Ask the Expert

Renal Artery Ultrasound

Looking for windows of opportunity... by Peter Coombs AMS

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Dear Expert,

Every few weeks I attempt a renal artery doppler scan for ? renal artery stenosis. I'm finding these scans technically frustrating and difficult. Can you suggest scanning techniques that will give me a greater level of confidence in the scan results or is this waste of time? "Bewildered"

Dear Bewildered,

You are not alone... In fact, it is reasonable to suggest that frustration with renal artery colour duplex is the sentiment of the majority of the ultrasound community.

The frustration you mention, arises for a number of reasons. Technical difficulty, patient habitus, intermittent referral patterns and uncertain criteria are usually the focus of blame. There's more to it than this though.

The renal artery examination exposes the way we teach and learn ultrasound. There are distinct movements and windows which we use everyday that aren't well described and communicated to our students. The student who understands the theory of how to best image a structure, is better equipped to perform this in a clinical setting. They are also better equipped to cope with the difficult patient.

The emphasis of this paper is that when the renal arteries are visualised, it is a suitably accurate examination.The main focus of this discussion therefore, will be describing "sonographic windows" through which we can successfully locate and image the renal arteries. Along the way, I'll mention some of the other issues that are created by this examination.

The Role of Ultrasound

Hypertension is problematic for the treating physician. Renal artery stenosis (RAS) causes hypertension in only 2-5% of hypertensive patients (1). This group is important as they are the only group that are treatable with angioplasty or surgery. It is also a significant cause of chronic renal failure. The treating physician aims to e*xclude a renal artery stenosis* before implementing long-term treatment strategies in these patients. High risk patients will proceed directly to MRA or angiography. (2) The physician requires a non-invasive, cheap screening test for lower risk patients. With considered patient selection, this is the void that ultrasound can fill.

A screening test for mid to low risk patients.

In the presence of a renal artery stenosis, the physician is faced with new, more difficult questions.

Is this stenosis significant enough to cause hypertension?

Is this stenosis the dominant cause of hypertension?

These are important questions to ponder. To do this we need to consider the physiological impact of a RAS and the notion of critical stenosis.

RAS as a Mechanism for Renovascular Hypertension

It is a complex interchange of factors that results in renovascular hypertension from RAS. Very simply, the RAS will reduce the volume of blood that arrives at the kidney. As a compensatory response, the kidney excretes renin.Renin in turn stimulates the angiotension conversions in the pulmonary bed. As a result, the body increases the blood volume by vasoconstriction and retains sodium and water. Blood pressure increases.

Critical Stenosis

Critical stenosis is an important concept in vascular ultrasound. A critical stenosis is **not** a stenosis greater than 90-95%. A critical stenosis is the point at which there is loss of volume and pressure across a stenosis. Let me explain:

If we suggest that in a given patient, the renal artery transports "x" amount of blood to the kidney per second. If we impose a 30% stenosis into that renal artery, it compensates across the stenosis (Bernoulli's theorem) by increasing the velocity. The volume of blood "x" will still arive at the kidney. If this stenosis is increased to 50%, the volume arriving at the kidney will still be "x" but the velocity across the stenosis will need to be greater to get the same amount of blood across the smaller space. At some point, *the critical stenosis*, the increase in velocity will be insufficient, to allow "x" blood to be transported across the stenosis. At this point, there is a reduction of the amount of blood being supplied to the kidney. The renal response is the excretion of renin as described. Renal vascular hypertension will follow.

Critical Stenosis of the Renal Artery?

This is a complex question which depends on the distribution and shape of the plaque. These factors affect the area reduction which we obviously are not able calculate. Critical stenosis renal arteries is reported at 82-84% area reduction. (3,4) which equates to around 70% reduction in diameter(5). Just as interesting is the data that suggests

Ask the Expert: Renal artery stenosis (con.)

that a 90% area stenosis is required to significantly change renin levels (6). The clinically significant RAS, are those in excess of 70%. With this background let's now consider that interminable debate.

