Acute Kidney Injury in Children

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- **A 3-year old child is brought to the ED with 2-days history of diarrhea and vomiting. The patient looks moderately dehydrated. Investigations reveal: Na+ 146 mEq/l, K 4.8 mEq/l, Creatinine 2.2 mg/dl, WBC 1500/mm3, normal platelet count; urine specific gravity 1.007, no blood, protein 1+, Nitrite and leucocyte esterase negative. No hydronephrosis is seen by an ultrasound examination of the kidneys.**

Approach to AKI

Cause

Leveling

Grading

AKI *vs.* CRF

When to suspect?

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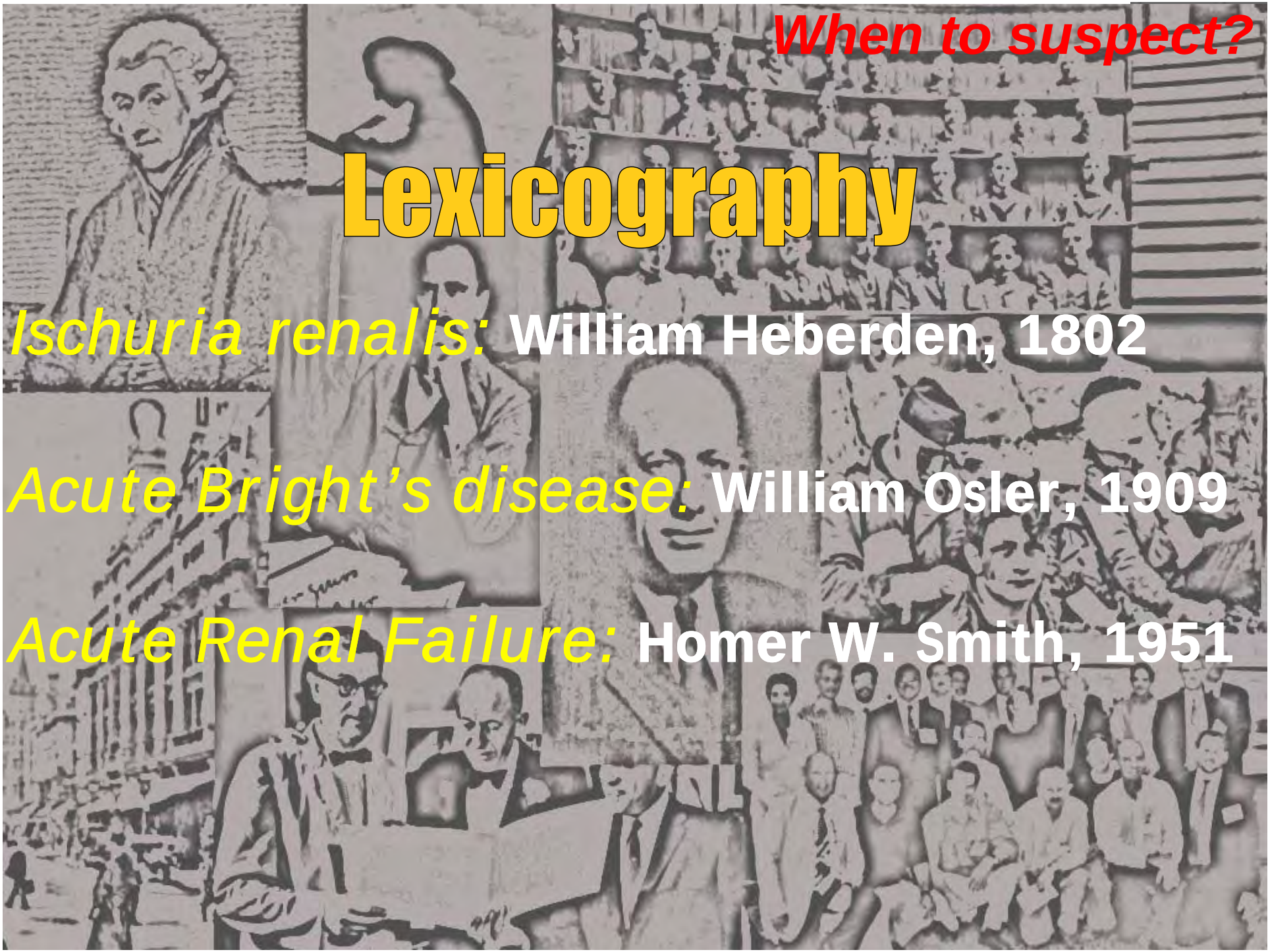
When to suspect?



When to suspect?

Lexicography

Ischuria renalis: **William Heberden, 1802**

Acute Bright's disease: **William Osler, 1909**

Acute Renal Failure: **Homer W. Smith, 1951**

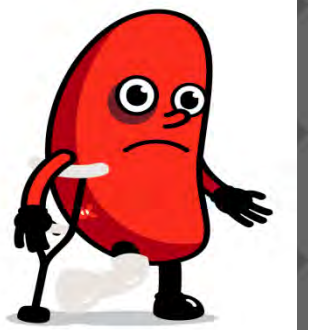
ARF definitions to 2002:

Over 30 definitions in published literature:

- Nearly all based on absolute or change in serum creatinine concentration
- All ARF is created equal 100% rise in SCr
- eCCL < 75 ml/min/1.73m2
- SCr twice normal for patient age.

Pediatric ARF definitions:

- Few prospective pediatric studies
- Retrospective studies assess ARF causes
- Control group without ARF not assessed to determine risk factors for ARF

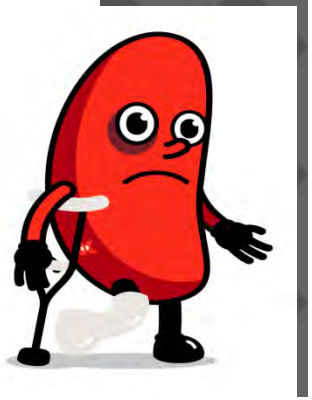


When to suspect?

Definition:

A rapid decline in glomerular filtration rate GFR resulting in the disturbance of renal physiological functions including:

- ♦ Impairment of nitrogenous waste product excretion
- ♦ Loss of water and electrolyte regulation
- ♦ Loss of acid-base regulation



When to suspect?

From ARF to AKI

From ARF to AKI

- **AKIN** proposed this term to reflect the entire spectrum of ARF
- Whatever the etiology, the acute decline in kidney function is **2ry to an injury** ✧ functional and structural changes in the kidney
- **The word failure** reflects only one end of the spectrum of the disease.

