# Acute Renal Failure

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**Motol**

# Overview

- Definitions
- Classification and causes
- Presentation
- Treatment

# Definition Acute Renal failure (ARF)

- Inability of kidney to maintain homeostasis leading to a buildup of nitrogenous wastes
- Different to renal insufficiency where kidney function is deranged but can still support life
- Exact biochemical/clinical definition not clear – 26 studies – no 2 used the same definition

# ARF

- Occurs over hours/days

- Lab definition
  - Increase in baseline creatinine of more than 50%
  - Decrease in creatinine clearance of more than 50%
  - Deterioration in renal function requiring dialysis

# ARF definitions

- Anuria – no urine output or less than 100mls/24 hours
- Oliguria - <500mls urine output/24 hours or <20mls/hour
- Polyuria - >2.5L/24 hours

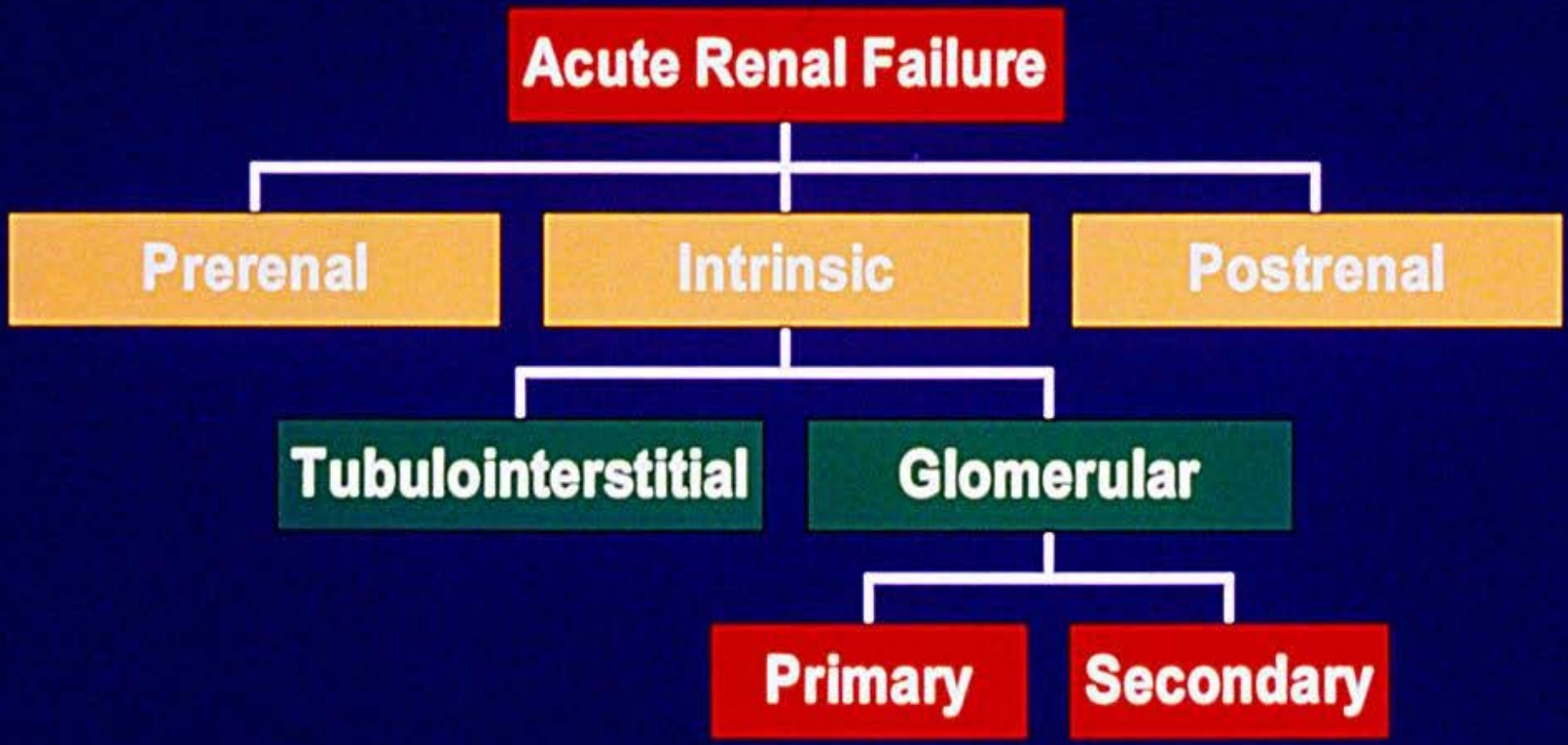
# KDIGO definition and classification of AKI

| | | |
|---|---|---|
| *Diagnostic criteria for AKI:* | | |
| AKI is defined as any of the following: | | |
| • Increase in serum creatinine by ≥0.3 mg/dl (≥26.5 µmol/l) within 48 h; or<br>• Increase in serum creatinine to ≥1.5 times baseline, which is known or presumed to have occurred within the prior 7 days; or<br>• Urine volume <0.5 ml/kg/h for 6 h. | | |
| *AKI staging system:* | | |
| AKI stage | Serum creatinine criteria | Urine output criteria |
| AKI stage I | Increase of serum creatinine by ≥0.3 mg/dl (≥26.4 µmol/L) | Urine output <0.5 ml/kg/h for 6–12 h |
| | or | |
| | increase to 1.5–1.9 times from baseline | |
| AKI stage II | Increase of serum creatinine to 2.0–2.9 times from baseline | Urine output <0.5 ml/kg/h for ≥12 h |
| AKI stage III | Increase of serum creatinine ≥3.0 times from baseline | Urine output <0.3 ml/kg/h for ≥24 h |
| | or | or |
| | serum creatinine ≥4.0 mg/dl (≥354 µmol/L) | anuria for ≥12 h |
| | or | |
| | treatment with RRT | |
| | or | |
| | in patients <18 years, decrease in estimated GFR to <35 ml/min per 1.73 $m^2$ | |

# ARF

- Pre renal (functional)
- Renal-intrinsic (structural)
- Post renal (obstruction)

# Work-up of Acute Renal Failure



# Causes of ARF

- **Pre-renal:**

  Inadequate perfusion
  - *check volume status*

- **Renal:**

  ARF despite perfusion & excretion
  - *check urinalysis, FBC & autoimmune screen*

- **Post-renal:**

  Blocked outflow
  - *check bladder, catheter & ultrasound*

# Causes of ARF

| **Pre-renal** | **Renal** | **Post-renal** |
|---|---|---|
| Absolute hypovolaemia | Glomerular (RPGN) | Pelvi-calyceal |
| Relative hypovolaemia | Tubular (ATN) | Ureteric |
| Reduced cardiac output | Interstitial (AIN) | VUJ-bladder |
| Reno-vascular occlusion | Vascular (atheroemboli) | Bladder neck-urethra |

# ARF Pre renal

- Decreased renal perfusion without cellular injury
  - 70% of community acquired cases
  - 40% hospital acquired cases

# ARF Intrinsic

- Acute tubular necrosis (ATN)
  - Ischaemia
  - Toxin
  - Tubular factors
- Acute interstitial Necrosis (AIN)
  - Inflammation
  - oedema
- Glomerulonephritis (GN)
  - Damage to filtering mechanisms
  - Multiple causes as per previous presentation

# ARF Post renal

- Post renal obstruction
- Obstruction to the urinary outflow tract
  - Prostatic hypertrophy
  - Blocked catheter
  - Malignancy

# Prerenal Failure 1

- Often rapidly reversible if we can identify this early.
- The elderly at high risk because of their predisposition to hypovolemia and renal atherosclerotic disease.
- This is by definition rapidly reversible upon the restoration of renal blood flow and glomerular perfusion pressure.
- THE KIDNEYS ARE NORMAL.
- This will accompany any disease that involves hypovolemia, low cardiac output, systemic dilation, or selective intrarenal vasoconstriction.

# Differential Diagnosis 2

- Hypovolemia
  - GI loss: Nausea, vomiting, diarrhea (hyponatraemia)
  - Renal loss: diuresis, hypo adrenalism, osmotic diuresis (DM)
  - Sequestration: pancreatitis, peritonitis,trauma, low albumin (third spacing).
  - Hemorrhage, burns, dehydration (intravascular loss).