Direct or Indirect Assessment?

The merits of direct versus indirect assessment have been debated in clinical centres endlessly. Advocates of the intrarenal method were mainly those in search of the 'miracle shortcut'. Most sites today reject intrarenal assessment however this rejection is directed at rejecting the 'miracle'. The preceding discussion has been included to show that this debate is complex. This is reflected in the literature. In my opinion, the literature tells us the following:

Direct method

- Direct visualisation is the method of choice. In studies where there has been good visualisation, there is adequate sensitivy and specificity. (7,8)
- The technique/ windows for performing direct assessment are not well documented.
- Examinations which have incomplete visualisation must be reported as such because of reduced accuracy.

Indirect method

- The indirect method alone will NOT detect renal artery stenoses of >60% with sufficient sensitivity or specificity.
- The indirect method has significantly improved accuracy at higher levels of stenosis. Stavros (9) reports 99% sensitivity, 91% specificty for stenoses >70%.
- It may be useful for accessory renal artery stenosis.
- Technique and quality of intrarenal assessment has varied considerably in literature.

But there are other on-going questions ...

Does a completely normal intrarenal waveform mean a clinically significant lesion is not present and thus extrarenal evaluation in this setting is not required?

Does the intrarenal assessment have sufficient accuracy to be used when there is poor direct visualisation so as to improve our overall sensitivity?

Is intrarenal assessment helpful in the *clinically relevant* stenoses rather than those that are over 60%?

Should intrarenal abnormality be described when there has been a positive diagnosis with the extrarenal method as a marker for the clinical significance of the lesion?

In my opinion, these questions are unresolved.

Badermacher et al (10) report a series of patients with RAS' who after diagnosis, had a renal angioplasty or surgery. In their series, *none* of the 35 (27%) who had an intrarenal resistive index greater than 0.8 had resolution of their hypertension after treatment. Like Badermacher, we need to look for new ways of using the intrarenal information. As such, intrarenal assessment should be performed as a predictor of treatment outcome. It should also be used as a 'marker' for RAS. Markers are used frequently in other ultrasound screening tests.

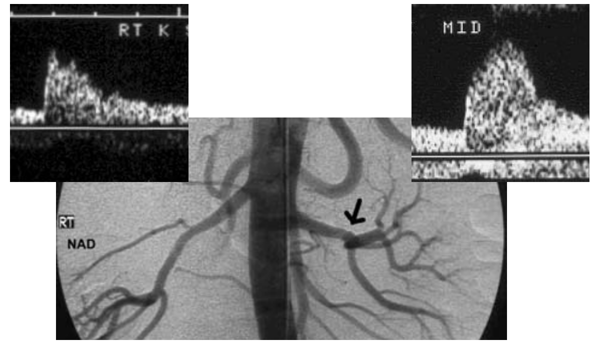


Fig 1. Abnormal left intrarenal waveform. Angiography shows a region of fibromuscular dysplasia in the distal LRA

Using intrarenal assessment in this way, means that we can simplify the way we perform and interpret the waveform. Traditionally, we have used values of acceleration time (AT > 0.07sec), acceleration index (AI<3.0) and the presence of an early systolic peak (ESP). Given this modified use of intrarenal, it is sufficient to use *pattern recognition*(11). Quite simply, the presence of a normal intrarenal waveform, in three parts of the kidney is a marker of normality. RI should be recorded to ensure it is less than 0.8 and to note variation between sides,

Criteria: In Summary

Direct Assessment:

Renal Artery: Aorta (RAR) ratio >3.0:1, PSV >180cm/s (12)*

* These numbers vary slightly within the literature. Your own department validation will further guide the values you use.

Indirect Assessment:

Pattern recognition: Normal, equivocal, abnormal

Loss of early systolic peak and flattening of the systolic upstroke is a marker for abnormality

An example of indirect assessment is seen above in figure 1.

