

Ultrasound in Acute Kidney Injury

Pamela Parker

Ultrasound Specialty Manager



Great Staff - Great Care - Great Future

Hull and East Yorkshire Hospitals

NHS Trust



Aims

- What is Acute Kidney Injury (AKI)?
- Discuss the implications of AKI for USS
- Revisit Resistive Index (RIs)



Why?



The FACTS

- AKI is responsible for a 20-30% in-patient mortality rate
- The mortality rate varies greatly depending on the severity, setting, and many patient-related factors but it is a **KILLER**.

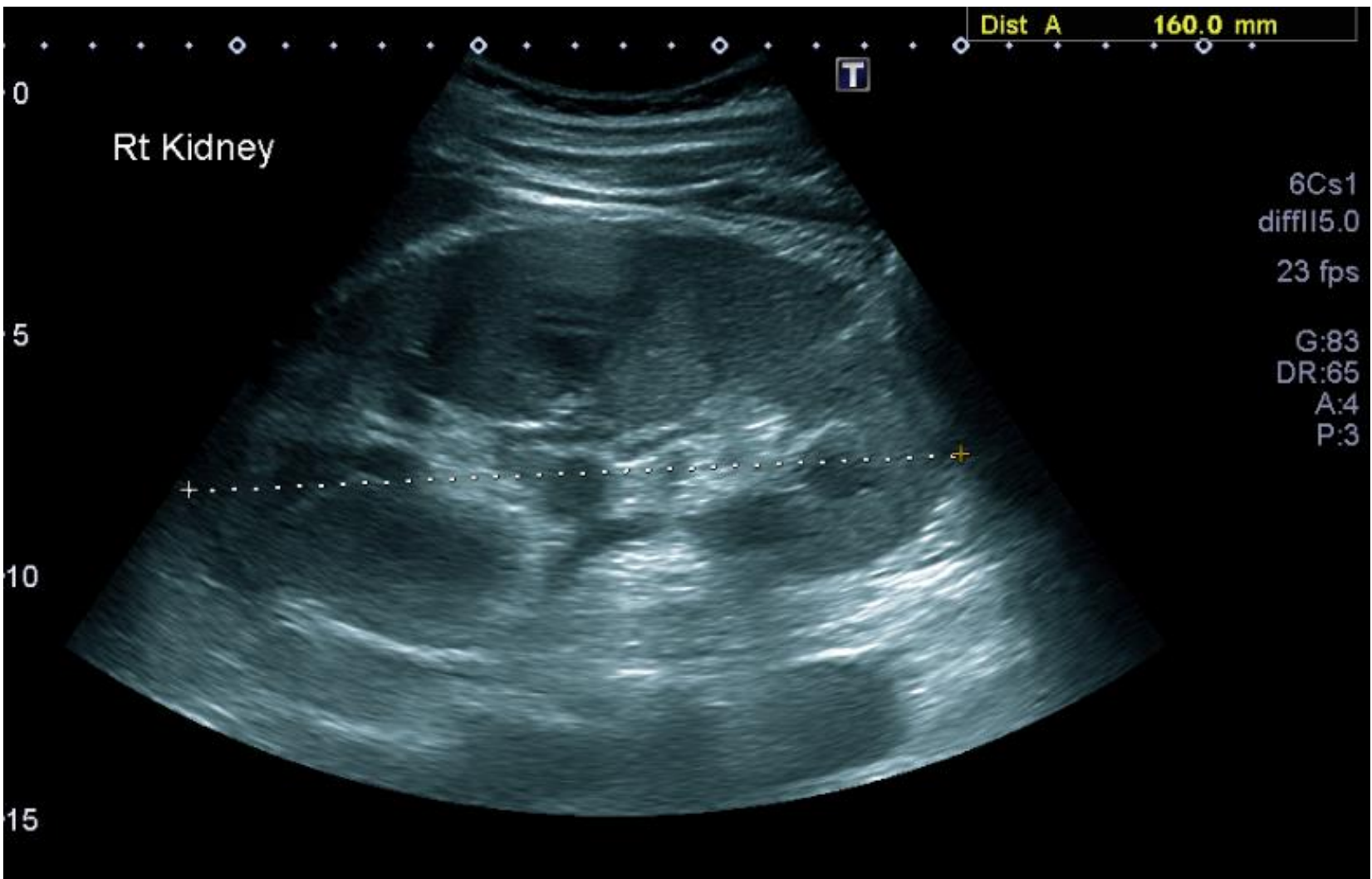
Dist A 160.0 mm

T

Rt Kidney

6Cs1
diff115.0
23 fps
G:83
DR:65
A:4
P:3

0
5
10
15



AKI Explained

- The older term is 'acute renal failure' (ARF).
- Acute kidney injury (AKI) is a rapid deterioration of renal function, resulting in inability to maintain fluid, electrolyte and acid-base balance.

AKI Explained

- It is detected and monitored by serial serum creatinine readings primarily, which rise acutely
- The definition of acute kidney injury has changed in recent years, and detection is now mostly based on monitoring creatinine levels, with or without urine output.

Acute Kidney Injury, adding insult to injury (2009)

- 2009 UK National Confidential Enquiry into Patient Outcome and Death (NCEPOD) found serious deficiencies in patients who died with a diagnosis of AKI.
- Only 50% of patients received good medical care

Why NICE?

- Acute kidney injury is seen in 13–18% of all people admitted to hospital, with older adults being particularly affected.
- The costs to the NHS of acute kidney injury (excluding costs in the community) are estimated to be between **£434 million and £620 million per year**,
- More than the costs associated with breast cancer, or lung and skin cancer combined.

Why NICE?

- Acute kidney injury: prevention, detection and management of acute kidney injury up to the point of renal replacement therapy
- NICE guideline August 2013

Why NICE?

- Estimated that improving care could save 12,000 lives in England and save the NHS £150 million per year

NICE Guideline 2013

Ultrasound

Offer urgent ultrasound of the urinary tract to patients with acute kidney injury who:

- have no identified cause of acute kidney injury, or
 - are at risk of urinary tract obstruction.
- **Ensure that the imaging is performed within 24 hours of assessment.**

Presentation

- It is estimated that 15% of adults admitted to hospital develop AKI
- The presentation will depend on the underlying cause and severity of AKI.
- There may be no symptoms or signs, but oliguria (urine volume less than 0.5 ml/kg/hour) is common.
- Accumulation of fluid and nitrogenous waste products demonstrated by a rise in blood urea and creatinine.

Risk Factors

- Age ≥ 65 years.
- Heart failure.
- Liver disease.
- Chronic kidney disease (particularly if eGFR < 60).
- Past history of AKI.
- Diabetes.
- Neurological impairment or disability resulting in reduce fluid intake
- Hypovolaemia.
- Oliguria (urine output less than 0.5 ml/kg/hour).
- Haematological malignancy.
- Symptoms or history of urological obstruction, or a risk factor for it.
- Sepsis.
- Use of iodinated contrast agents within the previous week.
- Current or recent medication with nephrotoxic potential [-7\]](#)
- Deteriorating early warning scores
- Additionally in children or young adults: severe diarrhoea, symptoms or signs of nephritis (such as oedema or haematuria) and hypotension.

Rt Kidney

T



Classification and Definitions

- **RIFLE** (**R**isk, **I**njury, **F**ailure, **L**oss, **E**nd stage kidney disease), 2004
- **AKIN** (**A**cute **K**idney **I**njury **N**etwork)
- **KDIGO** (**K**idney **D**isease: **I**mproving **G**lobal **O**utcomes), 2012
- **pRIFLE** paediatric version of RIFLE

Classification and Definitions

- NICE recommends that AKI can be detected by using any of the following criteria, in line with pRIFLE, AKIN or KDIGO definitions:

Diagnostic Criteria

Detect acute kidney injury by using any of the following criteria:

- a rise in serum creatinine of 26 micro mol/l or greater within 48 hours
- a 50% or greater rise in serum creatinine known or presumed to have occurred within the past 7 days
- a fall in urine output to less than 0.5 ml/kg/hour for more than 6 hours in [adults](#) and more than 8 hours in [children](#) and [young people](#)
- a 25% or greater fall in [eGFR](#) in children and young people within the past 7 days.

Diagnostic Criteria

- The stage of AKI affects both management recommendations and prognosis
- Importance of defining consistent stages
- KDIGO defines stage 1, 2 and 3 through increasing rises in creatinine levels and drop in urinary output.

