at high risk for RAS, non-invasive imaging techniques can diagnose RAS and identify patients likely to benefit from intervention. Duplex ultrasonography, contrast tomography angiography (CTA) and magnetic resonance angiography (MRA) are non-invasive alternatives to intra-arterial angiography for identifying the anatomic presence of stenosis. CTA or MRA provide high sensitivity and specificity in identifying RAS, with CTA providing additional abdominal pathology. Duplex ultrasonography enables morphologic examination and haemodynamic assessment, the calculation of renal resistivity being a possible method to predict the response to intervention. Angiotensin-converting enzyme inhibitor-augmented renography identifies the functional consequences of a renal artery obstruction. Therefore, this technique tests directly for the presence of RVHT and should be included in the diagnostic work-up of RVHT when RAS is recognised. Non-invasive imaging techniques are continuing to improve due to advances in contrast agents, image acquisition and post-processing techniques. Careful evaluation of individual patients by these methods will enable recommendation for angioplasty and stenting only

when necessary.

Introduction

Renovascular hypertension (RVHT) is defined as hypertension that is caused by renal artery stenosis (RAS). It is estimated that 3–5% of patients with hypertension have renovascular hypertension.¹

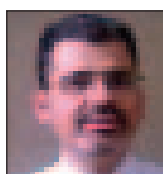
However, because it may be possible to affect a cure in these patients, RAS warrants diagnostic work-up and aetiological treatment. The most frequent cause of RAS is atherosclerosis, but fibromuscular dysplasia, radiation-induced arteritis, Takayasu's arteritis, spontaneous dissecting aneurysm and Von Recklinghausen's disease are also possible causes.

Despite the fact that the simple concomitant presence of atherosclerosis significantly increases the prevalence of RVHT, the prevalence is still too low to allow cost-effective screening. It is not appropriate to perform imaging of the renal artery in all patients presenting with hypertension and it is necessary to use a pre-screening test to isolate a population in which there would be a higher prevalence of RAS. The Sixth Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure² has recently reviewed the criteria suggestive of renal vascular disease (Table 1) and a prediction

Table 1. Criteria for isolating a population with a higher prevalence of RAS²

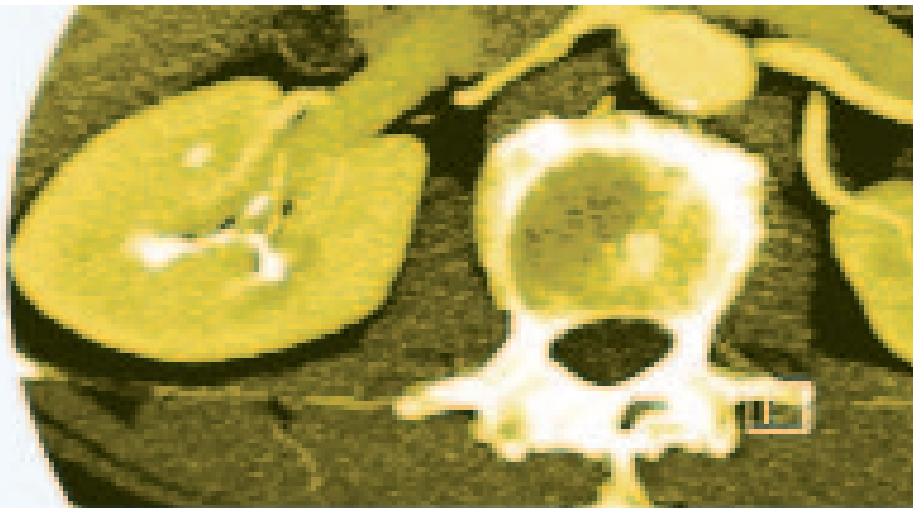
Clinical clues to renovascular disease:

- onset of hypertension before age 30, especially without a family history
- recent onset of significant hypertension after age 55
- an abdominal bruit, particularly if it continues into diastole and is lateralised
- accelerated or resistant hypertension
- recurrent (flash) pulmonary oedema
- renal failure of uncertain cause, especially with a normal urinary sediment
- coexisting, diffuse atherosclerotic vascular disease, especially in heavy smokers
- acute renal failure precipitated by antihypertensive therapy, particularly angiotensin-converting enzyme inhibitors or angiotensin II receptor blockers



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rule for RAS from clinical characteristics has been established by Krijnen *et al.*³ If one or more of these criteria are present, imaging of the renal arteries should be performed using one of the methods described below, according to its availability at the centre. Intra-arterial angiography is still the gold standard and should be performed when uncertainty remains after use of non-invasive imaging techniques, and when there is sufficient evidence to indicate that this method of treatment would be valuable.