Protocol for Renal Artery Evaluation

The examination protocol is to initially perform a B-mode renal evaluation. Renal size, cortical volume and other renal pathology is assessed. This is followed by the intrarenal assessment. The objective of intrarenal assessment is to obtain a *single* normal waveform from the segmental arteries in the superior, mid, and inferior parts of the kidney. Form your opinion about these prior to imaging the main renal arteries. Extrarenal evaluation then always follows. Include a spectral waveform of the Aorta at the level of the SMA origin.

TIP: This is a 60 minute procedure. Divide the assessment into two 30 minute components (Right/Left). This will ensure that fatigue from over-examining the first side doesn't affect the attention given to the contralateral side. Divide each of these 30 minute segments into B-mode (5mins), intrarenal (5

... 10 windows for renal artery assessment

mins), extrarenal (20 mins.). This will ensure the focus of your attention is the main renal artery assessment. In cases where intrarenal assessment is very difficult, it can be limited to a single trace or not performed.

Intrarenal Assessment

This is done using a lateral patient position which brings these arteries closer and perpendicular to the transducer. The spectral set-up must have a low scale, fast sweep speed and no filter.

Warning: Slight variations in respiration or patient movement will significantly affect the waveform. This will inappropriately give the impression that there is loss of the ESP.

Technique: Direct Assessment

While the previous discussion is important, solving sonographer frusration depends on finding ways of visualising the renal arteries. There are many potential windows and strategies for scanning renal arteries. The following is a structured approach which uses 10 windows of visualisation. Attention to minor detail such as arm position, phase of respiration and location and pressure of the transducer is essential. Set-up your system with a reduced dynamic range and vary your transducer frequency. Ultimately, your goal should be visualisation of both renal arteries in their entirety in over 90% of patients.

1. Right Renal A; Sub-hepatic (fig 2.)

This is the important window on the right.

Patient Position:45° Oblique, right arm fully above the patient's head.

Transducer: Antero-lateral costal margin.Must sit just below the inferior edge of the 12th rib.

Respiration: Full inspiration or full abdominal distension. (ie. "Push your tummy out")

Objective: Insonnate between the liver and the hepatic flexure to demonstrate the origin, proximal & mid RRA. In males, it is occassionally necessary to slide the transducer into the 11-12 rib interspace.

Fig. 2 W1 45° oblique showing the full length of the RRA

2. Right Renal A;Transduodenal (fig 3.)

Patient Position:Supine, arms by the side, head slightly raised.

Transducer: Midline, rolled 15° to the right, gentle sustained compression.

Respiration: Gentle, varied

Objective: Gentle pressure on the duodenum will remove the gas exposing the proximal & mid RRA. The transducer should be rolled accentuating the angle of insonnation. If the pressure is graduated, it can be increased over time without significant discomfort to the patient.

Fig. 3 W2 Supine, angling down the proximal RRA

3. Right Renal A;Transduodenal (fig 4.)

Patient Position:Supine, arms by the side, head slightly raised.

Transducer: Midline, rolled 15° to the left, gentle sustained compression.

Respiration: Gentle, varied

Objective: Again, gentle pressure on the duodenum will remove the gas. This time the transducer is rolled in the other direction down the 'barrel' of the Rt RRA origin. The key to these windows is the sustained nature of the compression and having confidence that you are in the correct position.

Fig. 4 W3 Supine, angling down the origin: RRA

Ask the Expert: Renal artery stenosis

4. Right Renal A;Transcaval (fig 5.)

Patient Position:30° oblique, head slightly raised.

Transducer: Mid-clavicular line, vertical. Rotate from transverse to sagittal. Gentle sustained compression

Respiration: Mild inspiration

Objective: Insonnate lateral to the duodenum with the liver used as a window for the IVC. The IVC provides an excellent window of the proximal RRA. This is the most important window through which to assess for an accessory renal artery. Subtle angulation from the IVC will insonnate the renal artery origin.