Stage	eGFR (ml/min/1.73 m ²)	Description	Qualifier
1	≥ 90	Kidney damage, normal or increased GFR	Kidney damage (presence of structural abnormalities and/or persistent haematuria, proteinuria or microalbuminuria) for ≥ 3 months
2	60-89	Kidney damage, mildly reduced GFR	
3A	45-59	Moderately reduced GFR ± other evidence of kidney damage	GFR < 60 ml/min for ≥ 3 months ± kidney damage
3B	30-44		
4	15-29	Severely reduced GFR ± other evidence of kidney damage	
5	< 15	Established kidney failure	

Causes

Pre-Renal 40-70%	Renal 10-50%	Post-Renal 10%
Renal Hypoperfusion	Acute tubular necrosis	Obstruction
<ul style="list-style-type: none"> • Hypovolaemia 	(Ischaemia of renal tubules)	
<ul style="list-style-type: none"> • Sepsis 	Drugs	
<ul style="list-style-type: none"> • CCF 	Contrast agents	
<ul style="list-style-type: none"> • Cirrhosis 	Haemoglobinuria	
<ul style="list-style-type: none"> • NSAIDs or ACEi 	myeloma	
	Vasculitis	

Assessment and Investigations

- It is important to first identify the cause of AKI, as this will affect management, particularly where there is a potentially treatable cause (for example obstruction, hypovolaemia, nephrotoxic drugs or glomerulonephritis).

Assessment and Investigations

- History
- Examination
- Urinalysis
- Blood Tests
- Ultrasound
 - But **ONLY** when the cause of the acute kidney injury has **NOT** been identified
 - Risk of urinary tract obstruction

Ultrasound

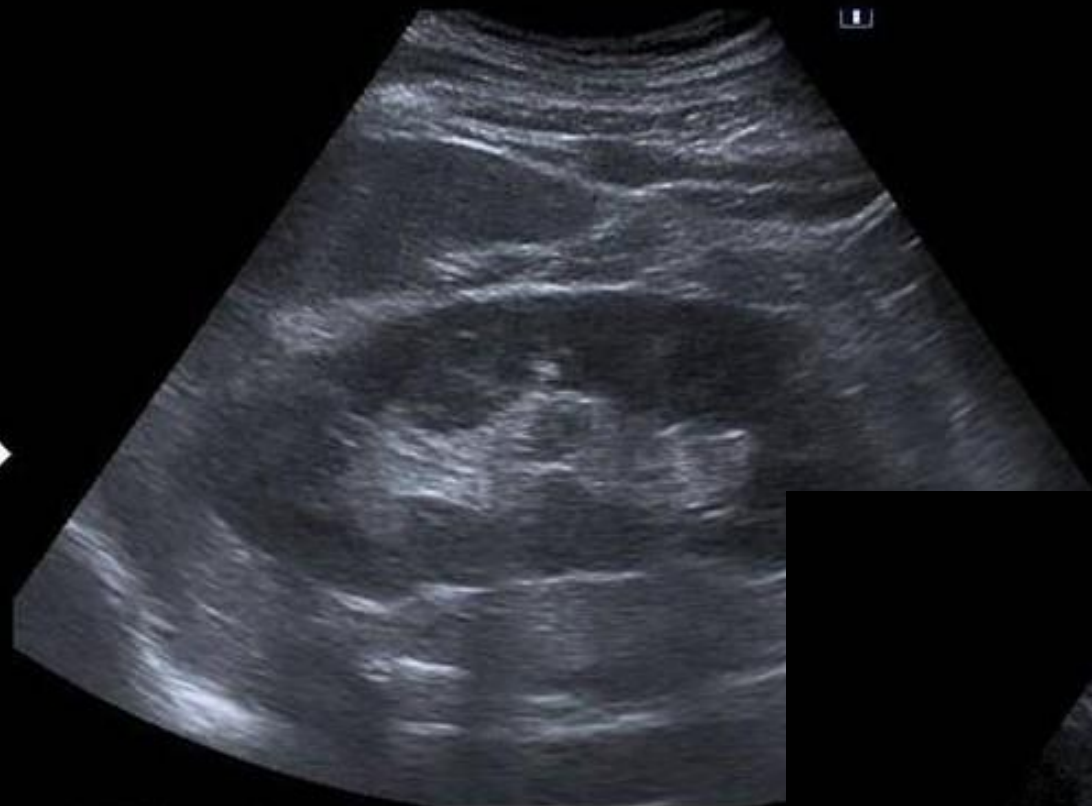
Within 6 hours

When pyonephrosis (infected and obstructed kidney[s]) is suspected in adults, children and young people with acute kidney injury, offer immediate ultrasound of the urinary tract

Within 24 hours

When adults, children and young people have no identified cause of their acute kidney injury or are at risk of urinary tract obstruction, offer urgent ultrasound of the urinary tract (to be performed within 24 hours of assessment).

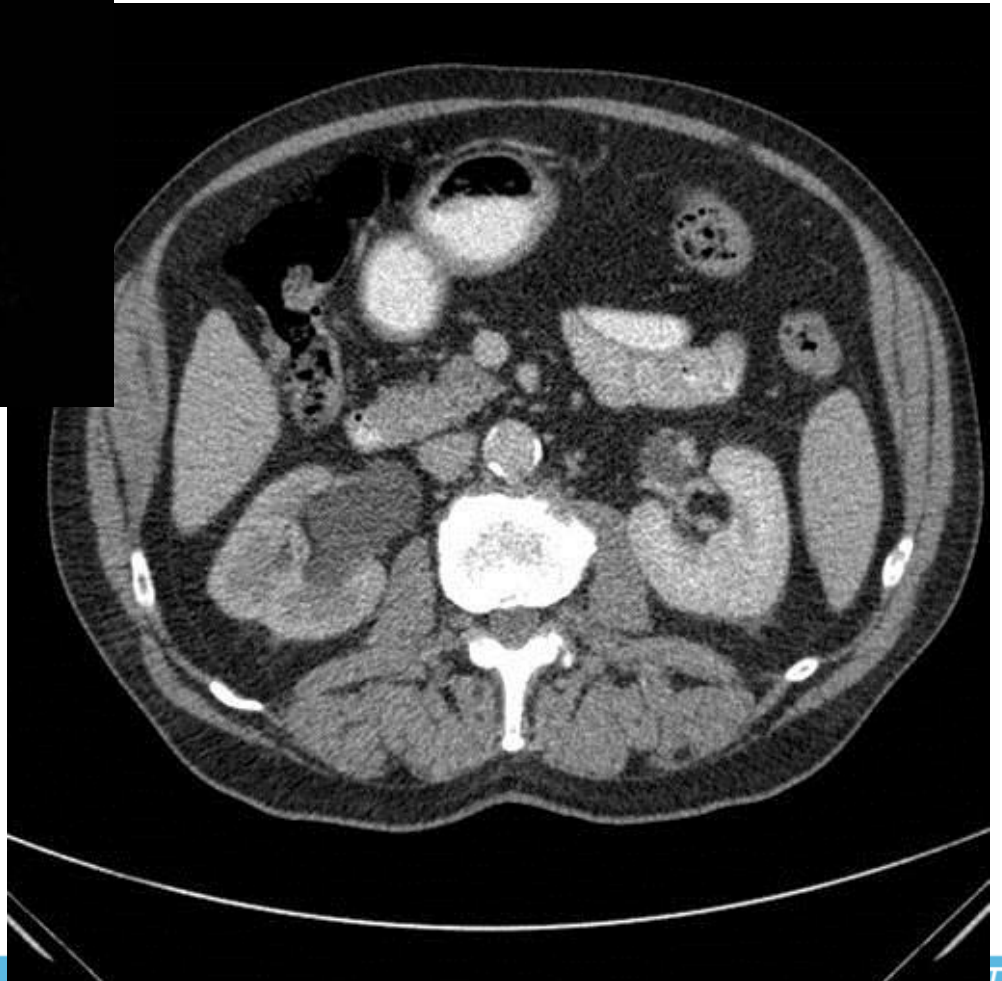
[Acute kidney injury](#). NICE clinical guideline 169 (2013)