In general, the available tests can be divided into those that identify the functional consequences of a renal artery obstruction (angiotensin-converting enzyme inhibitor-augmented renography) and those that identify the anatomic presence of stenosis (duplex ultrasonography, magnetic resonance angiography, contrast tomography (CT) angiography and intra-arterial digitised angiography). The aims of imaging techniques are the following: to diagnose appropriately the presence of a haemodynamically significant RAS (> 50% reduction in diameter); to locate it in the course of the renal artery (ostial, post-ostial, truncular, arterial branches); and to provide information on its aetiology.

We will review the results, advantages and drawbacks of each method, and then comment on the most appropriate strategy for the diagnosis of RVHT considering that, overall, the most appropriate diagnostic approach is based largely on the clinical index of suspicion, the potential aetiology of the renal artery lesion and the individual patient's physiology and presentation.

Duplex ultrasonography

Duplex ultrasonography is a non-invasive and low-cost method which plays a key role in the diagnosis of RVHT. Its sensitivity is estimated to be between 70%

and 90% and its specificity between 80% and 98%.⁴ Its limitations of use are in obese and non-echogenic patients, and hence estimates suggest that it cannot be performed in satisfactory conditions in as many as 15% of patients. In addition, it is difficult to visualise accessory arteries and the distal arterial network, and the data obtained are operator-dependent to a much larger extent in comparison with concurrent methods.

In recent years, the interest in echo contrast media has increased, and attention is being given to increasing the level of feasibility of echo contrast-enhanced duplex ultrasonography in evaluating RAS.⁵ In addition, some preliminary work has shown recently that the measurement of resistivity index using Doppler sonography, with and without captopril, could be a predictor of RVHT.⁶

From a technical point of view, a strict protocol should be followed for duplex ultrasonography: morphologic examination of the kidneys (size, cortical differentiation) followed by haemodynamic assessment of possible stenosis using duplex. The signs of a haemodynamic stenosis are: increased velocity at the level of the stenosis (>150 cm/sec); a peak systolic velocity renal artery/aorta ratio >3.5; and post-stenotic turbulence. Indirect signs are also of value: increased systolic ascension time (>50 msec); increased resistivity index (10%) when compared with the contralateral side and difference in size of the kidney (>2 cm). Two of these signs are accepted as predictors of the presence of a significant RAS: peak systolic velocity >350 cm/sec and a difference in resistivity index >5%.

Doppler ultrasonography evaluation of the renal resistance index ($[1 - (\text{end diastolic velocity}/\text{maximum systolic velocity}) \times 100]$) has been suggested as the best method of classifying patients as responders or non-responders to intervention. In patients with a renal resistance index $\geq 80\%$, improvement of renal function or blood pressure is highly unlikely, despite successful

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correction of renal artery stenosis.⁷

CT angiography

Contrast tomography angiography (CTA) is a widespread, readily available and highly standardisable modality for the diagnosis of RAS (Figure 1). It also carries the advantage of scanning the entire abdominal cavity thereby allowing depiction of unsuspected pathologies such as kidney cancer or adrenal masses. However, it requires contrast injection and use of ionising radiation.

Multidetector CT enables rapid covering of the whole abdominal aorta in a few seconds using a reduced amount of contrast medium, while keeping an isotropic voxel of less than 1 mm, and probably less than 0.5 mm in newer generation 50- or 64-detector systems. Typically, a power injector is used to inject 50 to 80 ml of 350 to 400 mg/ml contrast media at a rate of 3 to 5 ml/sec. Automatic bolus chasing techniques

yield

excellent reproducibility of arterial enhancement, which should be at least 280 Hounsfield units. Post-processing techniques are of a various nature, the most reliable being multiplanar reconstruction and volume rendering technique.