  - combination of **hypovolemia, hypotension and diminished renal perfusion** is the **most common cause of ARF**

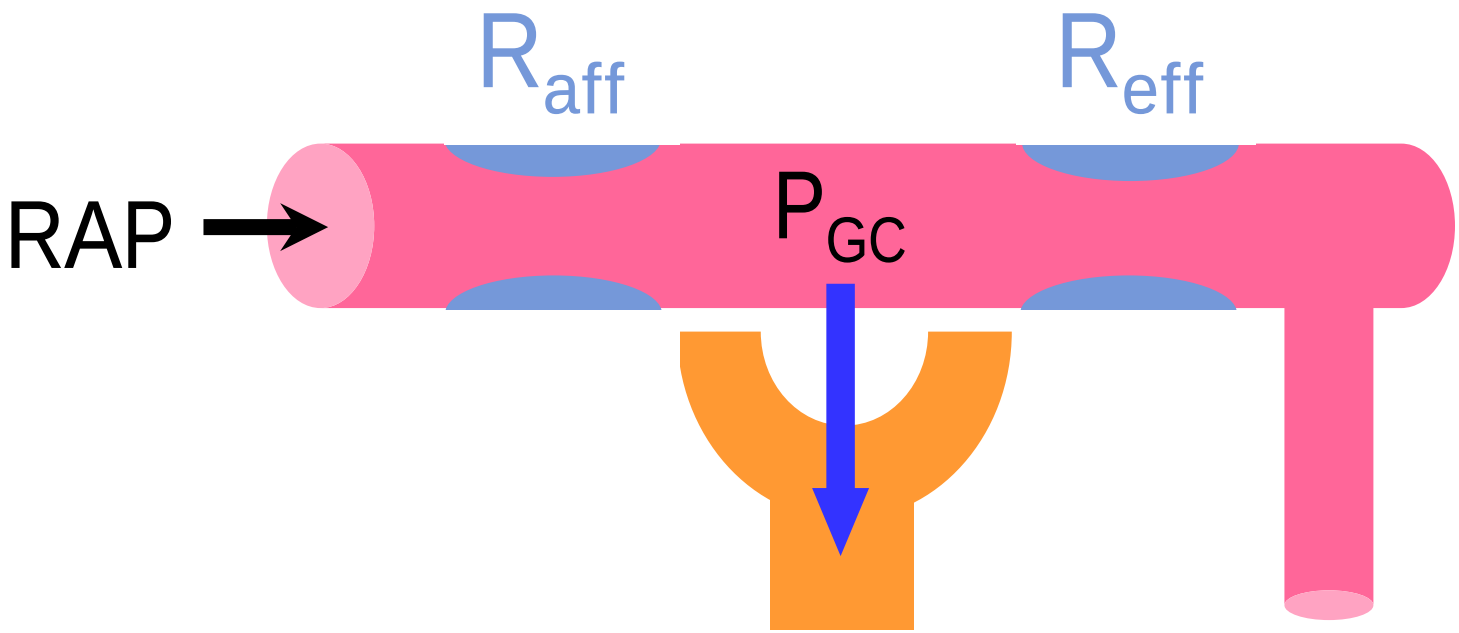
# Differential Diagnosis 3

- Renal vasoconstriction: hypercalcaemia, adrenaline/noradrenaline, cyclosporin, tacrolimus, amphotericin B.
- Systemic vasodilation: sepsis, medications, anesthesia, anaphylaxis.
- Cirrhosis with ascites
- Hepato-renal syndrome
- Impairment of autoregulation: NSAIDs, ACE, ARBs.
- Hyperviscosity syndromes: Multiple Myeloma, Polycyaemia rubra vera

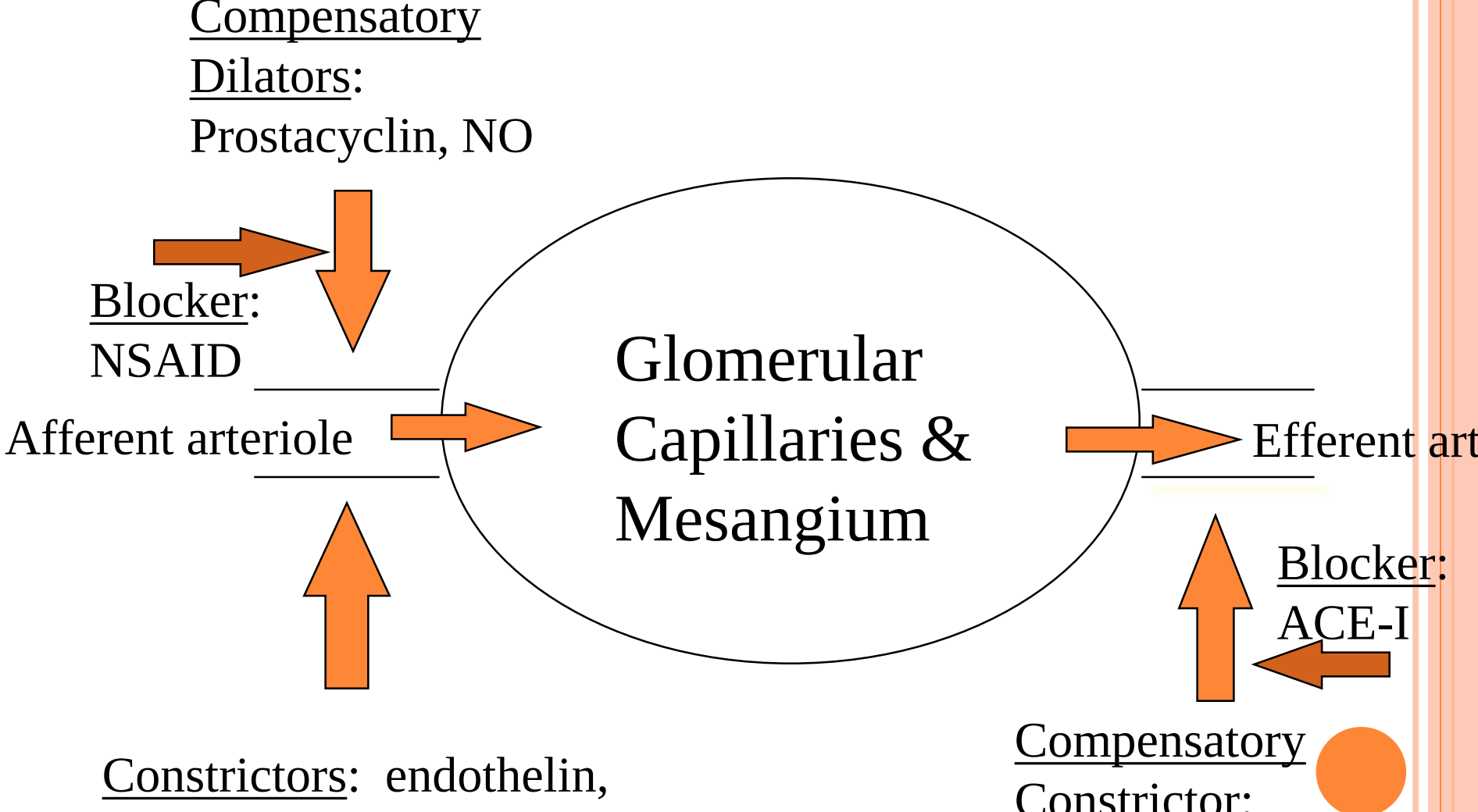
# Differential Diagnosis 4

- Low CO
  - Myocardial diseases
  - Valvular heart disease
  - Pericardial disease
  - Tamponade
  - Pulmonary artery hypertension
  - Pulmonary Embolus
  - Positive pressure mechanical ventilation

# The only organ with entry and exit arteries


$R_{aff}$
$R_{eff}$
RAP
$P_{GC}$

# Glomerular blood flow



# Pre-Renal Azotemia Pathophysiology 7

- Renal hypoperfusion
  - Decreased renal blood flow and GFR
  - Increased filtration fraction (GFR/RBF)

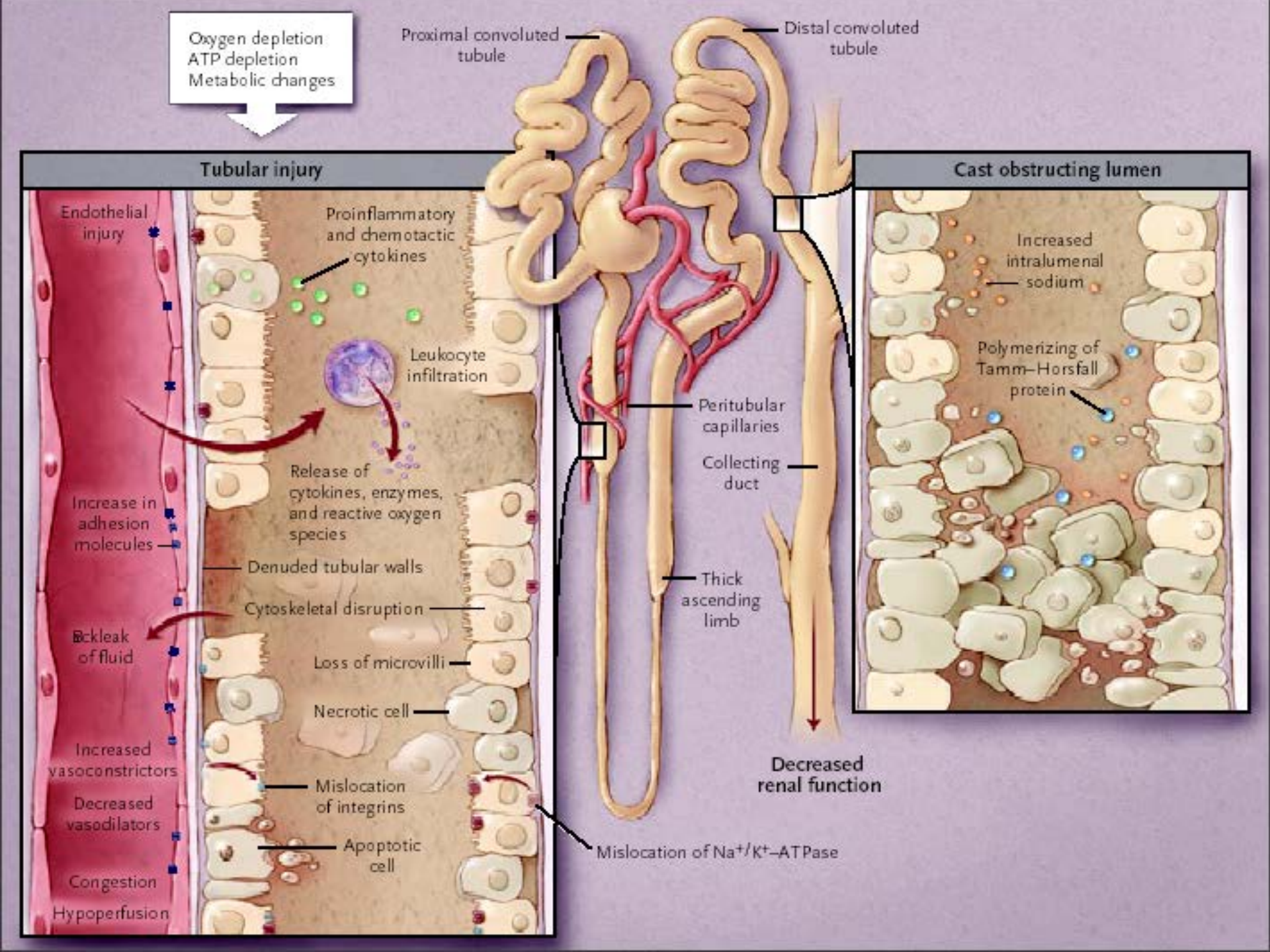
- Increased Na and $H_2O$ reabsorption
  - Oliguria, high $U_{osm}$, low $U_{Na}$
  - Elevated BUN/Cr ratio