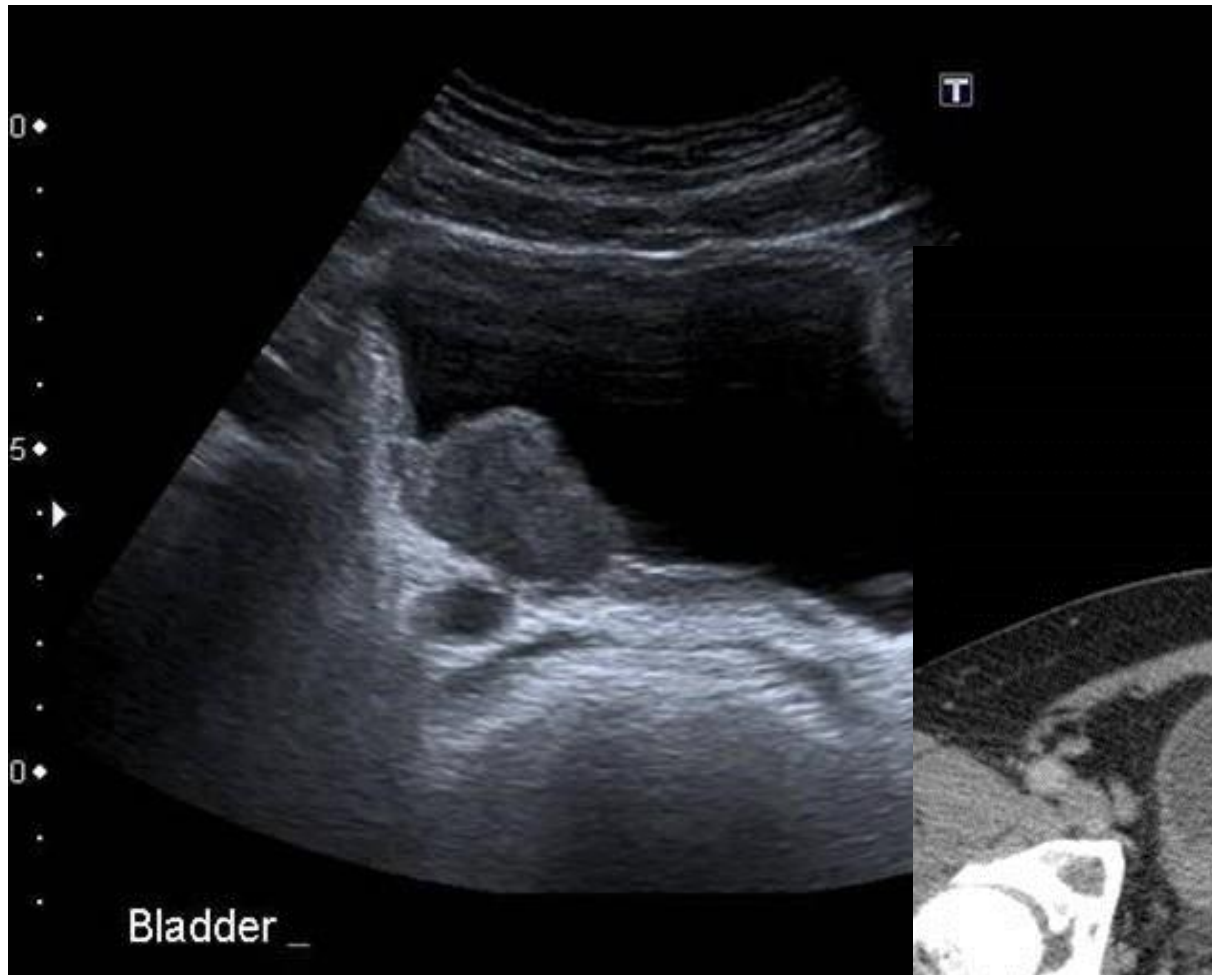


L.Kidney Oblique



R.Kidney Oblique





Prognosis

- 20-30% inpatient mortality
- Indicators of poor prognosis include older age, multiple organ failure, oliguria, hypotension, number of transfusions and acute on chronic renal failure.
- Prognosis is closely related to the underlying cause.
- Patients who need dialysis have a higher mortality
- The risk of mortality increases with the stage of AKI.
- Patients who have had AKI are at increased risk of developing CKD
- There may be an ongoing requirement for dialysis

Treatment

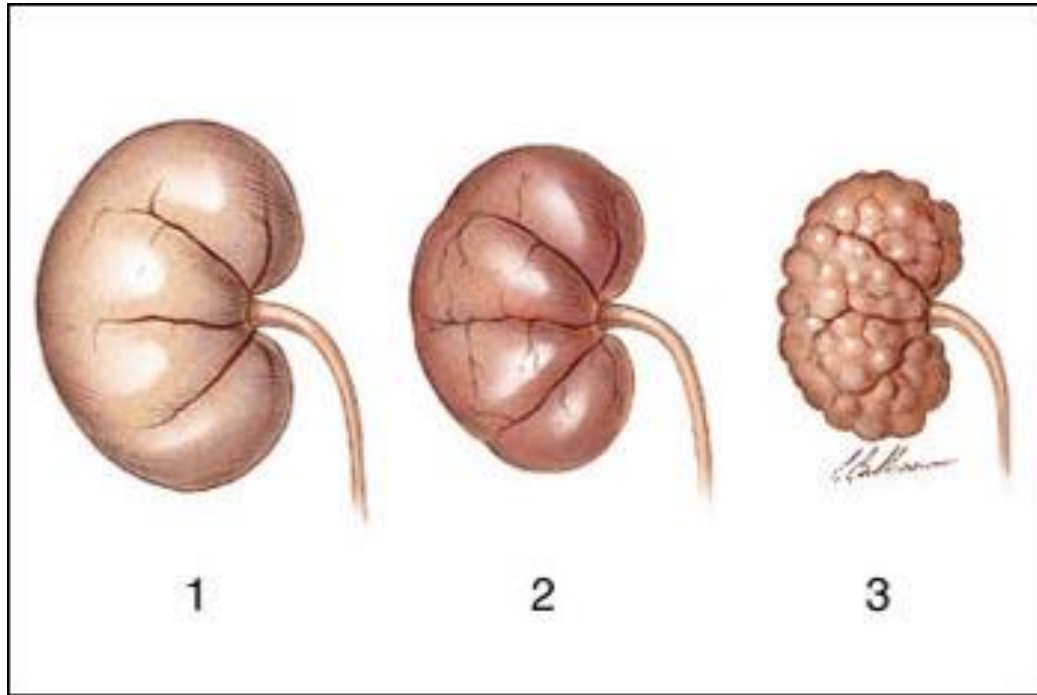
- **The best "treatment" of acute kidney injury (AKI) is prevention.**
- Timely identification of AKI and underlying cause required.
- Ultrasound scan should not be delayed
- USS should identify or exclude obstruction
- USS recognise acute vs chronic RF

Ultrasound

- Imaging technique most commonly used in initial evaluation of patients with suspected AKI
- Widely available
- Easy to use and free of complications
- Portability, especially for critically ill patients in ICU
- Although the rate of abnormal ultrasound findings in the setting of AKI is not high (about 10%), these findings can have a significant impact on patient management

Ultrasound - Basic information

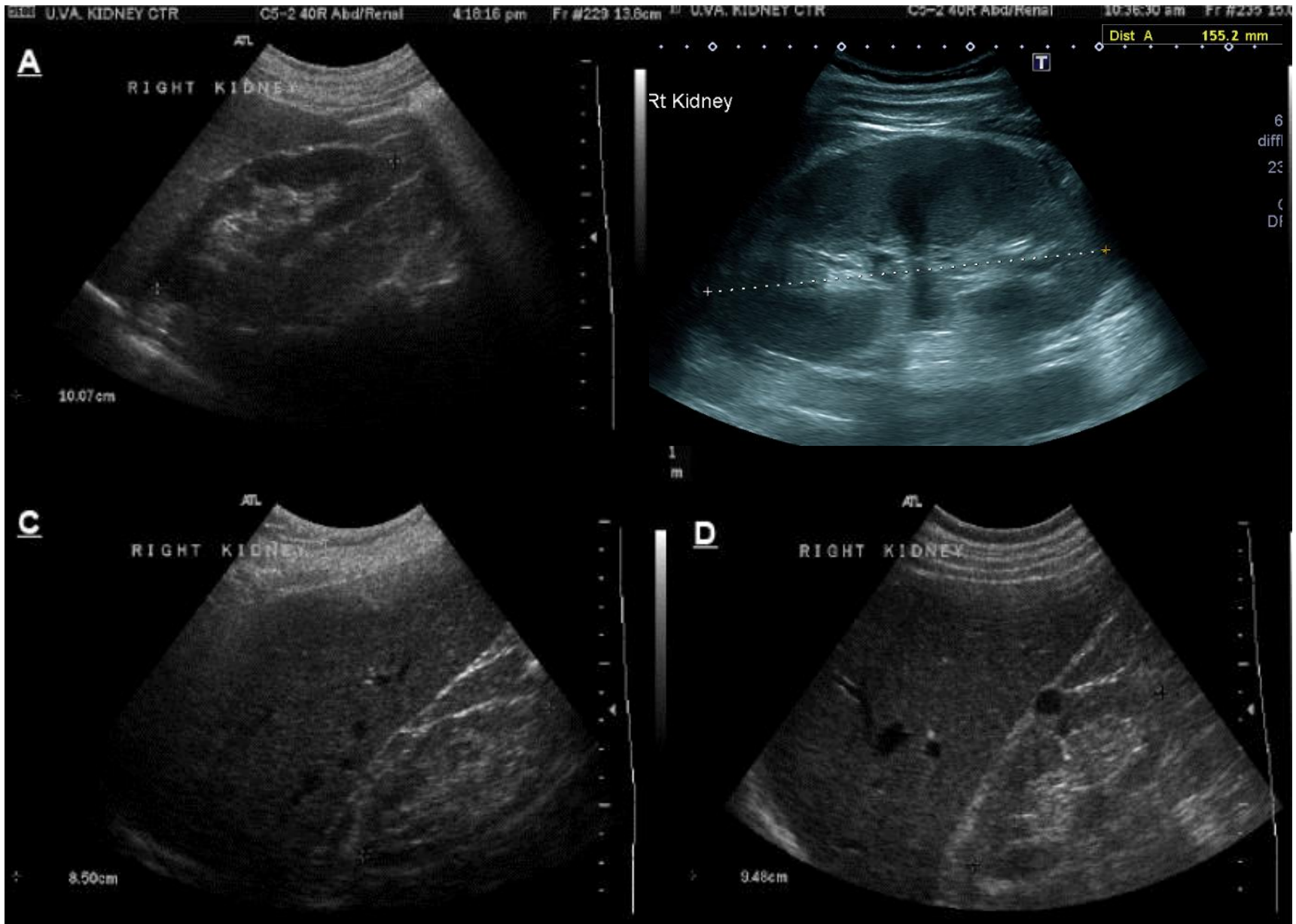
- Renal size and cortical echogenecity
 - Normal range 9 – 10.5am
 - = / Hypoechoic to Liver
- Large (AKI) vs Small (CRF)
- Cortical Thickness / preservation
 - Normal range >1cm
- Thick (AKI) vs Thin (CRF)