Definition and Diagnostic criteria of AKI

An abrupt (within 48 h) reduction in kidney function defined as an absolute increase in serum creatinine level of ≥ 26.4 μmol/l (0.3 mg/dl) OR a percentage increase in serum creatinine level of ≥50% (1.5-fold from baseline) OR a reduction in urine output (documented oliguria of <0.5 ml/kg/h for >6 h).

Acute Dialysis Quality Initiative (ADQI), 2004

Creatinine Clearance

Serum Creatinine

When to suspect?

Measured

$$^{1}\text{CrCl (mg/ml)} = \frac{U_{Cr}\ (\text{mg/dL}) \times U_{vol}\ (\text{cc})}{P_{Cr}\ (\text{mg/dL}) \times \text{time (min)}} \times \frac{1.73}{\text{BSA}}$$

$$\text{Body Surface Area (BSA, m}^2\text{)} = \text{square root of } \frac{\text{height (cm)} \times \text{weight (kg)}}{3600}$$

- Newborn - 0.3 to 1.0 mg/dL
- Infant - 0.2 to 0.5 mg/dL
- Child - 0.3 to 0.7 mg/dL
- Adolescent - 0.5 to 1.0 mg/dL

Schwartz formula

$$\text{GFR} = \frac{\delta \times \text{height (cm)}}{P_{Cr}}$$

Proportionality Constants (δ) :

Age Group	δ
Low birth weight infants, age < 1 yr	0.33
Term infants, age < 1 yr	0.45
Children, ages 2-12 years	0.55
Girls, ages 13-21 years	0.55
Boys, ages 13-21 years	0.70

$$\text{GFR} = \frac{\text{½ the height of the patient}}{\text{Serum creatinine}}$$

Calculated

When to suspect?

Pediatr Nephrol
DOI 10.1007/s00467-016-3373-x

CrossMark

EDUCATIONAL REVIEW

2016

Measuring and estimating glomerular filtration rate in children

Hans Pottel[1]

The updated bedside Schwartz equation

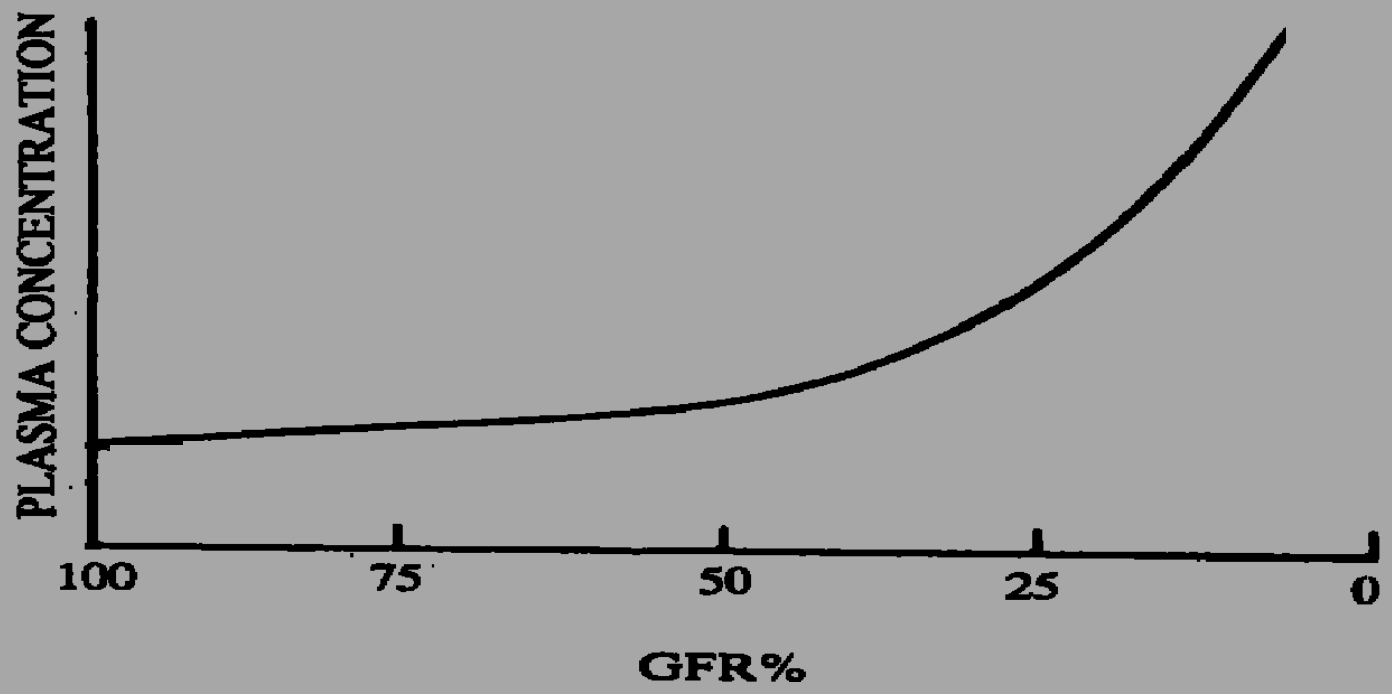
k=0.413

For all children

Limitations

When to suspect?

- Serum creatinine concentrations may not change until about 50% of kidney function has already been lost.
- Serum creatinine does not accurately reflect the GFR in a patient who is not in steady state.
- Creatinine is removed by dialysis.



When to suspect?

This presents the need to find new biomarkers to early identify and manage AKI

When to suspect?