# ARF Intrinsic Causes 1

- ATN
- AIN
- GN

# Acute Tubular Necrosis (ATN) Classification

- Ischemic
- Nephrotoxic


Oxygen depletion
ATP depletion
Metabolic changes
Proximal convoluted tubule
Distal convoluted tubule
Tubular injury
Endothelial injury
Proinflammatory and chemotactic cytokines
Leukocyte infiltration
Release of cytokines, enzymes, and reactive oxygen species
Increase in adhesion molecules
Denuded tubular walls
Cytoskeletal disruption
Backleak of fluid
Loss of microvilli
Necrotic cell
Increased vasoconstrictors
Decreased vasodilators
Mislocation of integrins
Apoptotic cell
Congestion
Hypoperfusion
Peritubular capillaries
Collecting duct
Thick ascending limb
Mislocation of Na+/K+–ATPase
Decreased renal function
Cast obstructing lumen
Increased intralumenal sodium
Polymerizing of Tamm–Horsfall protein

# Acute Renal Failure
# Nephrotoxic ATN

- Endogenous Toxins
  - Heme pigments (myoglobin, hemoglobin)
  - Myeloma light chains
- Exogenous Toxins
  - Antibiotics (e.g., aminoglycosides, amphotericin B)
  - Radiocontrast agents
  - Heavy metals (e.g., cis-platinum, mercury)
  - Poisons (e.g., ethylene glycol)

# Acute Interstitial Nephritis Causes

- Allergic interstitial nephritis
  - Drugs
- Infections
  - Bacterial
  - Viral
- Sarcoidosis

# Allergic Interstitial Nephritis(AIN)

## Clinical Characteristics

- Fever
- Rash
- Arthralgias
- Eosinophilia
- Urinalysis
  - Microscopic hematuria
  - Sterile pyuria
  - Eosinophiluria

# Contrast-Induced ARF Prevalence

- Less than 1%  in patients with normal renal function
- Increases significantly with renal insufficiency

# Contrast-Induced ARF Risk Factors

- Renal insufficiency
- Diabetes mellitus
- Multiple myeloma
- High osmolar (ionic) contrast media
- Contrast medium volume

# Contrast-induced ARF Clinical Characteristics

- Onset - 24 to 48 hrs after exposure
- Duration - 5 to 7 days
- Non-oliguric (majority)
- Dialysis - rarely needed
- Urinary sediment - variable
- Low fractional excretion of Na

# Pre-Procedure Prophylaxis

1. IV Fluid

**1-1.5 ml/kg/hour x12 hours prior to procedure and 6-12 hours after**

2. N-acetylcysteine

**Free radical scavenger; prevents oxidative tissue damage 600-1200mg x 4 doses (2 before procedure, 2 after)**

3. Bicarbonate (JAMA 2004)

Alkalinizing urine should reduce renal medullary damage

**5% dextrose with 3 amps HCO3; bolus 3.5 mL/kg 1 hour preprocedure, then 1mL/kg/hour for 6 hours postprocedure**

4. Not helpful! Diuretics, Mannitol

# Contrast-induced ARF Prophylactic Strategies

- Use I.V. contrast only when necessary
- Hydration
- Minimize contrast volume
- Low-osmolar (nonionic) contrast media
- N-acetylcysteine,

# ARF Post-renal Causes 1

- Intra-renal Obstruction
  - Acute uric acid nephropathy
  - Drugs (e.g., acyclovir)
- Extra-renal Obstruction
  - Renal pelvis or ureter (e.g., stones, clots, tumors, papillary necrosis, retroperitoneal fibrosis)
  - Bladder (e.g., BPH, neuropathic bladder)
  - Urethra (e.g., stricture)

# Acute Renal Failure Diagnostic Tools

- Urinary sediment
- Urinary indices
  - Urine volume
  - Urine electrolytes
- Radiologic studies

# Urinary Sediment

- RBC casts or dysmorphic RBCs
  - Acute glomerulonephritis
  - Small vessel vasculitis
- WBC Cells and WBC Casts
  - Acute interstitial nephritis
  - Acute pyelonephritis
- Renal Tubular Epithelial (RTE) cells, RTE cell casts, pigmented granular ("muddy brown") casts
  - Acute tubular necrosis

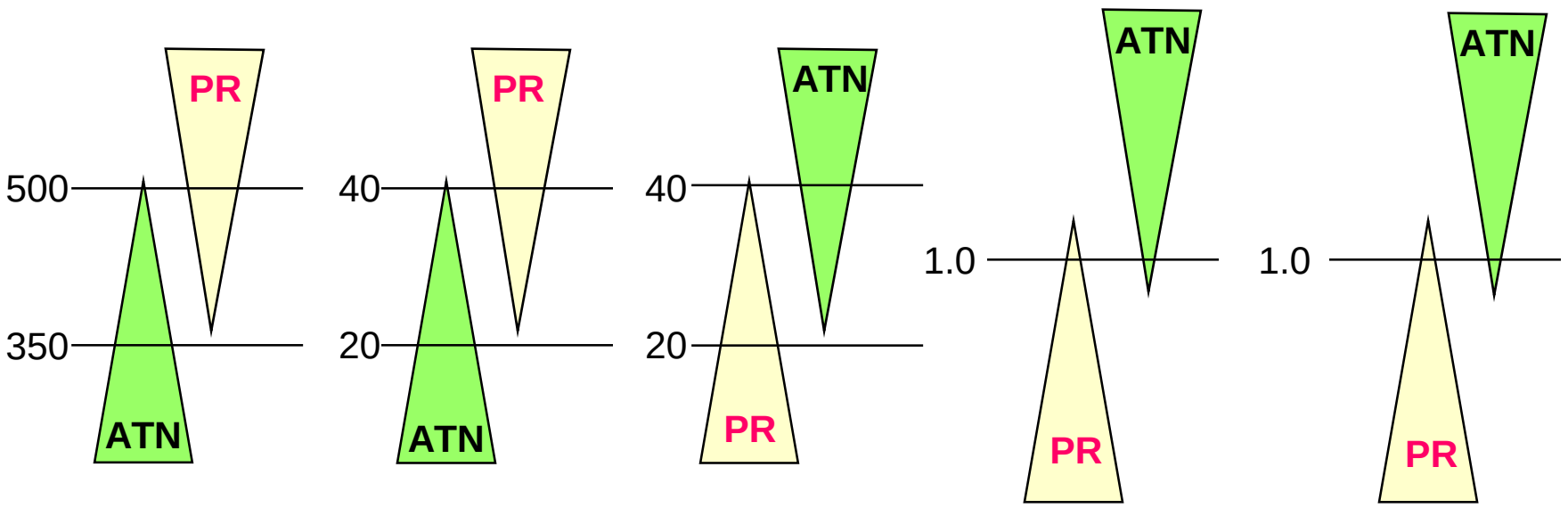
# Acute Renal Failure
# Urine Volume (1)

- Anuria (< 100 ml/24h)
  - Acute bilateral arterial or venous occlusion
  - Bilateral cortical necrosis
  - Acute necrotizing glomerulonephritis
  - Obstruction (complete)
  - ATN (very rare)

# Acute Renal Failure
# Urine Volume (2)

- Oliguria (<100 ml/24h)
  - Pre-renal azotemia
  - ATN
- Non-Oliguria (> 500 ml/24h)
  - ATN
  - Obstruction (partial)

# Acute Renal Failure
# Urinary Indices




$U_{Osm}$ (mOsm/L)