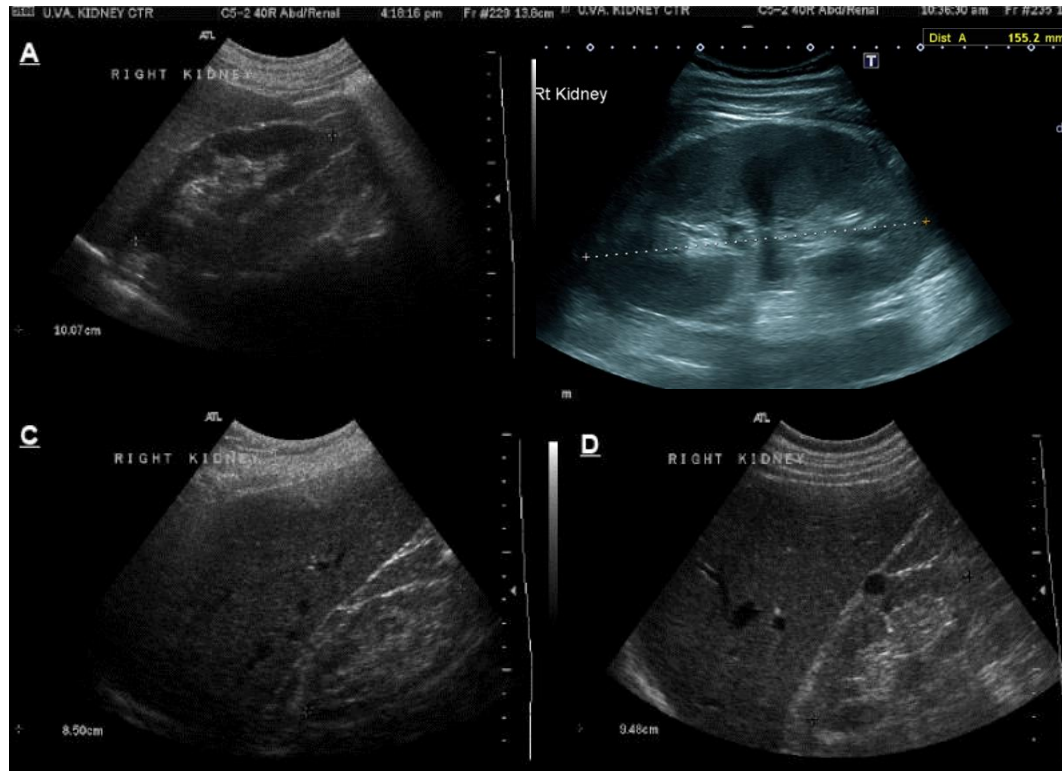


1: AKI

2: Normal

3: CRF





A: Normal

B: AKI

C: CRF

D: NFA / Mild CRF

Can we do more?

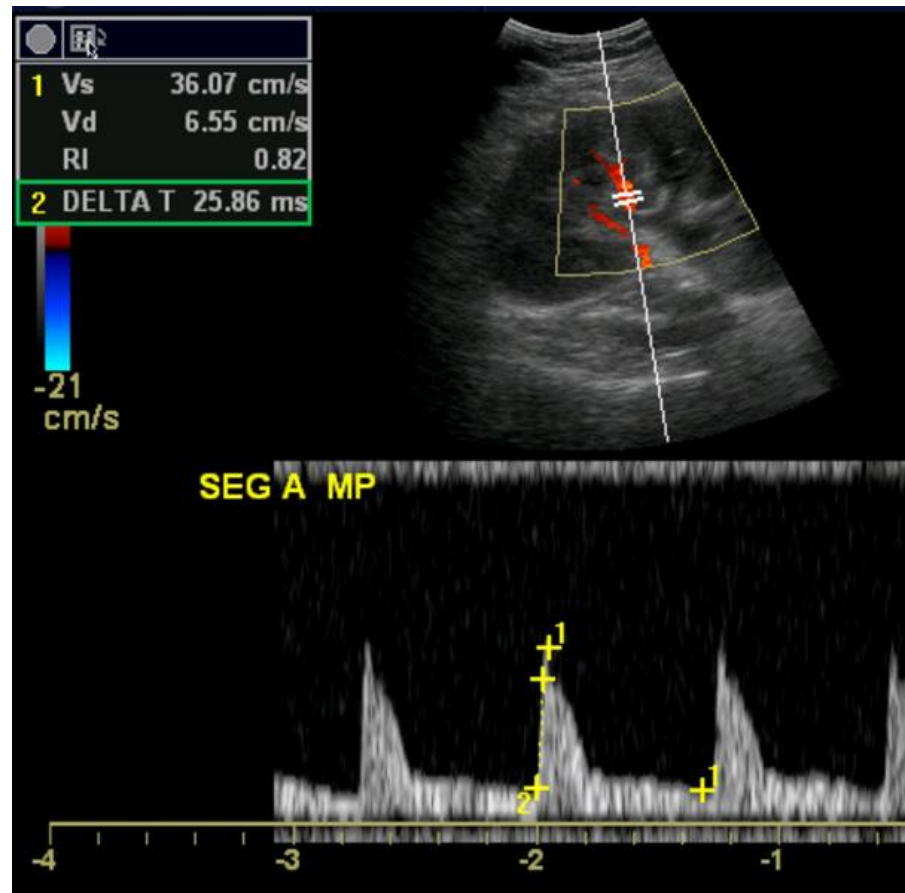
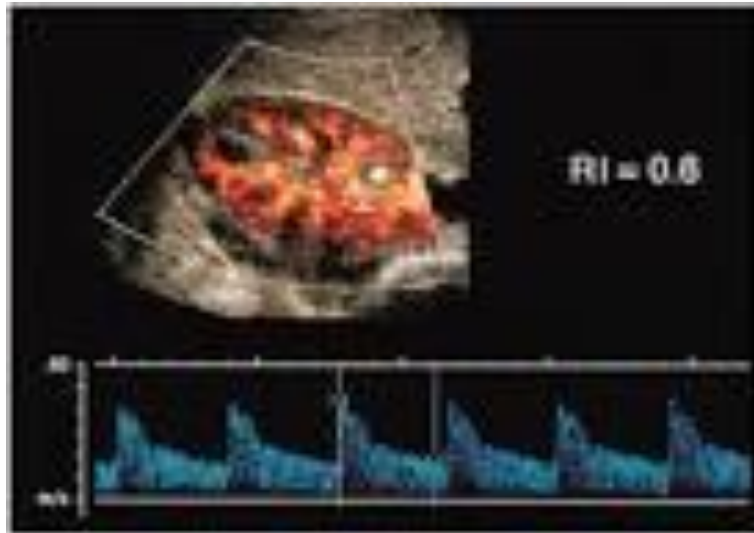
- In the early 1990s, several groups postulated that the pathophysiology of urinary obstruction might be reliably manifested by changes in arterial Doppler spectra
- Haemodynamic response obstruction
- Renal blood flow decreases, and renal vascular resistance increases

Resistive Index

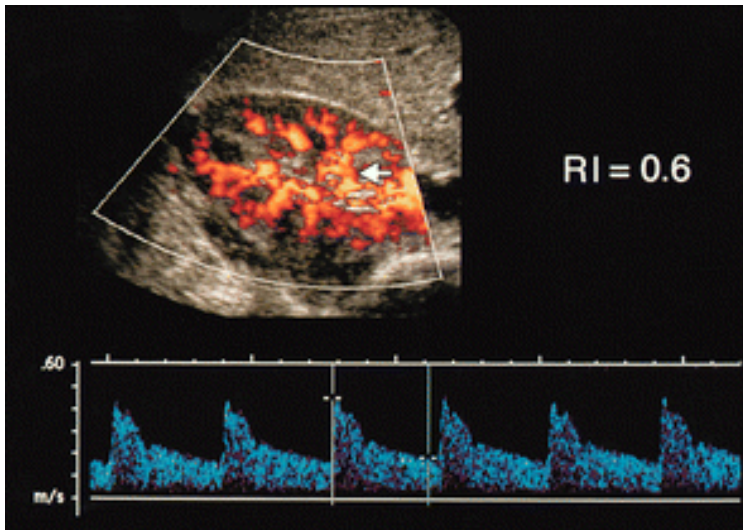
- This vasoconstriction response is an ideal phenomenon to be detected by changes in the RI
- RI can be increased by extrinsic factors such as kidney compression, breath holding during the Valsalva manoeuvre and extreme bradycardia
- RI values are also correlated with arteriovascular disease (check if bilateral)

Resistive Index in AKI

- RI greater than 0.70 or a difference of greater than 0.06–0.10 in mean RI values between kidneys is found to be highly specific and sensitive for acute obstruction
- Evidence of obstruction identified before the development of collecting system dilatation with the use of RI values



Resistive Index



	Patients	RI
Keogan M <i>Radiology</i> 1996; 199:165 –169	58	0.6+/- 0.01
Norris C <i>J Vasc Surg</i> 1984; 1:192 –201	21	0.64+/- 0.05
Platt J <i>Radiology</i> 1989; 171:515 –517	50	0.58+/- 0.05
Kim S <i>J Ultrasound Med</i> 1990; 9:S25	28	0.62 +/- 0.04

Case 1



The right renal length measures 10.8cm.