BIOMARKERS FOR AKI

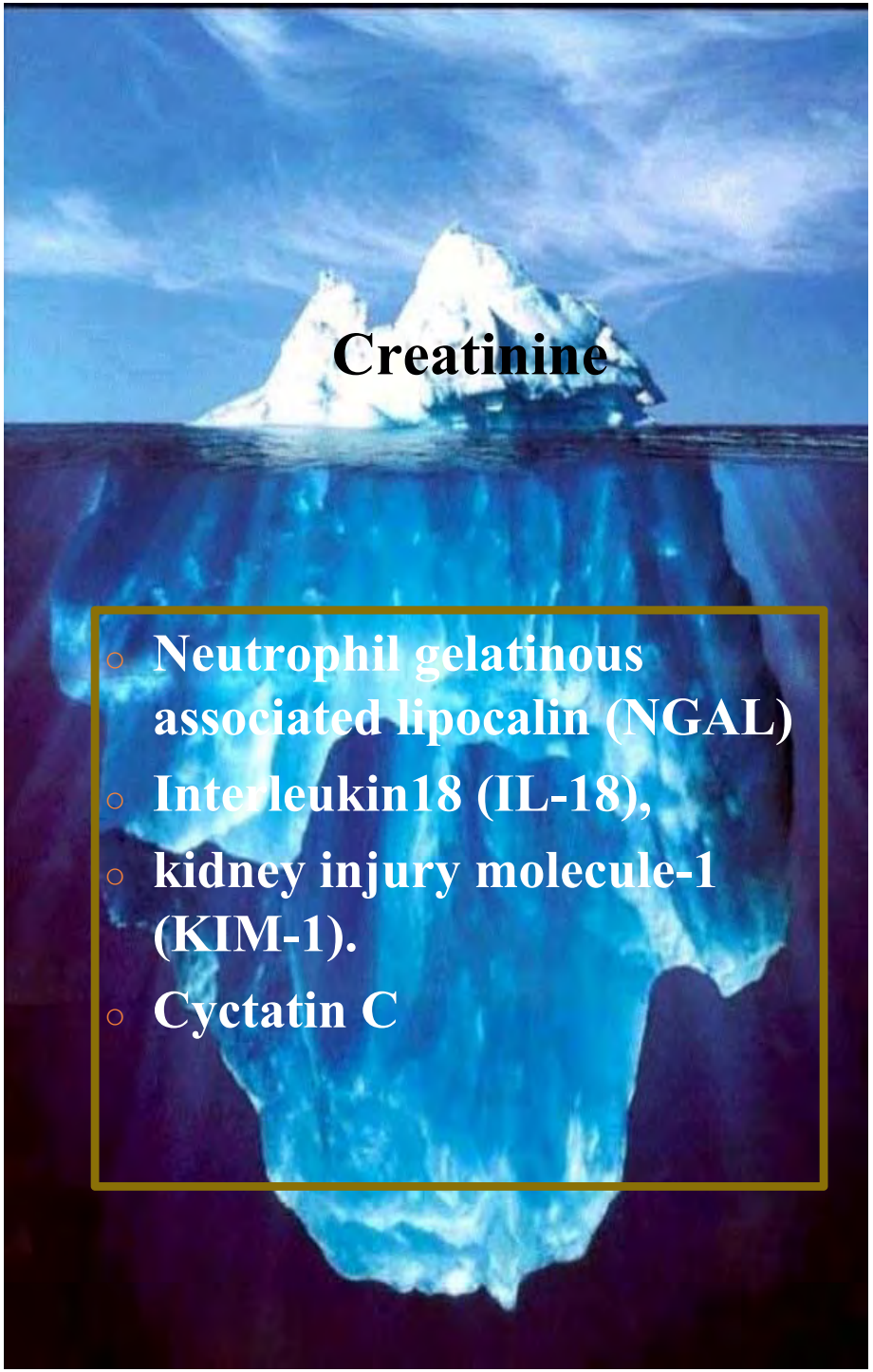
Urine

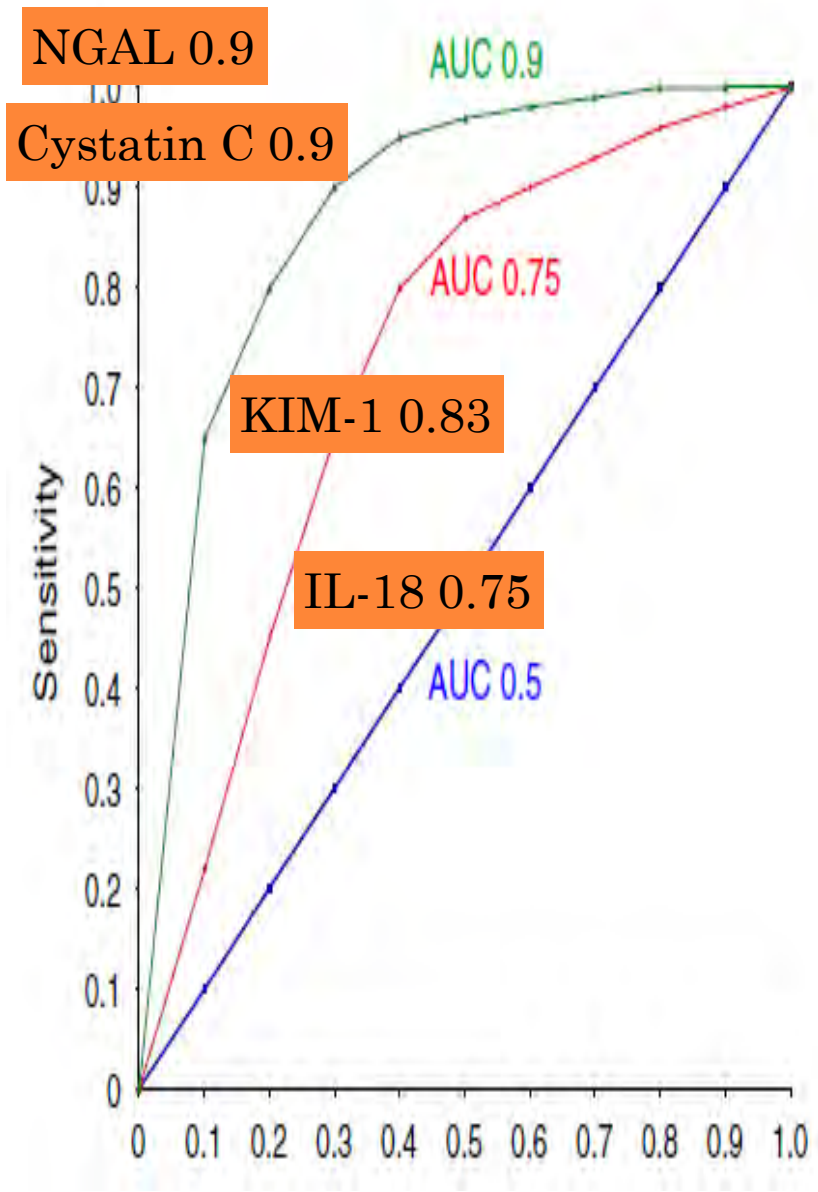
- Neutrophil gelatinous associated lipocalin (NGAL)
- Interleukin18 (IL-18),
- kidney injury molecule-1 (KIM-1).

Blood

- Neutrophil gelatinous associated lipocalin (NGAL)
- Cystatin C

When to suspect?