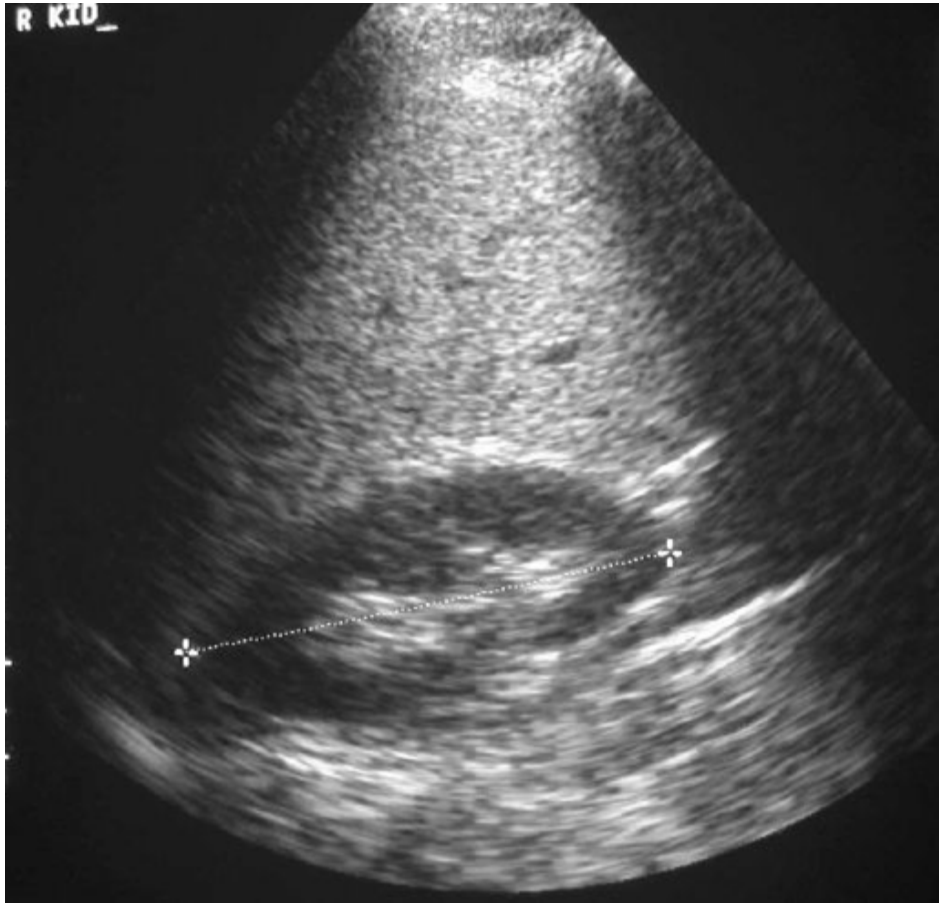
$(U/P)_{Cr}$

$U_{Na}$ (mEq/L)

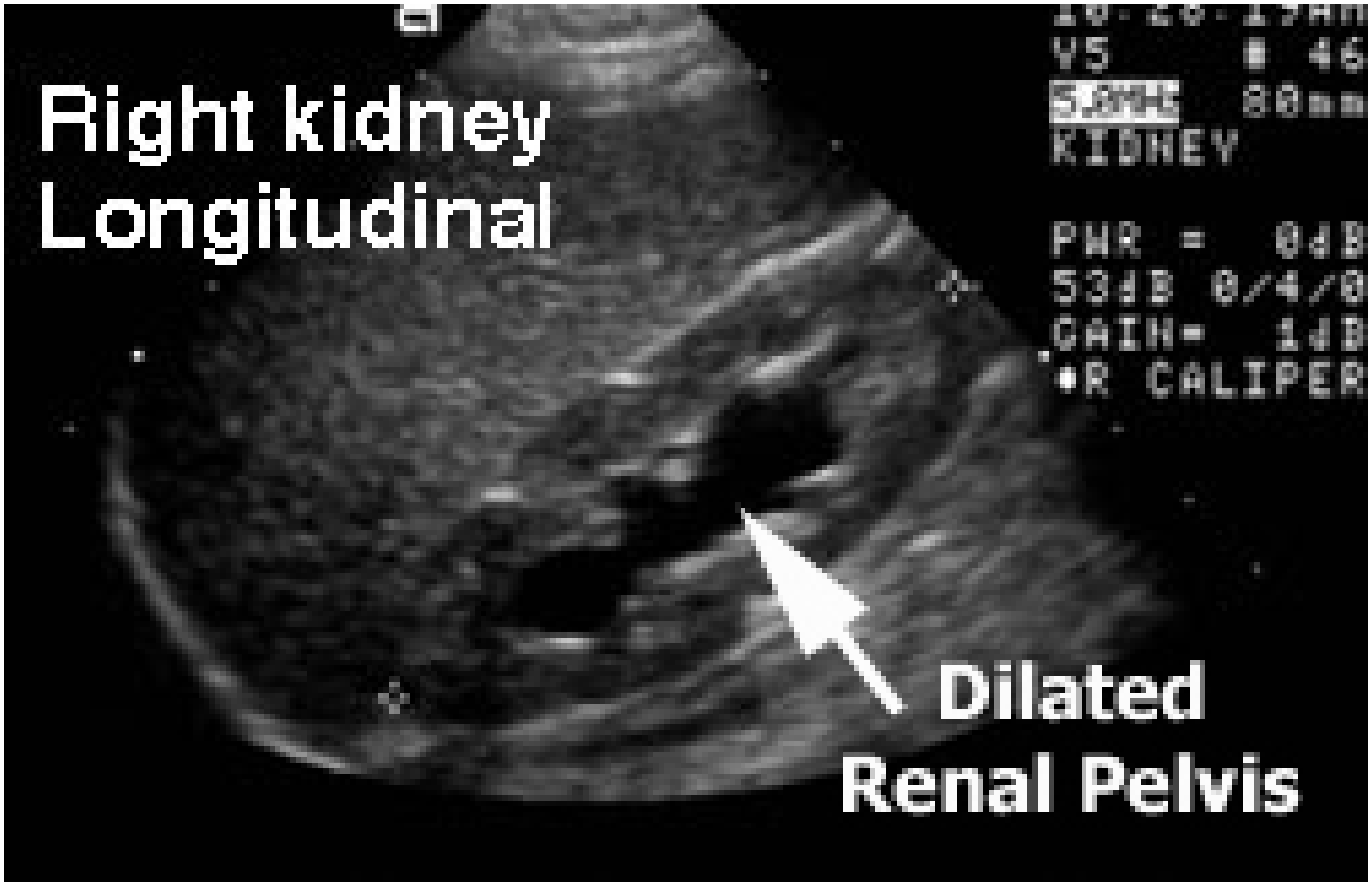
RFI

$FE_{Na}$

# Normal Renal Ultrasound



# Hydronephrosis



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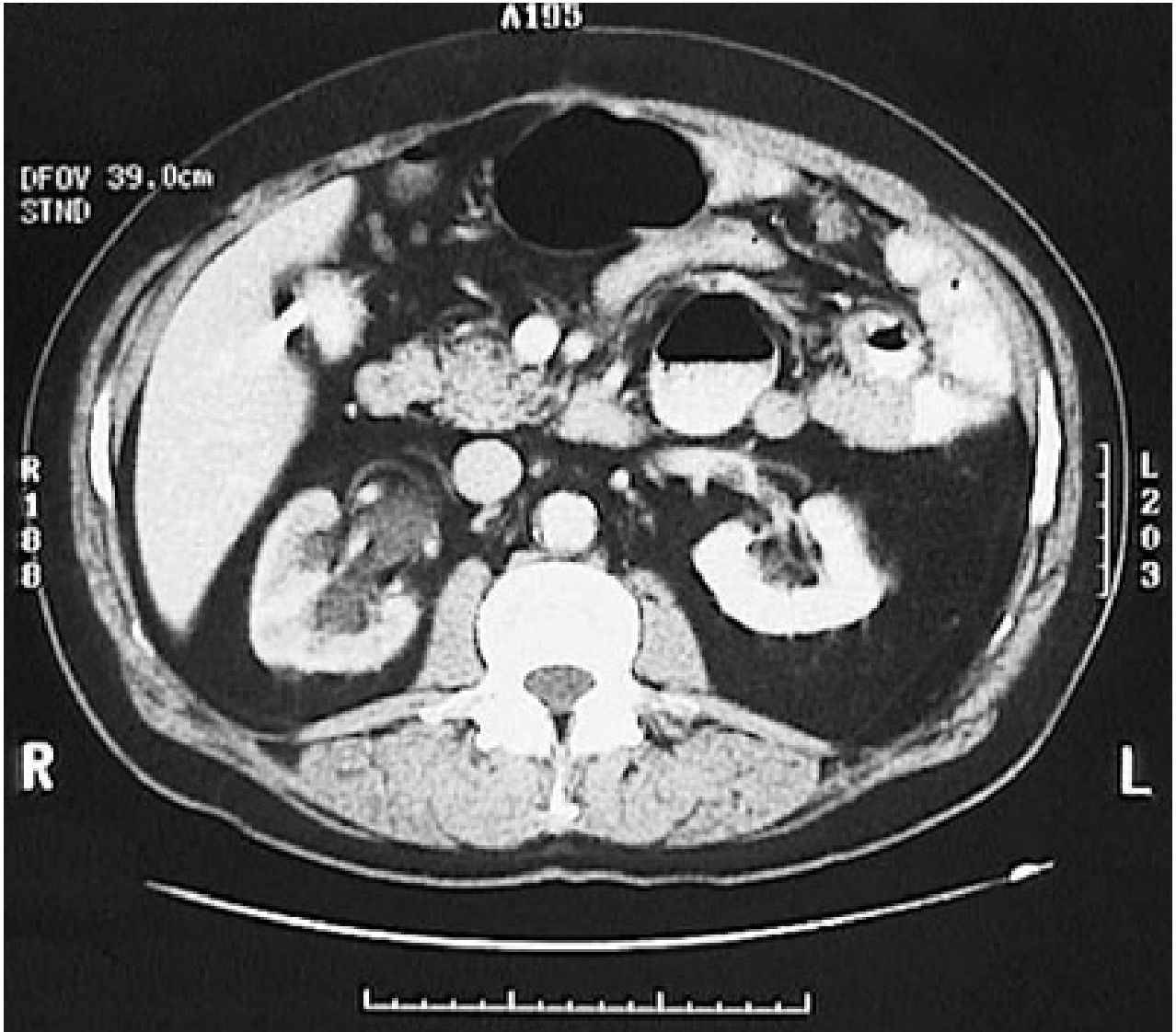
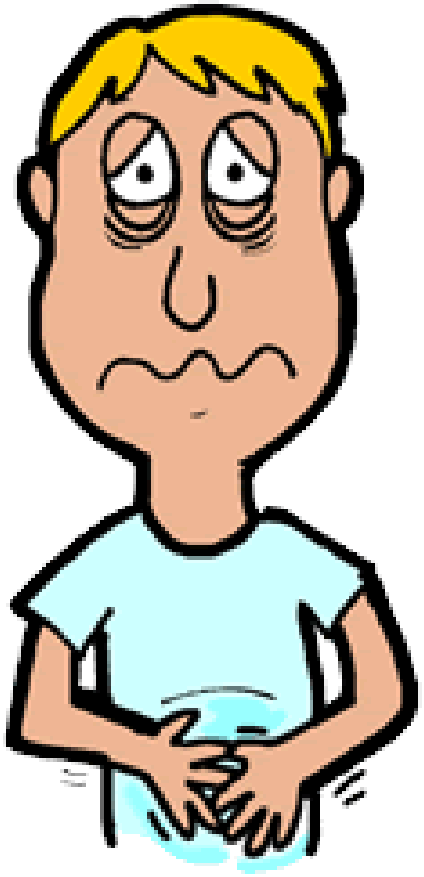