The most recent publication on CTA reports both the sensitivity and specificity to be >95% for this modality.⁸ In a prospective study, 82 patients with arterial

hypertension underwent CTA and digital subtraction angiography to exclude RAS. For CTA, a contrast medium bolus of 100–150 ml (flow rate 3 ml/sec) was injected. Transverse maximum intensity projections (MIP) or multiplanar reconstruction projections were used for stenosis detection. For haemodynamically relevant RAS (>50%) the sensitivity and specificity were 96% and 99%, respectively. CTA additionally depicted five adrenal masses.⁸ It is currently accepted that negative predictive values of greater than 95%

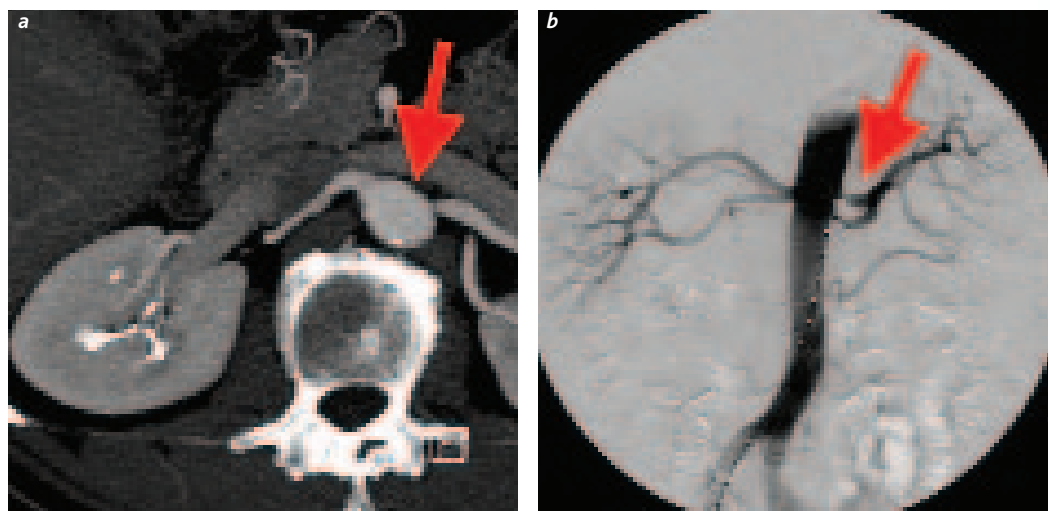


Figure 1. CT angiography of a renal artery stenosis. (a) Axial thin MIP mode showing a tight stenosis of the left renal artery (arrow). (b) Conventional angiography prior to percutaneous transluminal angioplasty (PTA) confirms the stenosis of the left renal artery (arrow).

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directly for the presence of renovascular hypertension; other imaging examinations test for the presence of renal artery stenosis. The goal of ACEI renography is to detect those patients with hypertension who have renal artery stenosis as the cause of their hypertension and who would benefit from revascularisation.

Imaging is performed using technetium 99m-DTPA (diethylene triamine pentaacetic acid) to assess glomerular filtration or technetium 99m-MAG 3 (mercaptylacetyltriglycine) to evaluate tubular secretion and renal blood flow. The main limitations of use of renography are in renal failure and bilateral RAS. It is also an expensive technique that is not readily available in all centres. Angiotensin-converting enzyme inhibition renography is highly accurate in patients with suspected RVHT who have normal or near normal renal function. In this patient population, the sensitivity and specificity of ACEI renography for RVHT exceed 90%. Data from 10 studies evaluating cure or improvement in blood pressure in 291 patients undergoing revascularisation showed the positive predictive value of ACEI renography to be 92%.¹³ When azotaemic patients present with suspected RVHT, as many as 50% of patients may have an intermediate probability ACEI renogram.¹³ This method should therefore be included in the diagnostic work-up of RVHT when RAS is recognised.

Intra-arterial angiography

Intra-arterial angiography should be performed to identify a RAS that would be treated if found.¹

The major drawback of this technique is its invasiveness, but it is the true diagnostic tool that should be used prior to renal angioplasty or any other revascularisation technique. Global angiography is always needed, using at least antero-posterior projection, and 30° left anterior oblique projection.