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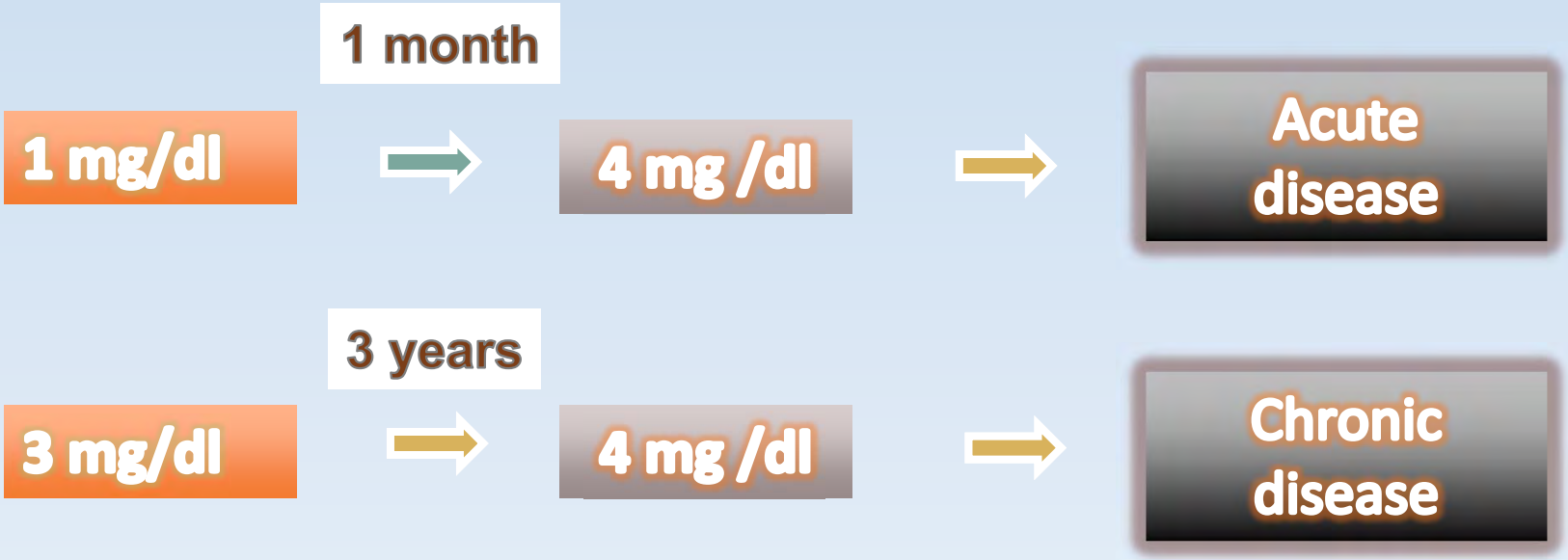
When to suspect

AKI vs. CRF

By comparing the current urinalysis or serum creatinine with previous results



When a previous urinalysis, serum creatinine, or radiographic study is unavailable

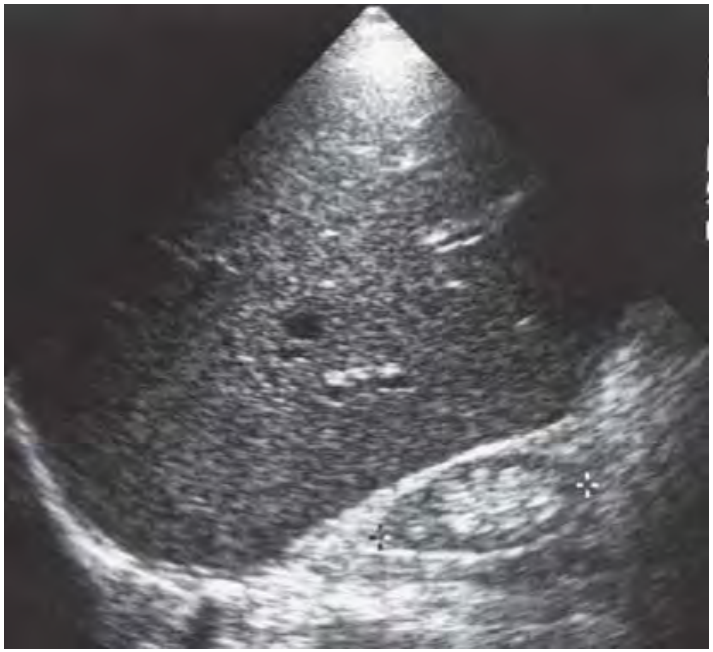
The recent onset of symptoms or signs, such as fever and discolored urine, suggests an **acute process**

Little or no output also suggests an **acute component**

An increasing serum creatinine after the initial evaluation is indicative of an **acute component** to the disease, while a stable value suggests a **chronic disease**

AKI vs. CRF

If renal ultrasonography, showing small kidneys it is mostly consistent with a **chronic disease**



Patients with growth failure and\or normocytic normochromic anemia is mostly consistent with a **chronic disease**

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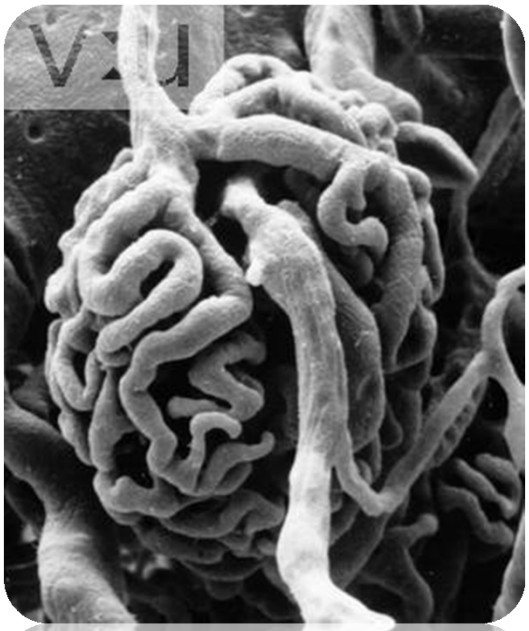

RIFLE (RISK, INJURY, FAILURE, LOSS, ESRD) & AKIN CRITERIA

Pediatric-modified RIFLE (pRIFLE) criteria

Grading

	Estimated	Urine output
Risk	eCCl decrease by 25%	UO <0.5 ml/kg/h x 8 h
Injury	eCCl decrease by 50%	UO < 0.5 ml/kg/h x 16 h
Failure	eCCl decrease by 75% or eCCl < 35ml/min/1.73 m^2	UO < 0.3 ml/kg/h x 24 h or Anuria x 12 h
Loss	Persistent failure >4 weeks	
ESRD	End-stage renal disease (persistent failure > 3 months)	

AKIN

	Cr Criteria	Urine Output (UO Criteria)
Step 1	Increase 0.3 mg/dl (27 umol/L) during 48 hours or increased 150%-200%	<0.5 mL/kg/hr for 8 hours
Step 2	≥200%-300%	<0.5 mL/kg/hr for 16 hours
Step 3	Increase ≥300%, serum creatinine ≥4mg/dL (≥354umol/L) or dialysis or estimated GFR <35mL/min/1073 m2 for those <18 years old	<5.0 mL/kg/hr for 24 hours or anuria for 12 hours

- ***Baseline eCCl :***
  - -From three months before PICU
  - -If no data available 100 ml/min/1.73m^2

Patients who receive renal replacement therapy (RRT) are considered to have met the criteria for stage 3 irrespective of the stage that they are in at the time of commencement of RRT.