# ARF-Signs and Symptoms

- Weight gain
- Peripheral oedema
- Hypertension

# ARF Signs and Symptoms

- Hyperkalemia
- Nausea/Vomiting
- Pulmonary edema
- Ascites
- Encephalopathy



# Lab findings

- Rising creatinine and urea
- Rising potassium
- Decreasing Hb
- Acidosis
- Hyponatraemia
- Hypocalcaemia

# ARF

- Immediate treatment of pulmonary edema and hyperkalaemia
- Remove offending cause or treat offending cause
- Dialysis as needed to control hyperkalaemia, pulmonary edema, metabolic acidosis, and uremic symptoms
- Adjustment of drug regimen
- Usually restriction of water, Na, and K intake, but provision of adequate protein
- Possibly phosphate binders and Na polystyrene sulfonate

# Recognise the at-risk patient

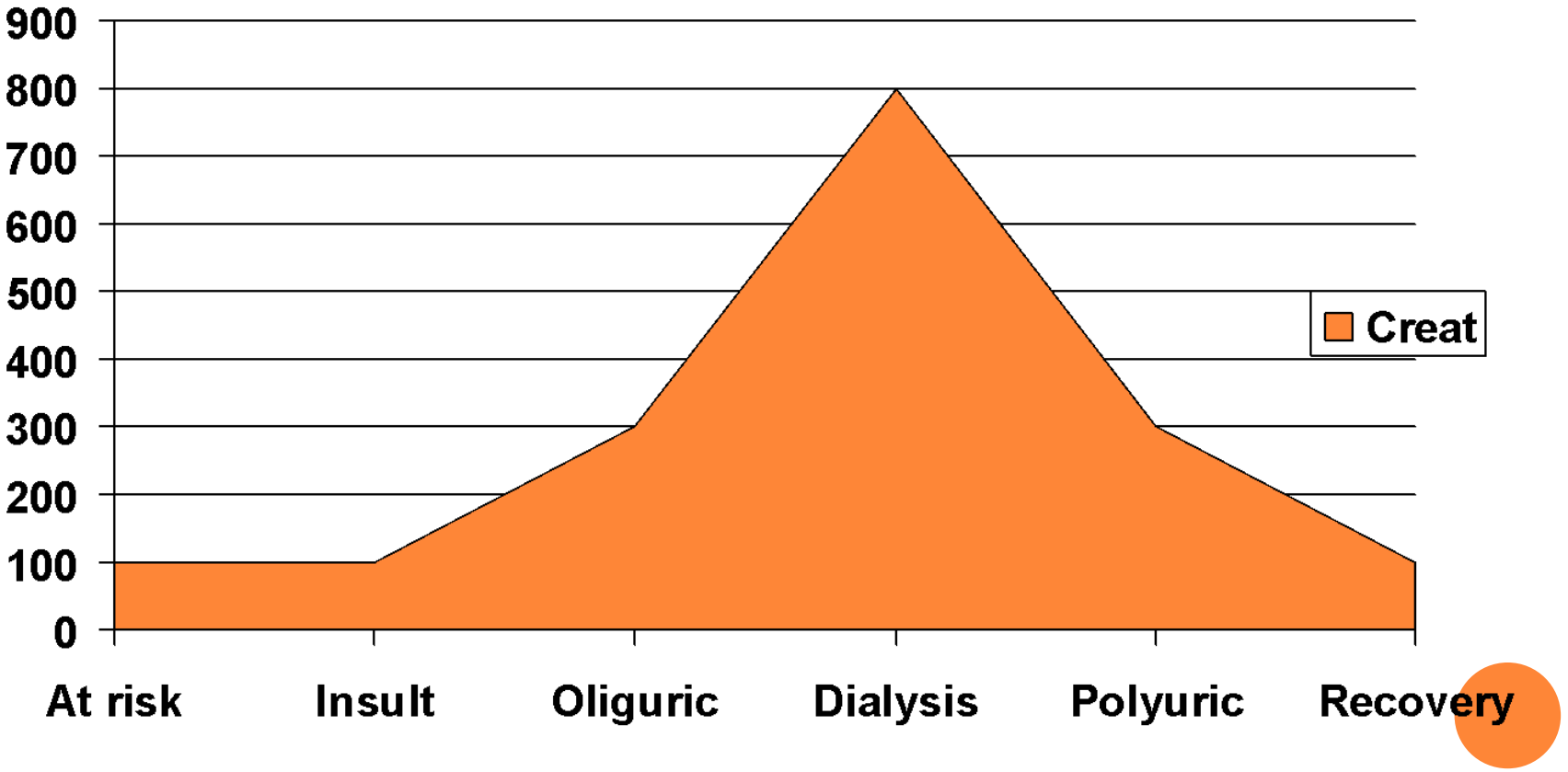
- **Reduced renal reserve:**

  Pre-existing CRF, age > 60, hypertension, diabetes
- **Reduced intra-vascular volume:**