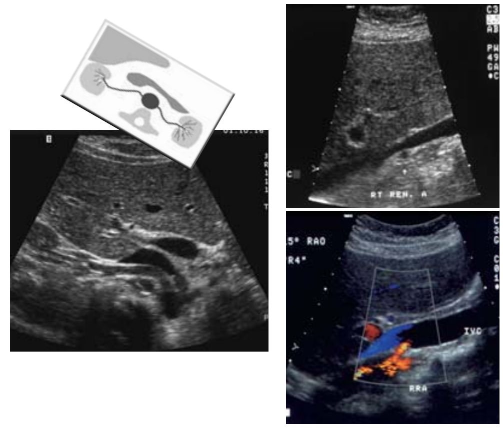


Fig. 5 W4 is an important window for accessory RRA's. This series of images show the IVC used as a window

5. Right Renal A;Transrenal (fig 6.)

Patient Position:Lateral, arm tucked above the head.

Transducer: Lateral, directed through the hilum of the kidney. Sagittal plane

Respiration: Inspiration

Objective: Insonation of the distal RRA. The renal sinus fat is often quite attenuative with significant degradation of image quality. Moving the transducer anteriorly or posteriorly and then angling toward the renal artery will overcome this.

Fig. 6 W5 insonnates through the rt. kidney

6. Left Renal A;Transduodenal (fig 7.)

Patient Position:Supine, arms by the side, head slightly raised.

Transducer: Just right of midline, rolled 15° to the left, gentle sustained compression. Tranverse plane relative to the abdomen.

Respiration: Gentle, varied

Objective: Gentle pressure on the duodenum will remove the gas exposing the origin and proximal LRA. In this position, the tendency is generally to scan too low. The transducer will need to abut the left costal margin.

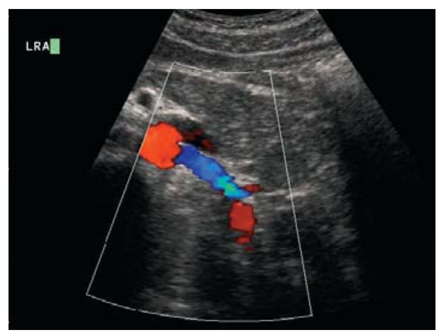
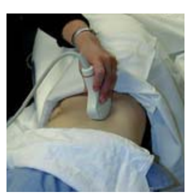


Fig. 7 W6 Supine angling down the origin of the LRA

7. Left Renal A; Pararenal (fig 8.)



Patient Position:Lt Lateral 80° (Not true lateral)

Transducer: Sagittal, antero-superior to the kidney angling across the front of the kidney

Respiration: Gentle inspiration

Objective: To insonnate between the attenuative renal sinus fat and the splenic flexure. Initially obtain an image of the aorta in the far field. When this is obtained, the entire renal artery is often visible. In difficult patients, the transducer needs to be moved slightly more anteriorly into the 11^{th}-12^{th} rib interspace.

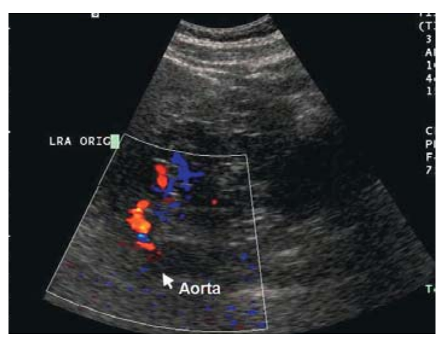


Fig. 8 W7 V. difficult case. Large elderly male with an atrophic left kidney. Identifying the aorta in the far field indicates that an adequate window has been found.

"Attention to minor detail such as arm position, phase of respiration and location and pressure of the transducer is essential."

8. Left Renal A;Transrenal (fig 9.)

Patient Position:Left lateral

Transducer: Sagittal, lateral

Respiration: Inspiration

Objective:The objective is to see the distal LRA. Insonnate directly through the anterior left kidney to show the distal LRA. Subtle angulation will again improve the image considerably as you avoid the renal sinus fat.