(Akcan-Arikan, KI Int 2007)

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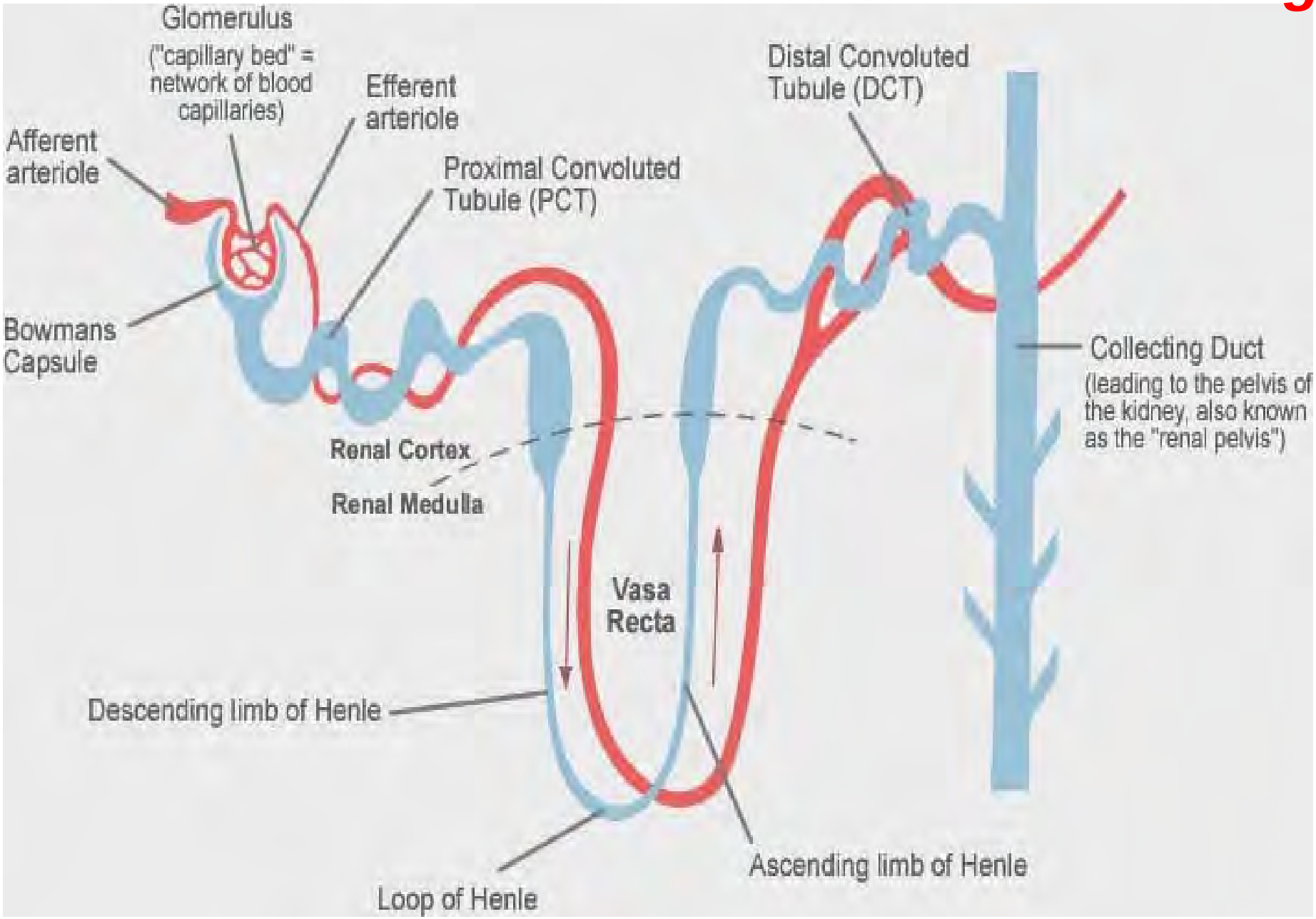
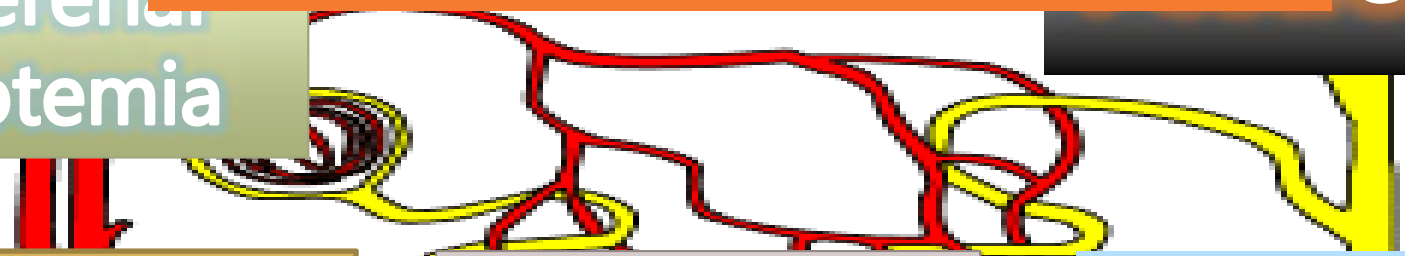

Glomerulus
("capillary bed" = network of blood capillaries)
Afferent arteriole
Efferent arteriole
Proximal Convoluted Tubule (PCT)
Distal Convoluted Tubule (DCT)
Bowmans Capsule
Collecting Duct
(leading to the pelvis of the kidney, also known as the "renal pelvis")
Renal Cortex
Renal Medulla
Vasa Recta
Descending limb of Henle
Ascending limb of Henle
Loop of Henle