  Diuretics, sepsis, cirrhosis, nephrosis
- **Reduced renal compensation:**

  ACE-I's (ATII), NSAID's (PG's), CyA

# Phases of ATN



# Indications for acute dialysis

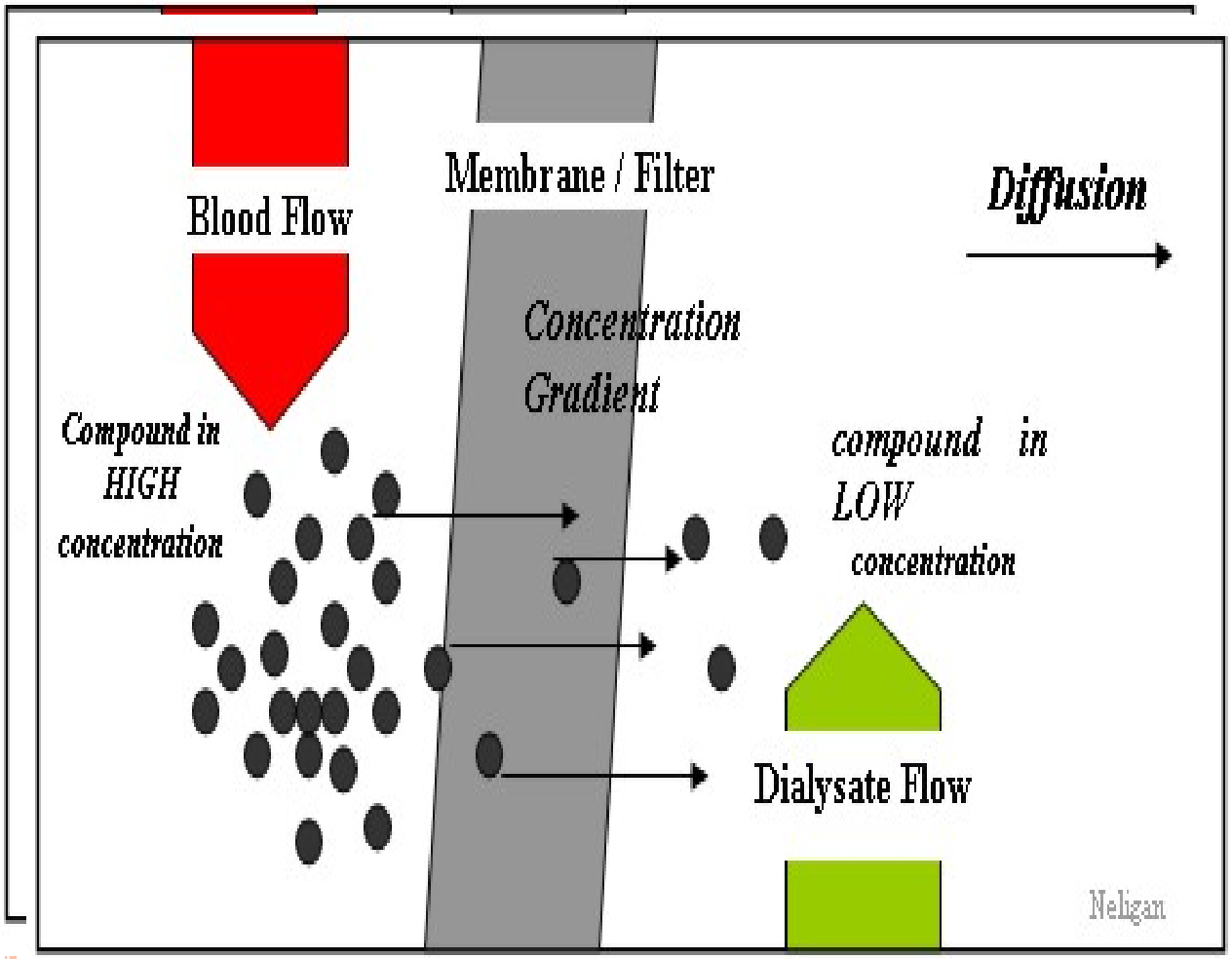
## AEIOU

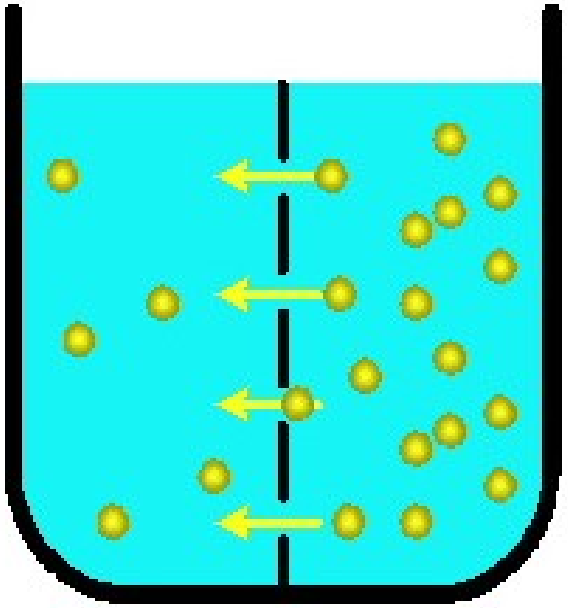
- Acidosis (metabolic)
- Electrolytes (hyperkalemia)
- Ingestion of drugs/Ischemia
- Overload (fluid)
- Uremia

# Dialysis

- Principles
- Ultrafiltration
- diffusion

# DIFFUSION

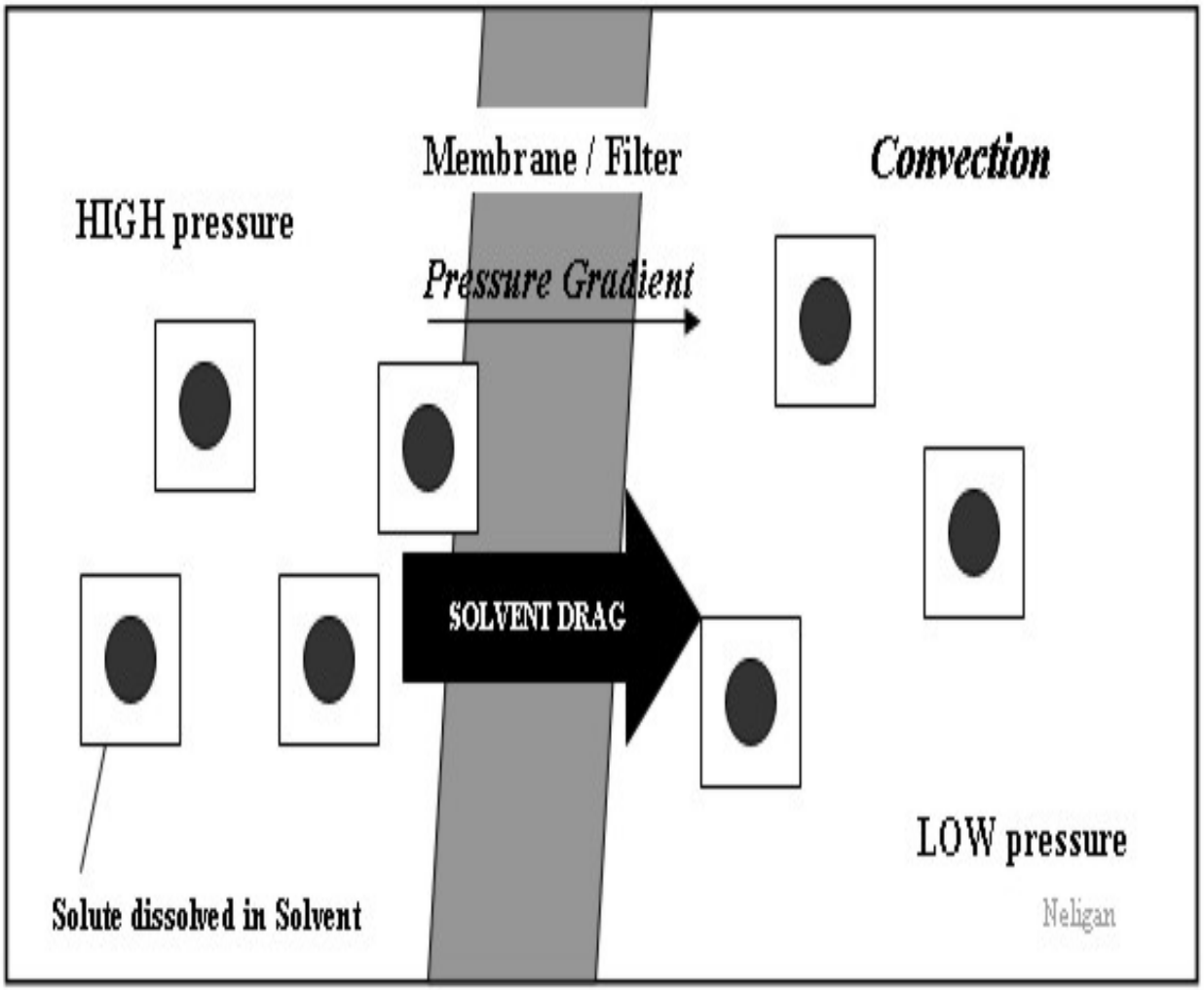


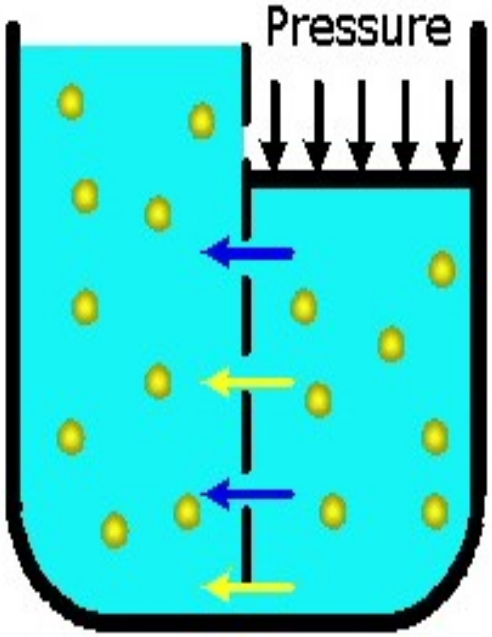



Diffusion

(Solvent moves by concentration gradient)

# FILTRATION



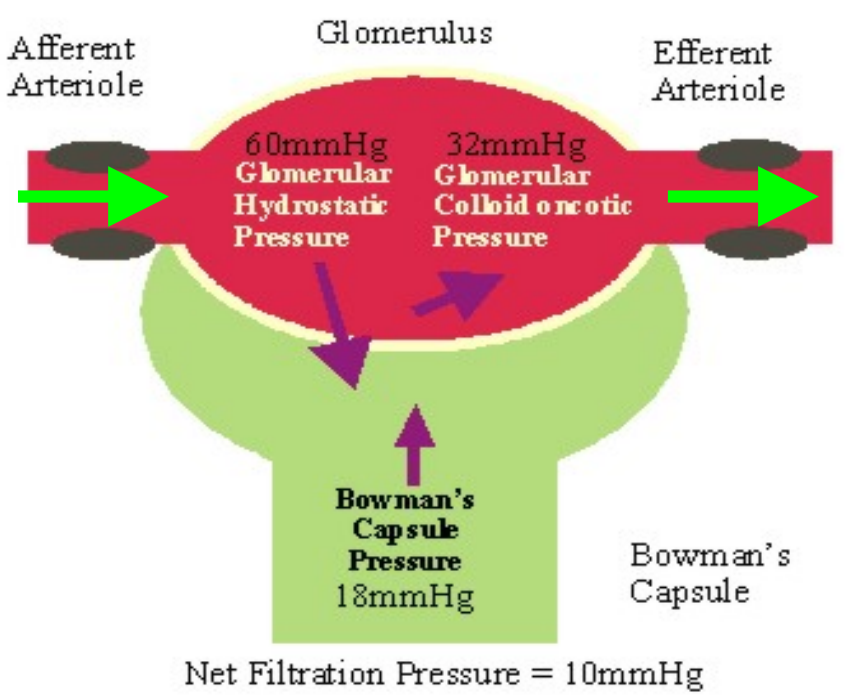

Ultrafiltration

(Solution moves by pressure gradient)