9. Left Renal A;Transhepatic (fig 10.)

Patient Position:Supine, arms by the side, head slightly raised.

Transducer: Right subcostal region, transverse, Rolled toward the left 45

Respiration: Gentle, varied

Objective: The objective is insonnation of the origin and proximal LRA. Often the origin of the RRA will be evident in this window. Placement of the transducer in the right upper quadrant allows the pancreas and liver to be used as the window. There is still a large amount of duodenal gas in this window which does inhibit visualisation.

10. Left Renal A;Transgastric (fig 11.)

Patient Position: 45° LAO , arm by the side, head raised

Transducer: Transverse, Left subcostal, gentle sustained compression. Transducer needs to be left in the same position for 30-60 secs.

Respiration: Expiration.

Objective: Gentle pressure on the stomach will remove the gas exposing the proximal & mid LRA. This is often tortuous on the left and this window will give an increased angle of insonnation in the mid vessel

Level of visualisation

Reporting the level of confidence of your examination is essential. It will guide your referrer to the level of confidence that they should have in your examination and direct alternative imaging when required. The levels that I use are seen in Table 1.

The Accessory Renal Artery

Although they occur in 15-20% of kidneys, accessory renal arteries are traditionally not well visualised. The incidence of isolated accessory renal artery stenosis and the significance of this finding is not well described in the literature. The amount that this non-visualised component affects our overall accuracy is difficult to assess. Suffice to say, attention to detail improves the number of these that are demonstrated. Windows 4 & 6 are particularly important. In addition, observe the pattern of flow into the intrarenal vessels as separation of these is a marker for an accessory vessel or an early bifurcation.

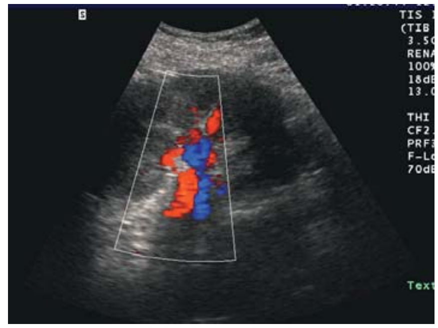


Fig. 9 W8 insonnates through the lt. kidney showing the distal LRA, LRV

Fig. 10 W9 uses the liver to clear a window for the origin of the LRA

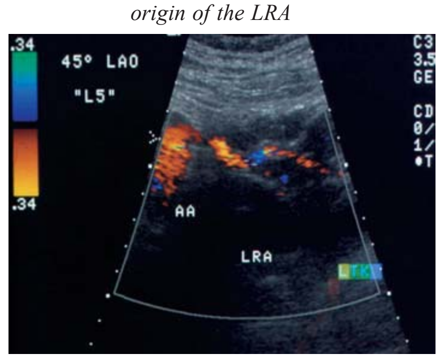


Fig. 11 W10 uses a 45° oblique position to provide angles of insonnation unavailable in the supine or the lateral positions.

Table 1: *Levels of RA visualisation*

0 = Non visualisation, no spectrum obtained

1 = V. poor colour, angle uncertainty

0,1 = Sub- optimal examination

2 = Segmental colour, angle certainty

3 = Full colour visualisation, angle certainty

4 = As per 3 +, colour enables assessment for focal aliasing.

The level of visulisation is reported in the origin, proximal, mid and distal renal artery on each side.

Ask the Expert: Renal artery stenosis (con.)

Conclusion

The renal artery artery colour duplex examination is a technically demanding procedure that requires acumen in interpreting the results. While direct visualisation will always be the priority, there is yet to be a final verdict on indirect assessment.. The emphasis in this discussion is that when there is adequate visualisation, ultrasound is a good screening test in the low-mid risk population. Structured windows have been described to aid this visualisation and importantly, to stimulate discussion in your own department about the way you achieve a success in this ‘bewildering’ examination.

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