Intrinsic Renal Disorders

Prerenal azotemia

renal



Vascular

- Thrombosis (arterial and venous)

Glomerular

- Acute G.N, which is commonly post

Tubular and interstitial disease (ATN)

- Ischemia due to

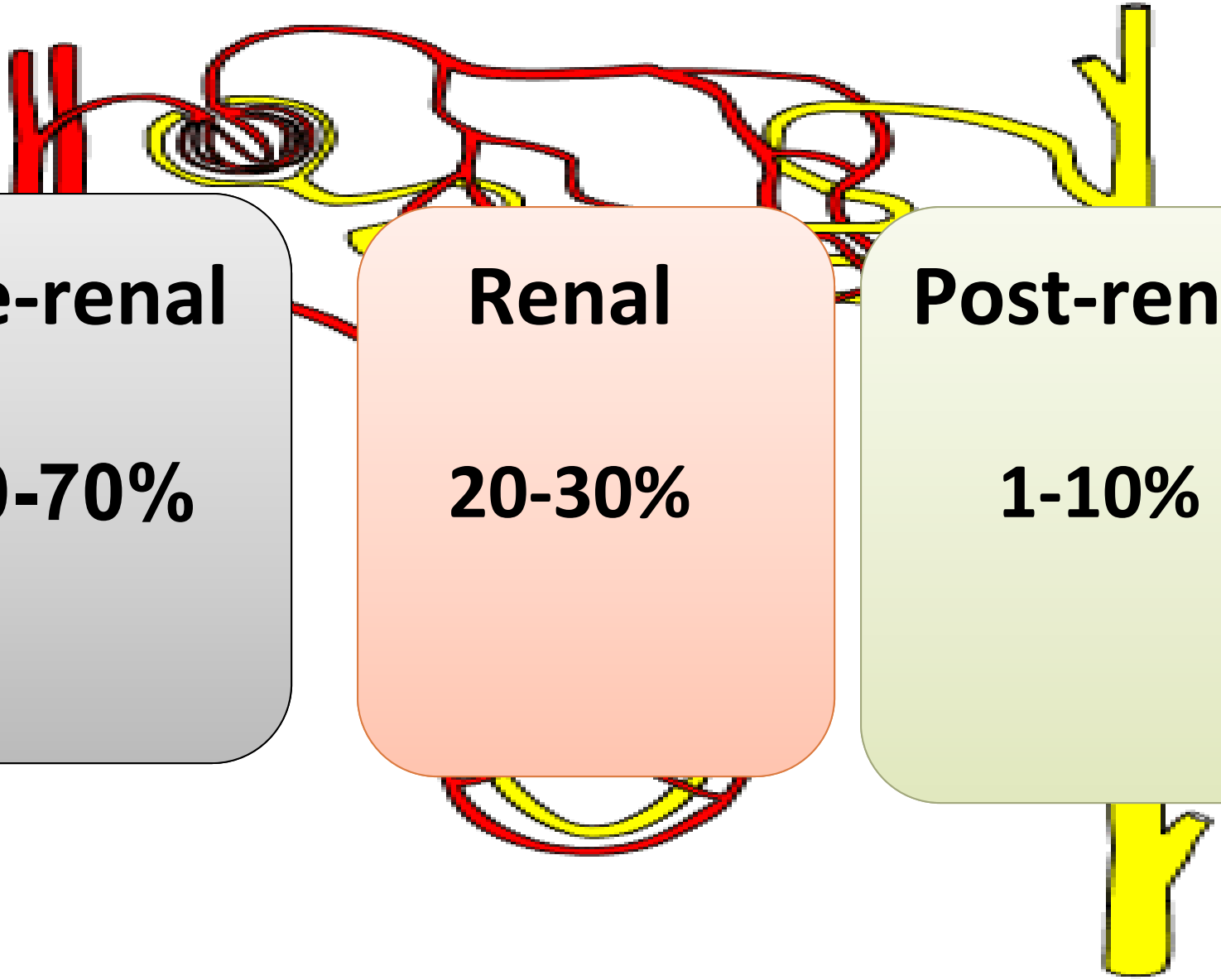
♦ Volume depletion due to bleeding (surgery, trauma, gastrointestinal bleeding), GASTROINTESTINAL (VOMITING, DIARRHEA), urinary (diuretics, diabetes insipidus), or cutaneous losses (burns).

♦ Decreased effective arterial pressure and/or effective circulating volume seen in heart failure, shock, or cirrhosis.

l urinary tract obstruction
here is a solitary kidney.

ates, urinary tract
tion, due to posterior urethral
s the most common cause of
al failure