# HEMOFILTRATION

- Only filtration – more physiological

- Similar to primary urine formation in Bowman‘s capsule i.e. glomerular filtration

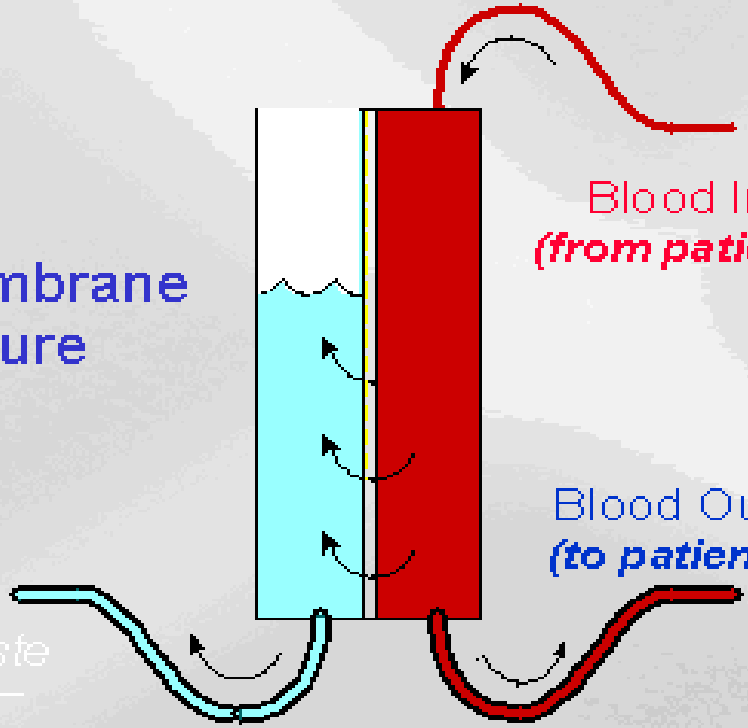


# Hemofiltration

- The resulting fluid are not able to concentrate like the kidneys
- The UF is repaced by substitution fluid – similar content of ions as serum

prismaflex

# Ultrafiltration

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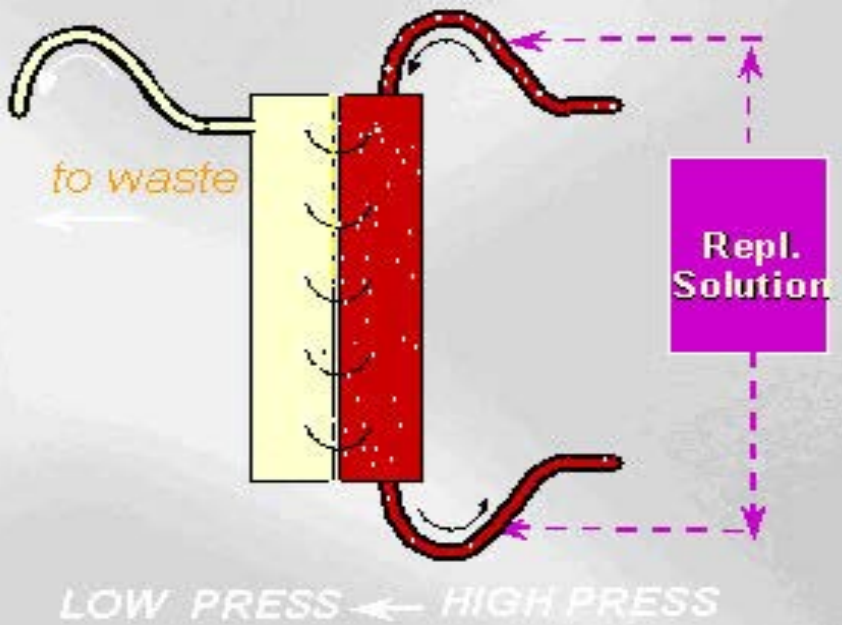
# HEMOFILTRACE

prismaflex

## Hemofiltration

Removal of relatively large volumes of fluid by ultrafiltration, resulting in removal of solutes through convection.