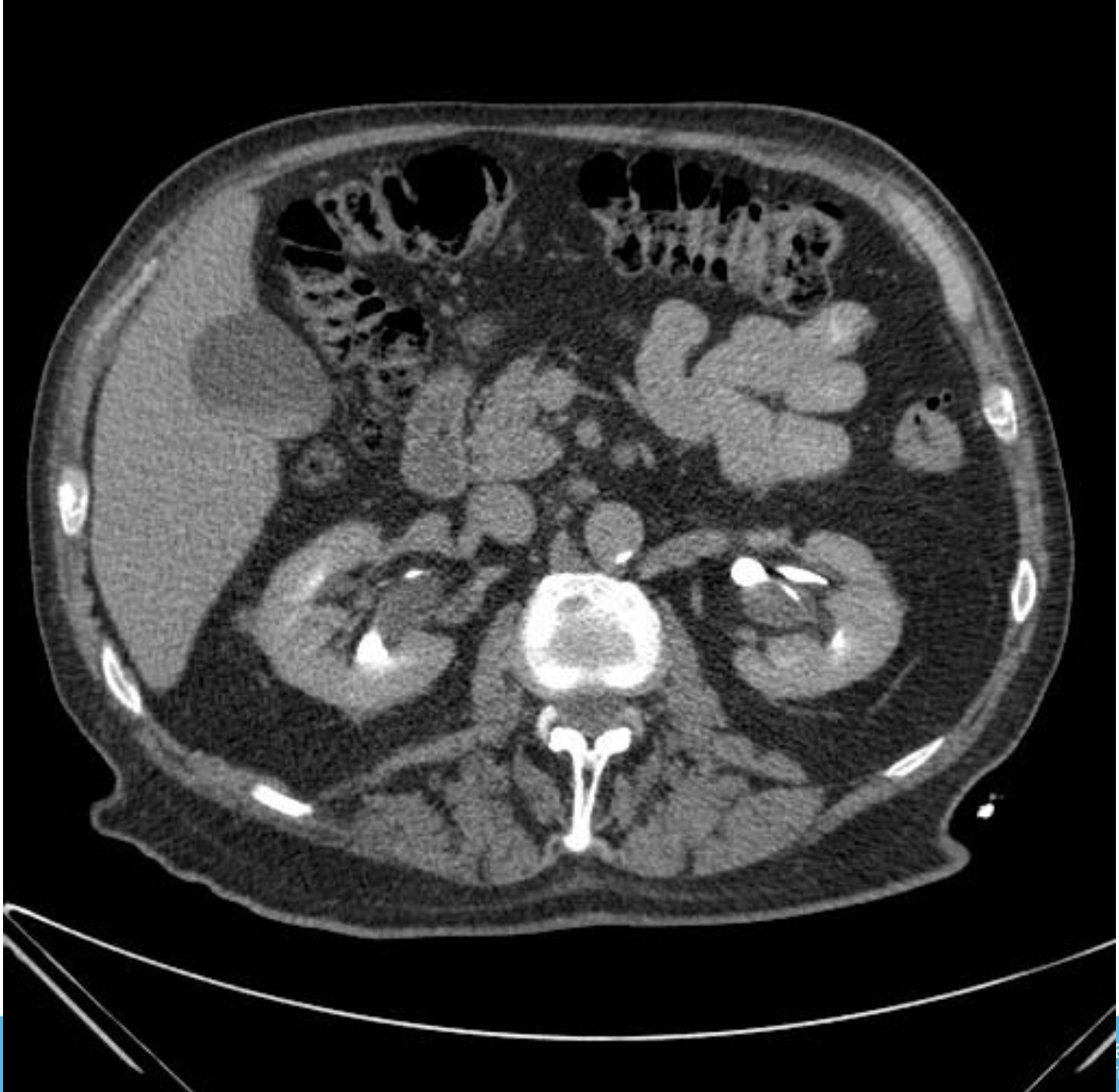
The left renal length measures 11.3cm.

There is mild left renal pelvic fullness with a maximum AP diameter of 1 cm. There is a small cortical cyst arising from the right kidney. Otherwise both kidneys demonstrate normal collecting system and cortex.

Good cortical preservation noted.

The bladder is poorly filled and therefore the prostate volume cannot be established.

The aorta is obscured by overlying bowel gas and cannot be measured today.



Platt J, Rubin J, Ellis J, DiPietro MA. Duplex Doppler US of the kidney; differentiation of obstructive from nonobstructive dilatation. *Radiology* 1989; 171:515 –517

University of Michigan, RIs from 21 hydronephrotic kidneys were obtained before nephrostomy. The mean RI in 14 kidneys with confirmed obstruction (0.77 ± 0.04) was **significantly higher** than the mean RI from seven kidneys with nonobstructive pelvicaliectasis (0.64 ± 0.04). Moreover, **RI values returned to normal after nephrostomy.**

Platt J, Rubin J, Ellis J. Distinction between obstructive and nonobstructive pyelocaliectasis duplex Doppler sonography. *AJR* 1989; 153:997 –1000

A larger study of 229 kidneys. In this study, a discriminatory RI threshold of 0.70 was used; the sensitivity and specificity of the Doppler diagnosis of obstruction were 92% and 88%, respectively. Moreover, the accuracy of the Doppler diagnosis of obstruction increased when the RI of the potentially obstructed kidney was compared with that of the unaffected contralateral kidney.

An RI difference greater than 0.10 between kidneys was seen only with true obstruction.