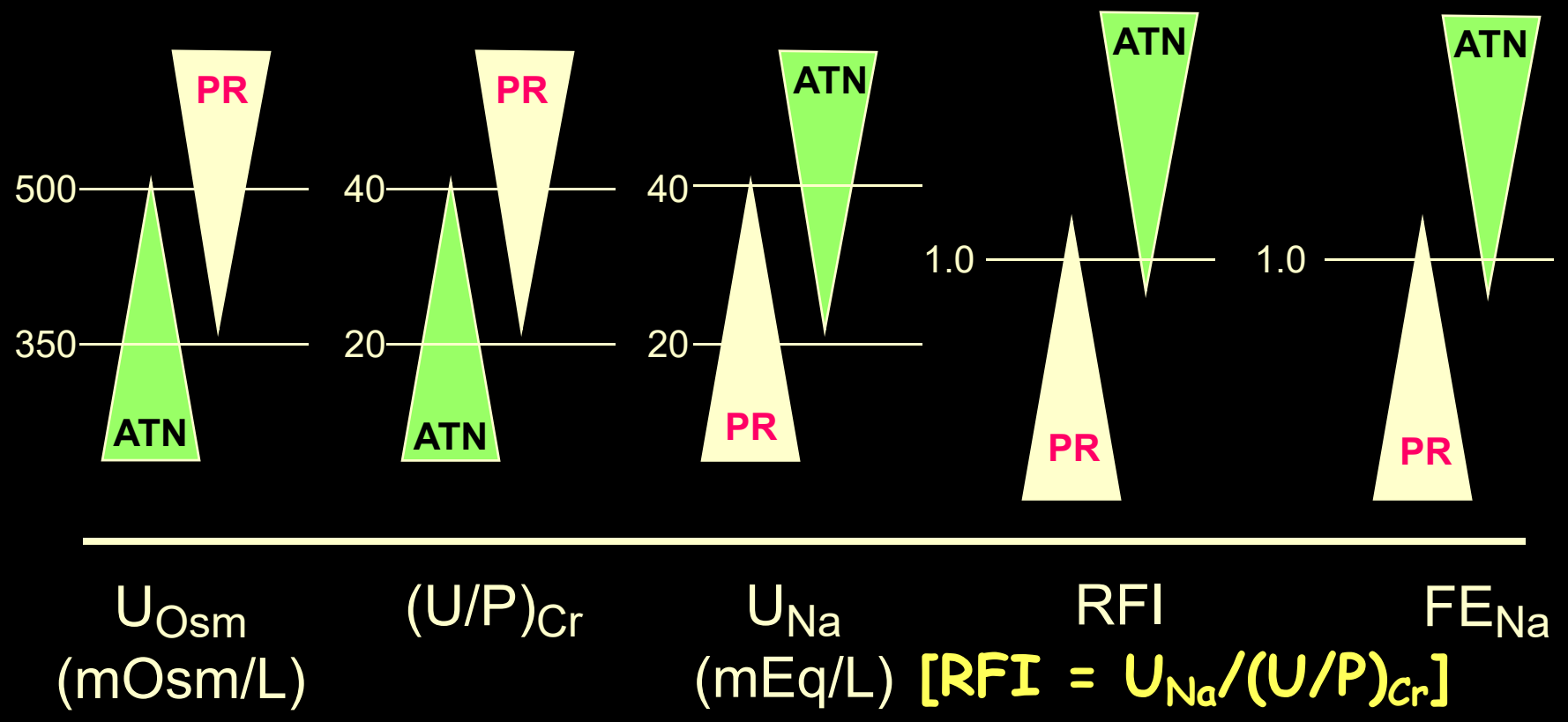
Leveling



Pre-renal	Renal	Post-renal
50-70%	20-30%	1-10%

Leveling

Acute Renal Failure
Urinary Indices



$[RFI = U_{Na}/(U/P)_{Cr}]$

$[FE_{Na} = 100(U_{Na} \times P_{Cr}) / (P_{Na} \times U_{Cr})]$

Leveling

Comparison of lab. Finding in AKI

Test	Prerenal AKI	Intrinsic AKI
Urine specific gravity	>1.020	≤1.010
Urine sodium, mEq/L	<20	>40
Fractional excretion of sodium	<1% (neonates <2%)	>2% (neonates >2.5%)
Fractional excretion of urea	<35%	>50%
Urine osmolality, mOsm/kg	>500	<350
Urea nitrogen-creatinine ratio	>20	10-15

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When to suspect

In the1990s,

Cause

Pediatric ARF Epidemiology at a Tertiary Care Center From 1999 to 2001

Shirley Hui-Stickle, MD, Eileen D. Brewer, MD, and Stuart L. Goldstein, MD

Table 1. Clinical Variables for Pediatric Patients With ARF Stratified by Age

Age (no. of patients)	GFR	Survival	ICU Stay/LOS	RRT*	Most Common ARF Cause
0-30 d (62)	11.5 ± 9.8	34 (56)	59 (97), 46	34 (58)	Ischemic 16 (26)
1-12 mo (37)	18.4 ± 14.3	22 (59)	32 (86), 26	10 (32)	Ischemic 13 (35)
1-5 y (43)	32.9 ± 20.1	36 (84)	30 (70), 21	8 (27)	Ischemic 10 (23)
6-15 y (83)	29.3 ± 20.4	61 (73)	49 (59), 18	28 (57)	Nephrotoxins 22 (26)
16-21 y (29)	35.5 ± 17	23 (79)	15 (52), 23	8 (53)	Nephrotoxins 6 (21)
Total (254)	35.2 ± 39.2	176 (70)	185 (73), 26	80 (43)	Ischemic 45 (22)

Most Common ARF Causes

- ATN-Dehydration (21%)
- Nephrotoxic drugs (16%)
- Sepsis (11%)
- Unknown (14%)

Am J Kidney disease

In the early 2000,

Cause


Kidney Failure in Infants and Children

Objectives

The most prevalent causes cited were:

- HUS
- Primary renal diseases

Causes	Developing Country/ Referral Center n (%)	Industrialized Country/ Tertiary Center n (%)
Hemolytic-uremic syndrome	25 (31)	5 (3)
Glomerulonephritis	18 (23)	–
Intrinsic renal disease	–	64 (44)
Urinary obstruction	7 (9)	–
Postoperative sepsis	14 (18)	49 (34)
Ischemic and prerenal	14 (18)	–
Organ and bone marrow transplant	–	19 (13)
Miscellaneous	2 (3)	9 (6)
Total	80	146

From Flynn JT. Causes, management approaches, and outcome of acute renal failure in children. *Curr Opin Pediatr*. 1998;10:184–189.

After adoption of pRIFLE 2007,

Cause

Modified RIFLE criteria in critically ill children with acute kidney injury

A Akcan-Arikan[1], M Zappitelli[1], L L Loftis[2], K K Washburn[1], L S Jefferson[2] and S L Goldstein[1]

Kidney International (2007) **71,** 1028–1035. doi:10.1038/sj.ki.5002231; published online 28 March 2007