Selective angiography should be limited to distal lesions (fibrodysplasia). In this setting, multiple projections should be performed to assess the possibility of a diaphragm that is sometimes difficult to diagnose.

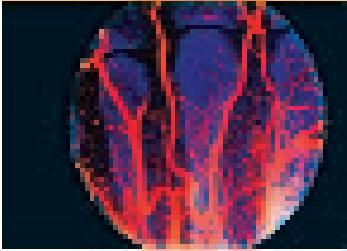
The limitation of the technique is that antero-posterior plaques can be underestimated as they appear only as a less opaque region in the artery and should be assessed using either intra-arterial pressure gradient, intravascular ultrasound or CTA.

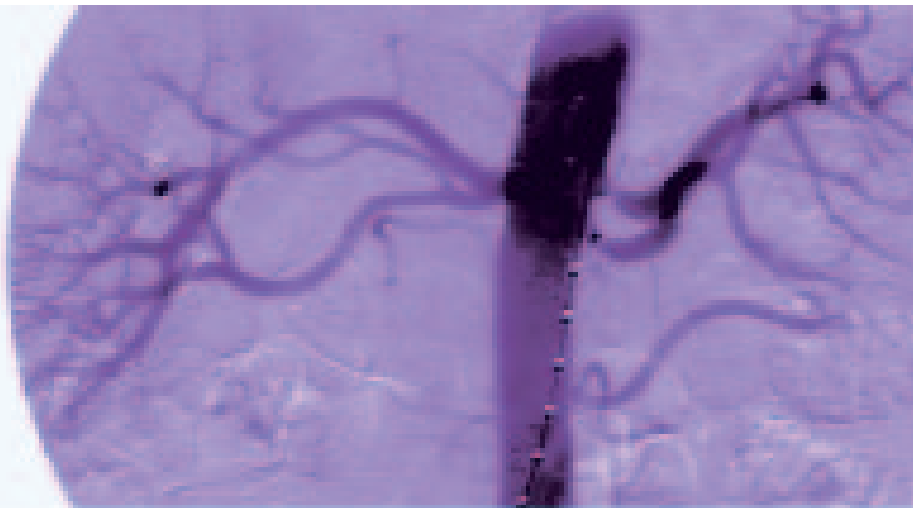
Imaging strategy

After clinical assessment suggestive of a high risk of RAS, the first imaging modality can be duplex ultrasonography, CTA or MRA. The modality of choice will vary according to local preferences and availability. If the patient has a high probability of RAS, the most reliable modality would be CTA followed by duplex ultrasonography. Initial use of CTA or MRA is the most clinically relevant scenario because of the low availability of appropriate operators to perform duplex ultrasonography. In fact, for patients with normal CTA or MRA, an RAS can be ruled out and use of duplex ultrasonography could be avoided. Duplex ultrasonography can then be performed only in cases where there is suspicion of >50% RAS on CTA or MRA. The choice between CTA and MRA would be CTA in patients with normal kidney function and MRA in cases of pre-existing renal failure. A preference for primary MRA is the case in some centres.

Conclusion

The diagnosis of RAS relies on non-invasive imaging techniques that are improving rapidly due to technical advances in image acquisition and post-processing techniques. The clinical problem of RVHT and its





Key Learning

- Renovascular hypertension is hypertension that can be cured by treating a renal artery stenosis (RAS)
- Diagnosis of RAS relies on the use of non-invasive imaging techniques
- Contrast tomography angiography (CTA) and magnetic resonance angiography (MRA) identify the anatomic presence of stenosis
- Duplex ultrasonography can offer some haemodynamic assessment in addition to anatomical features
- Angiotensin-converting enzyme inhibitor-augmented renography identifies the functional consequences of a renal artery obstruction
- Intra-arterial angiography is the 'gold standard' test and should be performed to identify a RAS that would be treated if found
- Use of non-invasive imaging allows recommendation for angioplasty and stenting only when necessary
- The sensitivity and specificity of non-invasive imaging techniques continue to improve with advances in contrast agents, image acquisition and post-processing techniques

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