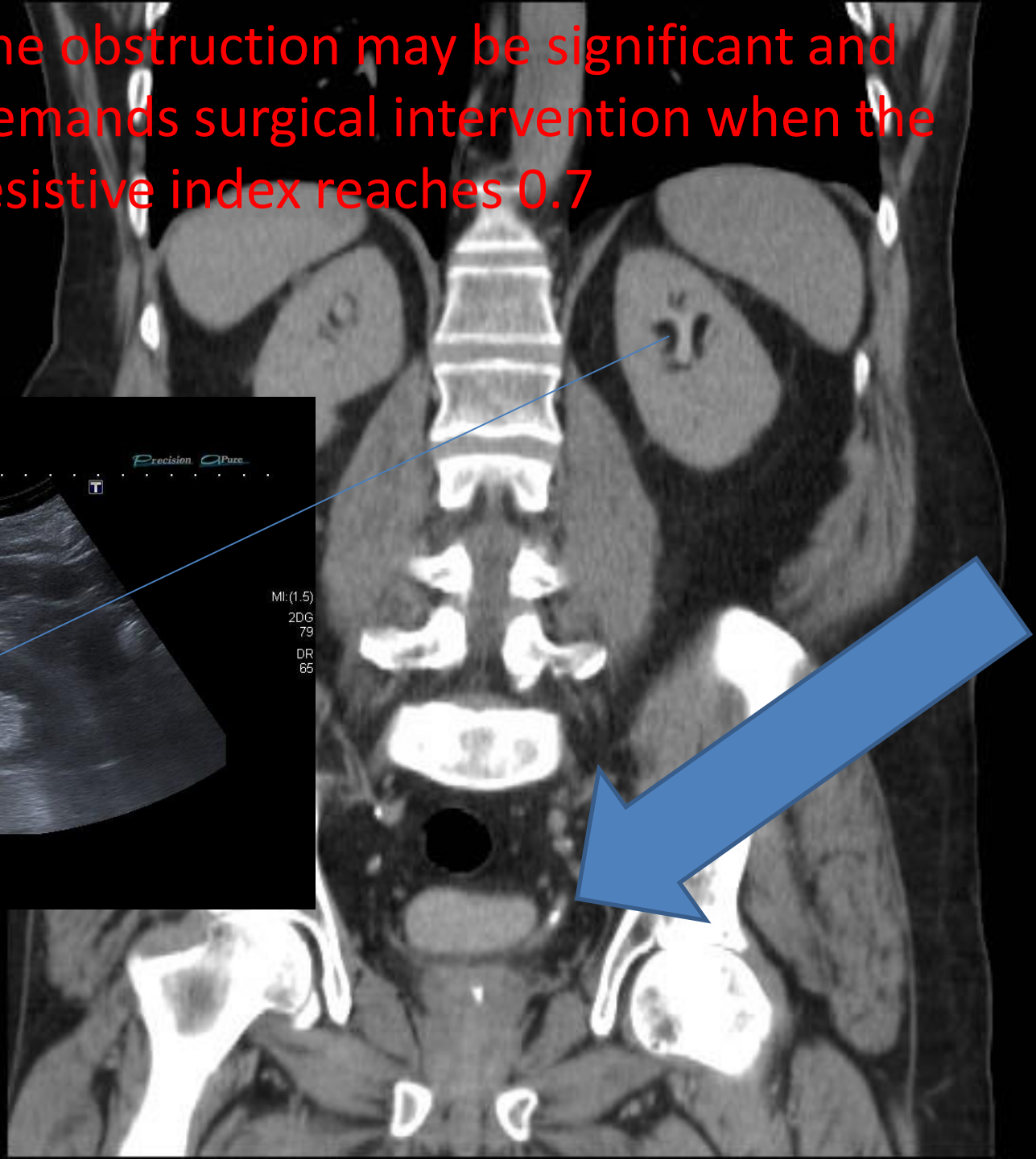
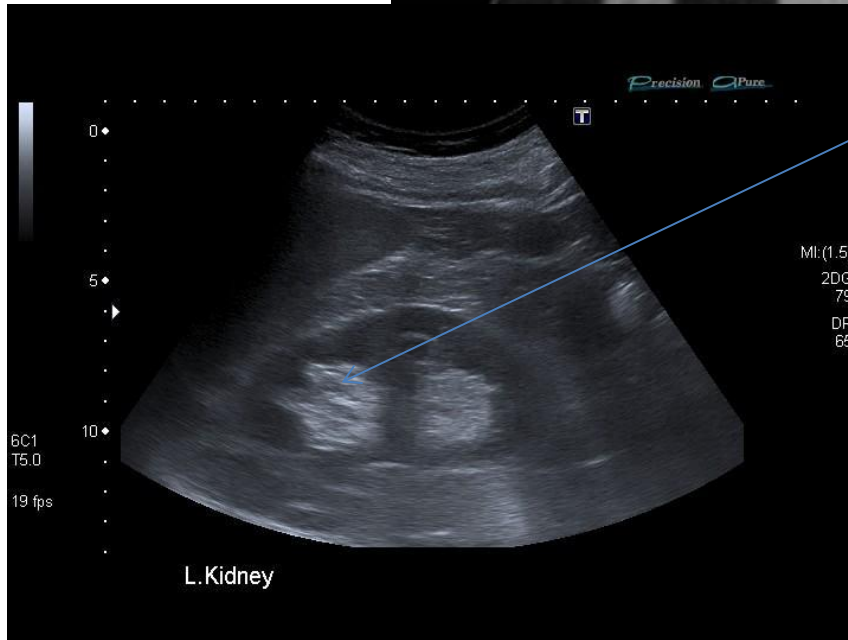
Chen J, Pu Y, Liu S, Chin TY. Renal hemodynamics in patients with obstructive uropathy evaluated by duplex Doppler sonography. *J Urol* 1993

Evaluated 56 kidneys in 28 normal subjects and 53 kidneys in 27 patients with unilateral or bilateral obstructive uropathy.

The mean resistive index values for mildly and significantly obstructed kidneys were 0.64 ± 0.08 and 0.74 ± 0.05 , respectively. More than 93.3% of the **significantly obstructed kidneys had resistive index values greater than or equal to 0.70.**

The obstruction may be significant and demands surgical intervention when the resistive index reaches that value. In contrast, with resistive index values of less than 0.70 renovascular resistance is minimally altered and obstruction may be mild.

The obstruction may be significant and demands surgical intervention when the resistive index reaches 0.7



Platt J, Rubin J, Ellis J. Acute renal obstruction: evaluation with intrarenal duplex Doppler and conventional US.
Radiology 1993; 186:685 –688

To evaluate duplex Doppler ultrasound (US) in acute renal obstruction, bilateral intrarenal Doppler US was performed in 23 patients with unilateral renal obstruction (proved by means of intravenous urography) of 36 hours duration or less. A mean renal resistive index (RI) was calculated for each obstructed and normal contralateral kidney and compared with findings on conventional US scans. The mean RI in the obstructed kidneys was elevated (.77 +/- .07 [standard deviation]) and was higher than the mean RI in the normal contralateral kidney (.60 +/- .04) (P < .001). RIs in the obstructed kidneys were as follows: .75 or greater in 15 kidneys, .70-.74 (mild RI elevation) in five kidneys (but > or = .10 higher than the RI in the normal contralateral kidney), and less than .70 in three kidneys (two of these three patients had pyelosis extravasation and one patient had clinical obstruction for only 4-5 hours).

RI elevation occurred before collecting-system dilatation in four patients (17%). RI elevation occurs by 6 hours of clinical acute renal obstruction and may precede pyelocaliectasis. Renal duplex Doppler US contributes useful clinical information, especially when US is the first modality used to evaluate acute renal colic.





Journal of Ultrasound (2012) 15, 239-246

The renal resistive index as a predictor of acute hydronephrosis in patients with renal colic

E.M.S. Piazzese a,* , G.I. Mazzeo a, S. Galipo` a,
F. Fiumara b, C. Canfora c, L.G. Angio` d

a General Surgery Unit, San Camillo Clinic, Messina, Italy

b Emergency Department, Humanitas-Gavazzeni Hospital,
Bergamo, Italy

c Radiology Service, Carmona Clinic, Messina, Italy

d School of Specialization in General Surgery I, University of
Messina, Messina, Italy

Abstract Introduction: The objective of this study was to determine whether the renal resistive index (RI) can predict hydronephrosis in patients with renal colic (RC) and whether or not its performance is time-dependent.

Materials and methods:

The study population was composed of 54 patients admitted for unilateral RC. At the time of the first observation (time point I, tpI), each patient underwent routine examinations, abdominal ultrasonography, and renal color Doppler ultrasound (CDUS) with measurement of the RI. The two imaging studies were repeated 6, 12, 18, 24, 36, and 48 h later (tpII, tpIII, tpIV, tpV, tpVI, tpVII). In addition, each patient underwent noncontrast urinary tract CT 48-60 h after admission. A mean renal RI of >0.70 (mRIp) for the symptomatic kidney was considered indicative of obstruction.

Patients were retrospectively divided into two groups:

those who developed dilatation (group A)

and those who did not (group B).

No. of cases of Hydronephrosis Group A (Dilatation developed)

Time point hydronephrosis	No. cases hydronephrosis	% cases
Admission	0	0
6 hours	0	0
12 hours	3/54	5.5
18 hours	14/54	25.9
24 hours	10/54	18.5
36 hours	2/54	3.7
48 hours	0	0
Total	29/54	53.7%

Number of RI +ve cases

	Group A No. of cases hydronephrosis	Hrs before	Group B No. of cases
Admission	0	0	-
At 6 hours	7/29 (24%)	1 case – 18h 12 cases-12h	4/25 (16%)
At 12 hours	16/29 (55.1%)	5 cases-12h 11 caes-6h	0
At 18 hours	5/29 (17.2%)	1 case – 18h 4 cases-6h	0
At 24hours	1/29 (3.4%)	1 case – 6h	0
At 36 + 48 hours	0	0	0
Total	29/29 (100%)	2/29-18hrs(6.9%) 8/29- 12hrs(27.6%) 19/29- 6hrs(65.5%)	4/25 (16%)

Relieving Obstruction

Refer all adults, children and young people with upper tract urological obstruction to a urologist. Refer immediately when one or more of the following is present:

- pyonephrosis
- an obstructed solitary kidney
- bilateral upper urinary tract obstruction
- acute kidney injury caused by urological obstruction.
- when nephrostomy or stenting is used to treat upper tract urological obstruction in adults, children and young people with acute kidney injury, undertake as soon as possible and within 12 hours of diagnosis.

[Acute kidney injury](#). NICE clinical guideline 169 (2013)

90% Non obstructive

Pre-Renal 40-70%	Renal 10-50%	Post-Renal 10%
Renal Hypoperfusion	Acute tubular necrosis	Obstruction
<ul style="list-style-type: none">• Hypovolaemia	(Ischaemia of renal tubules)	
<ul style="list-style-type: none">• Sepsis	Drugs	
<ul style="list-style-type: none">• CCF	Contrast agents	
<ul style="list-style-type: none">• Cirrhosis	Haemoglobinuria	
<ul style="list-style-type: none">• NSAIDs or ACEi	myeloma	
	Vasculitis	

Nonobstructive Renal Disease

Pre-renal and Renal causes of AKI

The lack of specificity of the gray-scale examination in evaluating intrinsic renal disease has been frustrating for decades.

- Renal size
- Cortical thickness
- Echogenicity

These findings do not aid in the differential diagnosis or management of renal disease; they are not objective.

Is there a role for RIs?