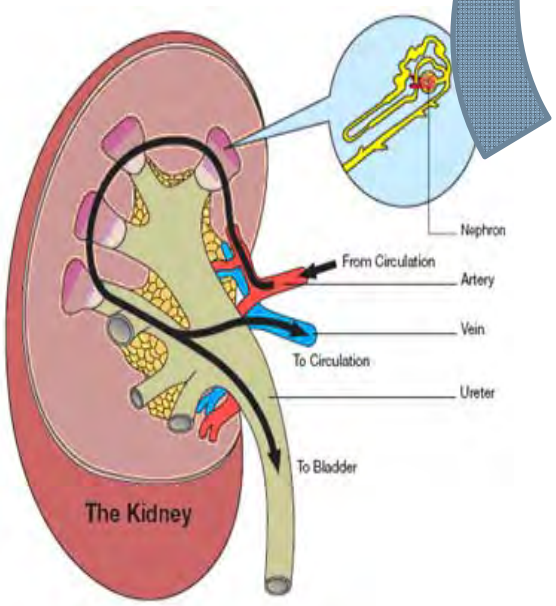
Most Common ARF Causes

- Pneumonia: 33%
- SIRS/Sepsis: 27%
- Cardiogenic: 10%

The etiology of AKI has changed over the last 10–20 years

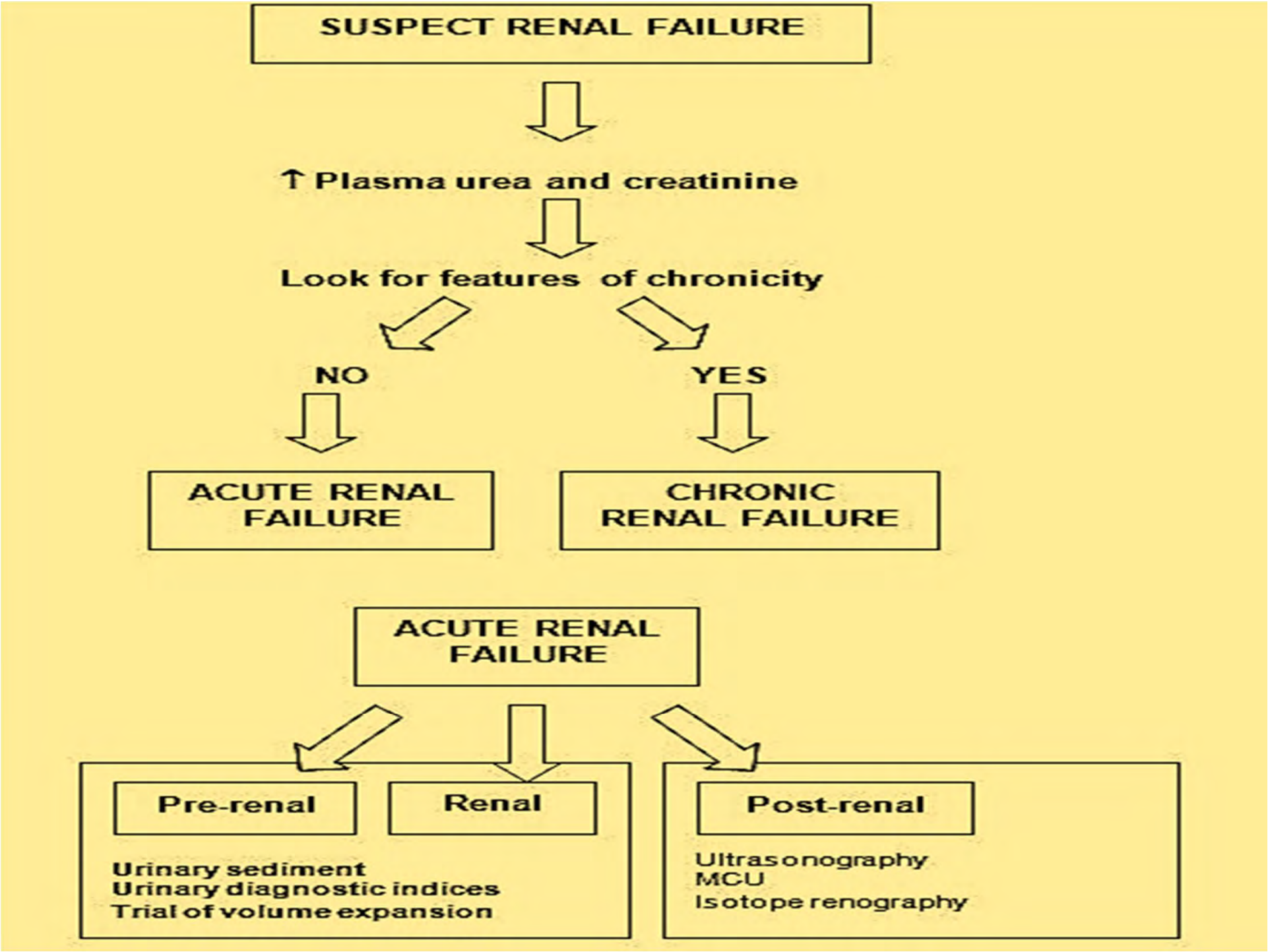
Cause

Renal complications of systemic illness



Primary renal disease **HUS**


Don't
Forget!!


SUSPECT RENAL FAILURE
↑ Plasma urea and creatinine
Look for features of chronicity
NO
YES
ACUTE RENAL FAILURE
CHRONIC RENAL FAILURE
ACUTE RENAL FAILURE
Pre-renal
Renal
Urinary sediment
Urinary diagnostic indices
Trial of volume expansion
Post-renal
Ultrasonography
MCU
Isotope renography

Thank You

A 3-year-old child is brought to the ED with 2-day history of diarrhea and vomiting. The patient looks moderately dehydrated. Investigations reveal: Na+ 146 mEq/l, K 4.8 mEq/l, BUN 42mg/dl, Creatinine 2.2 mg/dl WBC 15000/mm3, normal platelet count; urine specific gravity 1.007, no blood, protein 1+, Nitrite and leucocyte estrase negative. No hydronephrosis is seen by an ultrasound examination of the kidneys.

Of the flowing, which one is the most likely diagnosis?

A. **Pre-renal failure**

B. **Intrinsic renal failure**

C. **Post-renal failure**

D. **Disseminated intravascular coagulation (DIC)**

A 4-year-old female with recently diagnosed partial uretero-pelvic junction (UPJ) obstruction in the single right kidney is seen in the Emergency Department (ED) with one day history of abdominal pain. Laboratory investigations reveal: Na+ 136 mEq/l, K 5.3 mEq/l, BUN 38mg/dl, Creatinine 1.8 mg/dl a normal CBC; urine dipstick is nitrite and leucocyte esterase positive, protein 1+ and moderate blood.

Of the following investigations, which one is likely to be the most useful in determining the cause of the patient's acute renal failure?

A. **Fractional excretion of sodium**

B. **Urine culture**

C. **Renal ultrasound examination**

D. **IVP**

An 8-year-old patient was started on cefuroxime for chest infection. Three days later he developed oliguria and puffiness of the eyes. The blood pressure was 116/78 mm Hg and investigations revealed: serum creatinine 3.2 mg/dl, BUN 48mg/dl, Na+ 133 mEq/l, K 4.5 mEq/l, CO2 18 mEq/l, Ca++ 9.2 mg/dl, PO4 5.2 mg/dl, WBC 12,800/mm3, and platelets 180,000/mm3. Urinalysis revealed a specific gravity of 1.006, protein 1+, 15-20 RBC/HPF, no casts, and 30-40 WBC/HPF.

Which one of the following is the most likely cause for acute renal failure?

A. **Good Pasture syndrome**

B. **Tubulo-interstitial nephritis (TIN)**

C. **Acute glomerulonephritis**

D. **Dehydration with pre-renal failure**