- Platt J, Ellis J, Rubin J, DiPietro MA, Sedman AB. Intrarenal arterial Doppler sonography in patients with nonobstructive renal disease: correlation of resistive index with biopsy findings. *AJR* 1990; 154:1223 –1227
- Mostbeck G, Kain R, Mallek R, et al. Duplex Doppler sonography in renal parenchymal disease; histopathologic correlation. *J Ultrasound Med* 1991; 10:189 –194
- McDermott R, Teefey S, Middleton W, et al. The resistive index in renal parenchymal disease: no correlation with histopathologic findings. (abstr) *Radiology* 2000; 217(P):560

Platt J, Rubin J, Ellis J. Acute renal failure: possible role of duplex Doppler US in distinction between acute prerenal failure and acute tubular necrosis. *Radiology* 1991; 179:419 –423

Ultrasonography (US) of the native kidneys is commonly requested for acute renal failure (ARF), although in most cases the examination results are negative.

91 patients with ARF were studied to determine a mean resistive index (RI) for each patient.

Forty-six patients had **acute tubular necrosis** (ATN) with a **mean RI +/- 1 standard deviation of .85 +/- .06**, which was **significantly higher** than the mean RI of .67 +/- .09 in 30 patients with prerenal ARF (P less than .01).

Case 1 - AKI



- A. Offer a descriptive report with no advice.
- B. Use the word “fullness”.
- C. Perform RIs (inspired by BMUS)
- D. Advise immediate referral to a Urologist

Case 2- AKI



- A. Descriptive report with no advice
- B. Advise immediate referral to Urology
- C. Advise referral within 24hours
- D. Must do RIs

Relieving Obstruction

Refer all adults, children and young people with upper tract urological obstruction to a urologist. Refer immediately when one or more of the following is present:

- **pyonephrosis**
- **an obstructed solitary kidney**
- **bilateral upper urinary tract obstruction**
- **acute kidney injury caused by urological obstruction.**
- **when nephrostomy or stenting is used to treat upper tract urological obstruction in adults, children and young people with acute kidney injury, undertake as soon as possible and within 12 hours of diagnosis.**

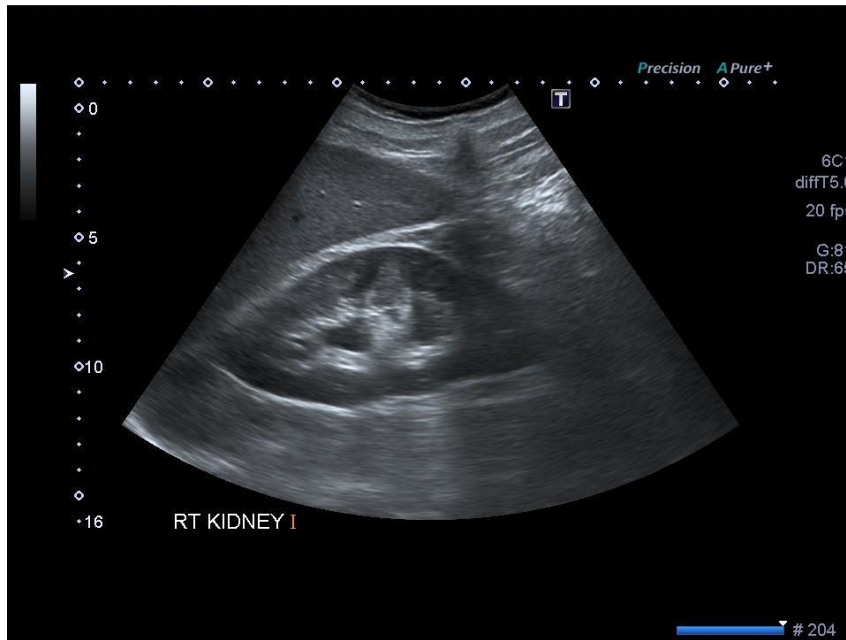
[Acute kidney injury](#). NICE clinical guideline 169 (2013)

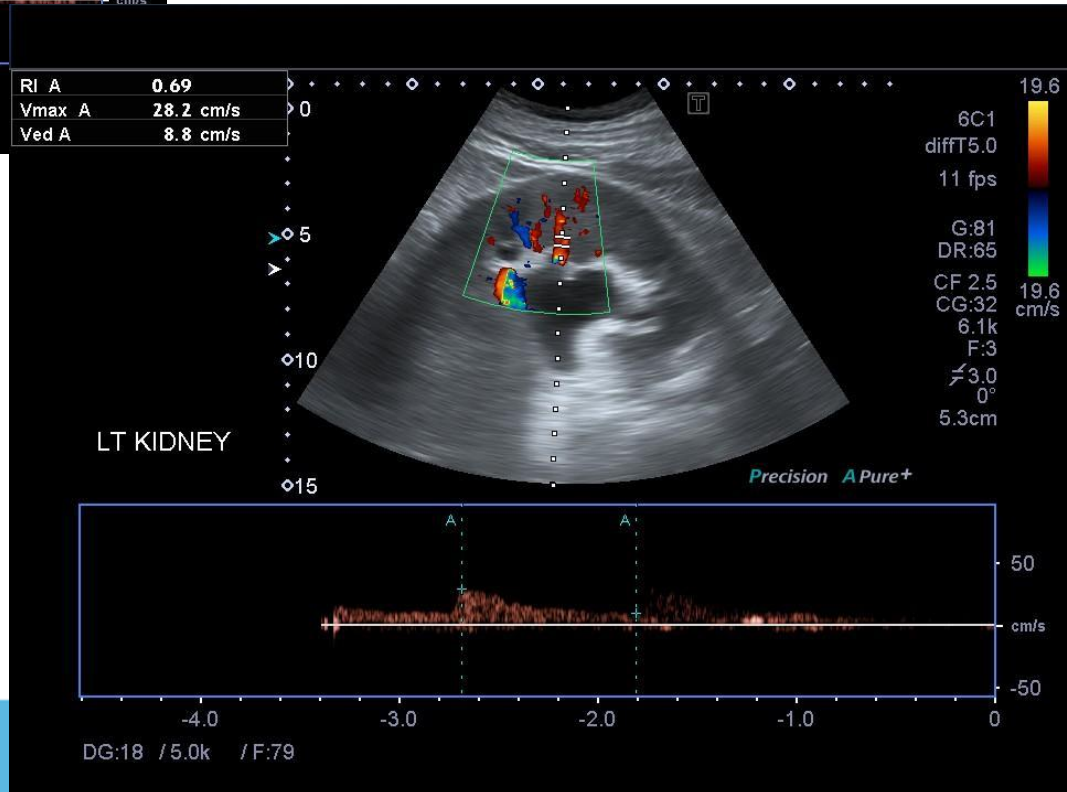
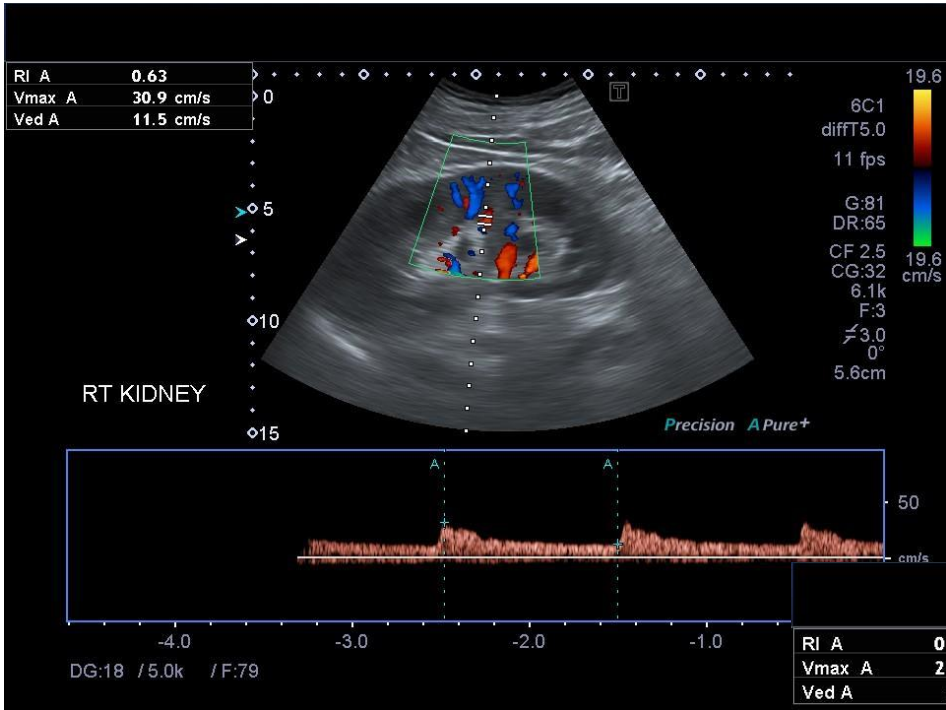
Case 3- AKI ?cause



- A. RIs(inspired by BMUS)**
- B. Advise immediate referral to Urologist**
- C. NICE Standards recommend Nephrostomy within 24 hours**
- D. All of above**

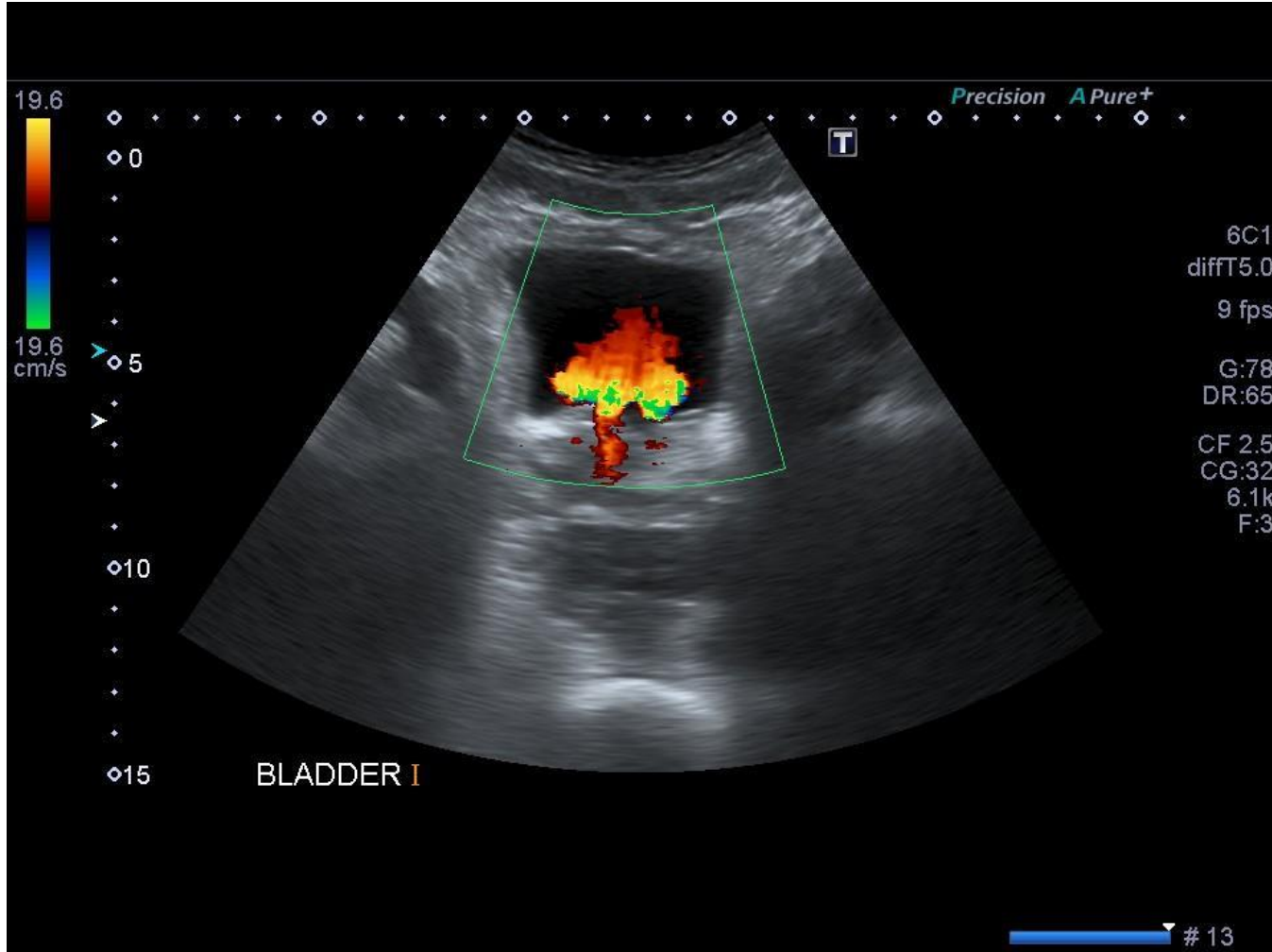
Case 4- AKI

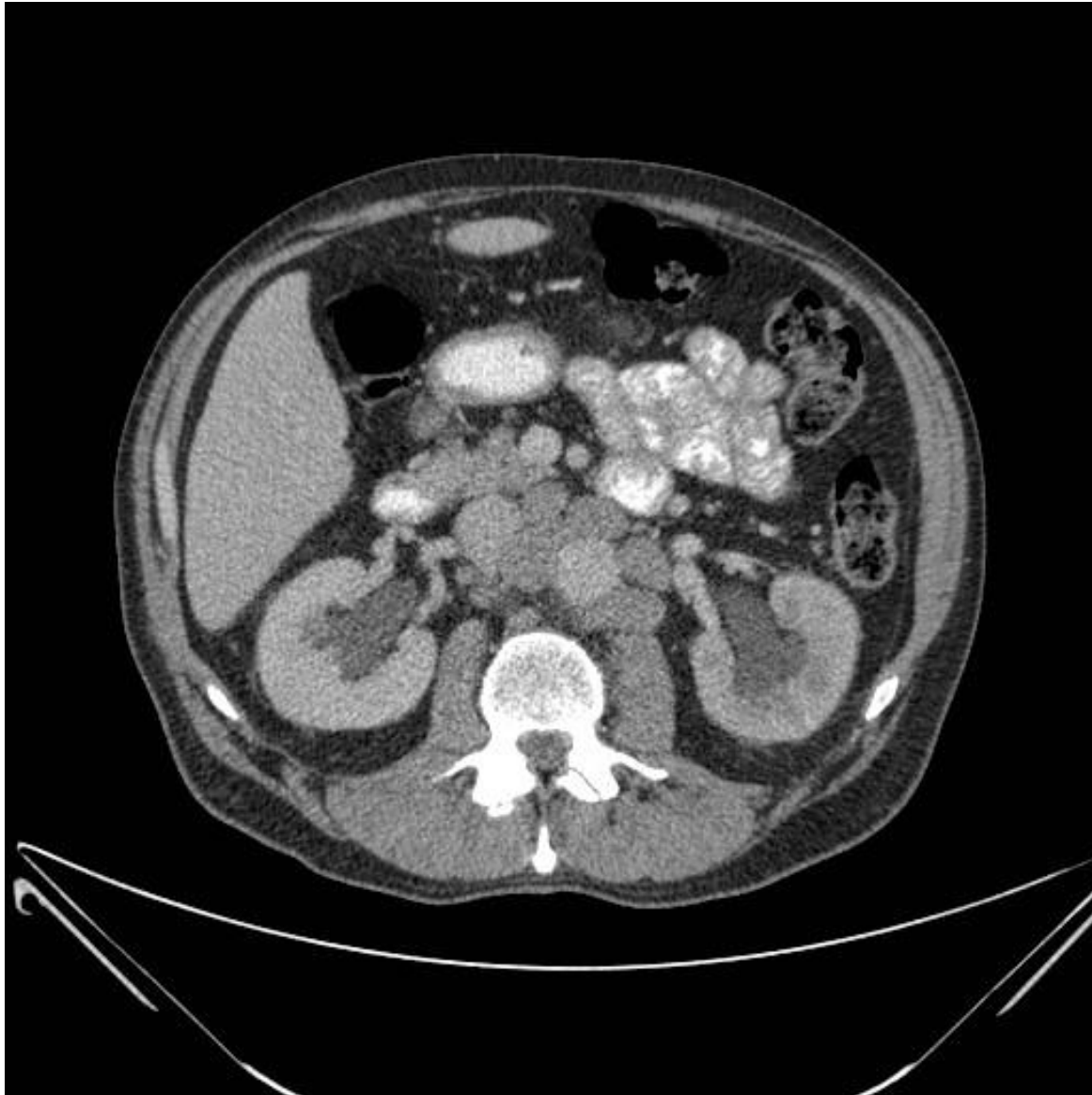




Case 4

- A. “I knew RIs were a waste of time”
- B. “These RIs must be wrong, I will repeat and alter that Doppler gate...”
- C. “ I bet Pam’s RIs would be greater than 0.7.”
- D. “This may be chronic obstruction in a patient with lymphoma, I will just look to see if there are any ureteric jets, thank goodness I checked the RIs before I advised immediate referral to Urology.”





Diagnostic criteria

Detect acute kidney injury by using any of the following criteria:

- a rise in serum creatinine of 26 micro mol/l or greater within 48 hours
- a 50% or greater rise in serum creatinine known or presumed to have occurred within the past 7 days
- a fall in urine output to less than 0.5 ml/kg/hour for more than 6 hours in [adults](#) and more than 8 hours in [children](#) and [young people](#)
- a 25% or greater fall in [eGFR](#) in children and young people within the past 7 days.

Conclusion

- Grey scale factors are valuable to differentiate between AKI & CRF
- Grey scale valuable assessment of hydronephrosis
- Causes of hydronephrosis should be identified and documented
- Assessment of obstruction can be made with RI's

Conclusion

- RI assessment useful tool in differentiating between fullness and obstruction
- In cases of AKI RI's can be an indicator of obstruction prior even in absence of hydronephrosis
- RI = or <0.7 is normal
- Difference > 0.10 between kidneys is significant and raises likelihood of obstruction in the higher RI value kidney

Thank You

- With thanks to Dr Oliver Byass and Andrew Hunter, Radiology HEYT for their contribution to this presentation