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# Hemofiltrace

## Substitution fluid

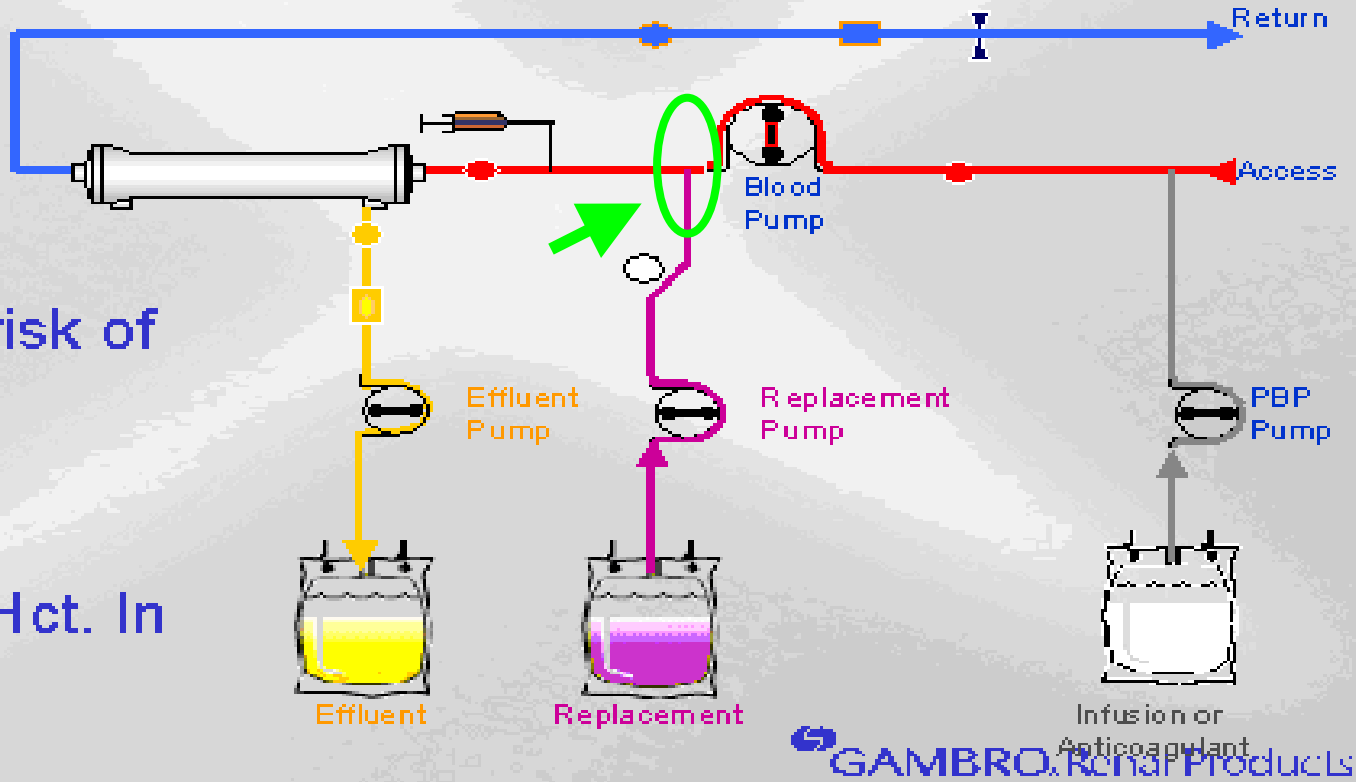
Predilution

postdilution

# PREDILUTION TYPE

prismaflex

## Replacement Solution




### Pre-Dilution

- Decreases risk of clotting
- Higher UF capabilities
- Decreases Hct. In filter

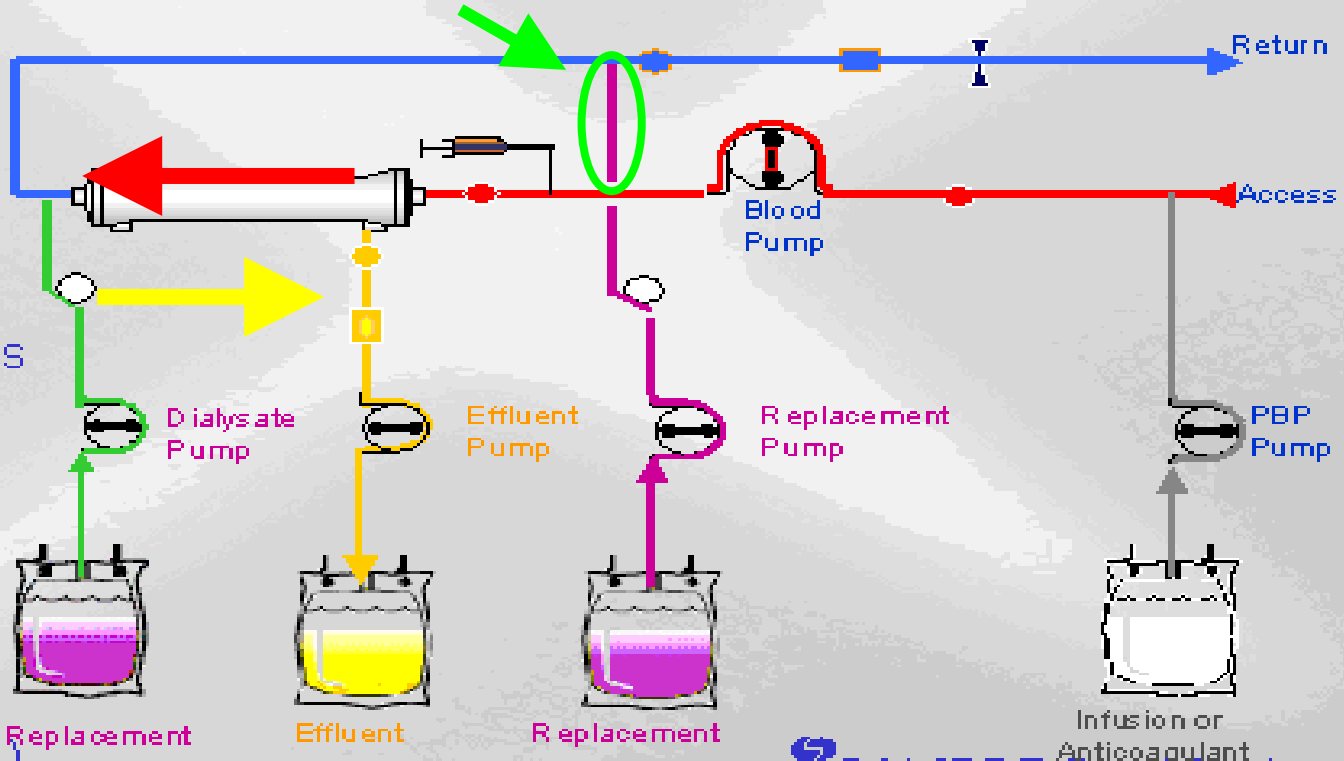
# POSTDILUTION TYPE

prismaflex

## Replacement Solution

### Post-Dilution

- Lower replacement rates (filtration %)
- Higher BFR (filtration %)
- Higher anticoagulation
- More efficient clearance (>15%)

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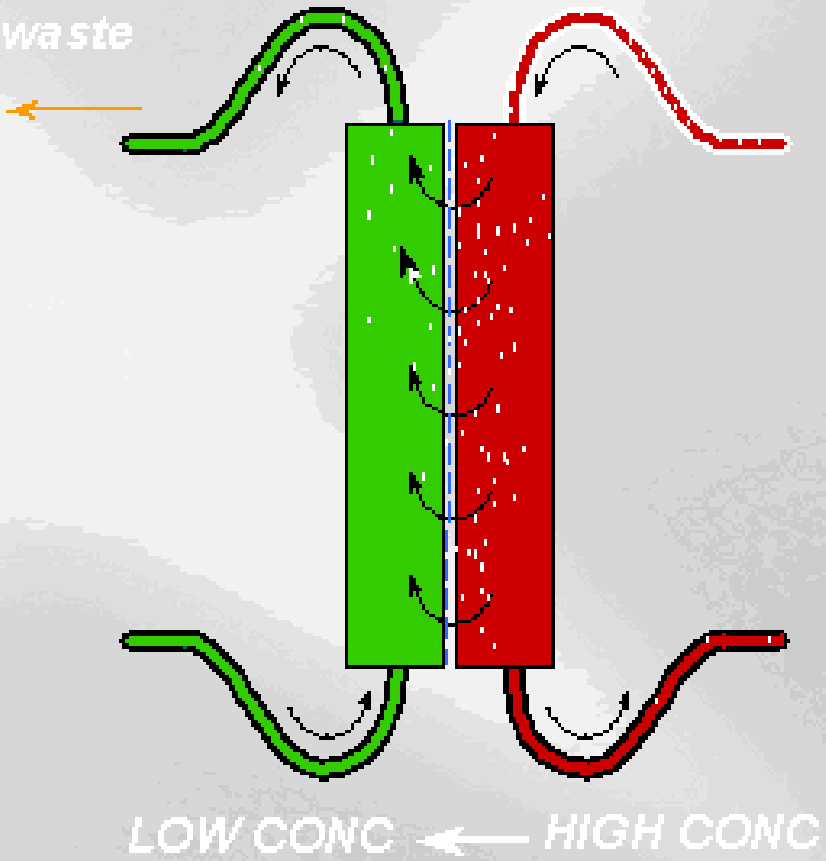
# Hemodialysis

- The major eliminating process is difusion (concentration gradient)
- counter-current exchange

prismaflex

# Hemodialysis

Movement of small solutes by diffusion through the addition of dialysate to the fluid side of the filter.

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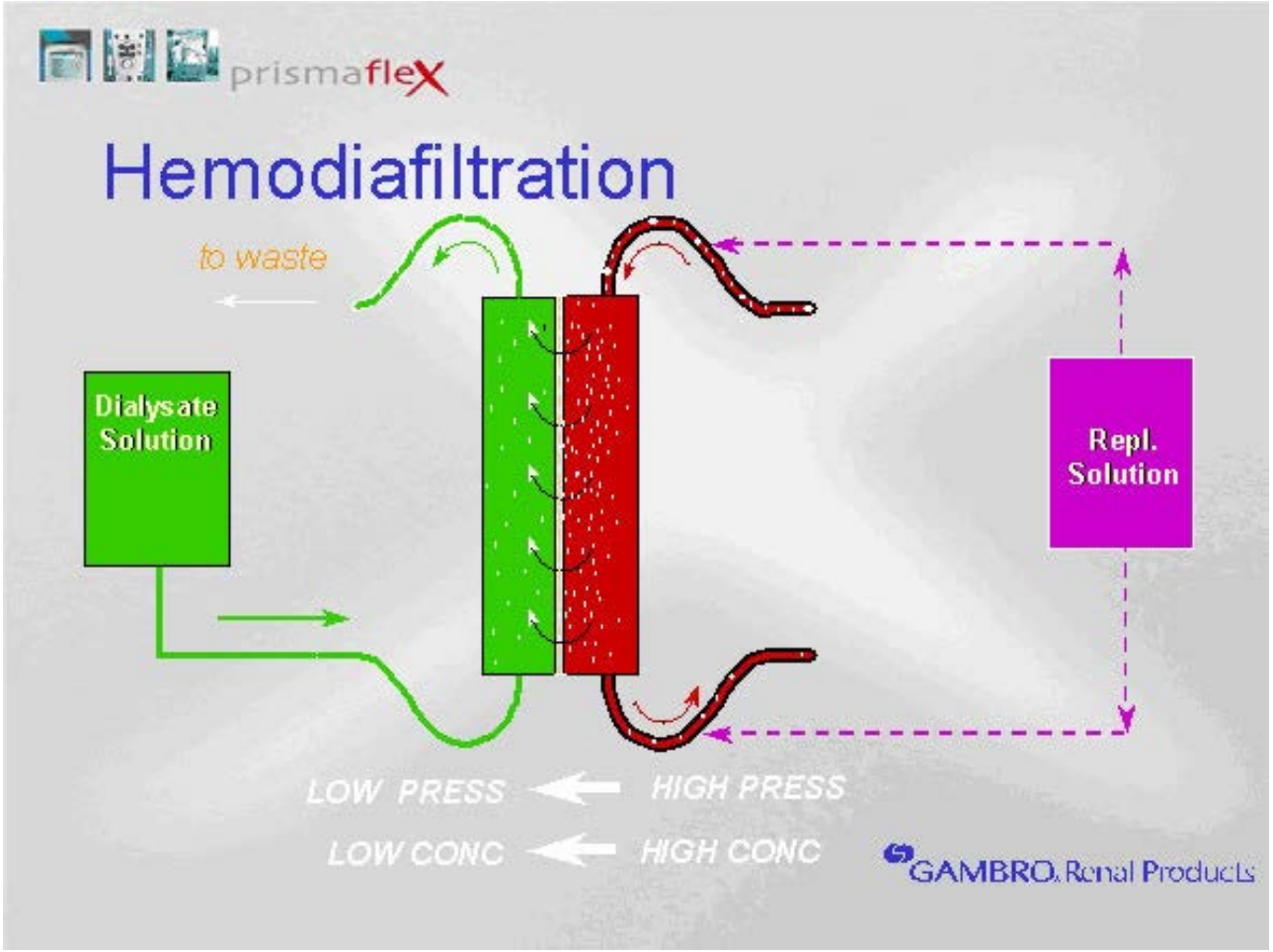
# Hemodiafiltration

- Combination of filtration & difusion

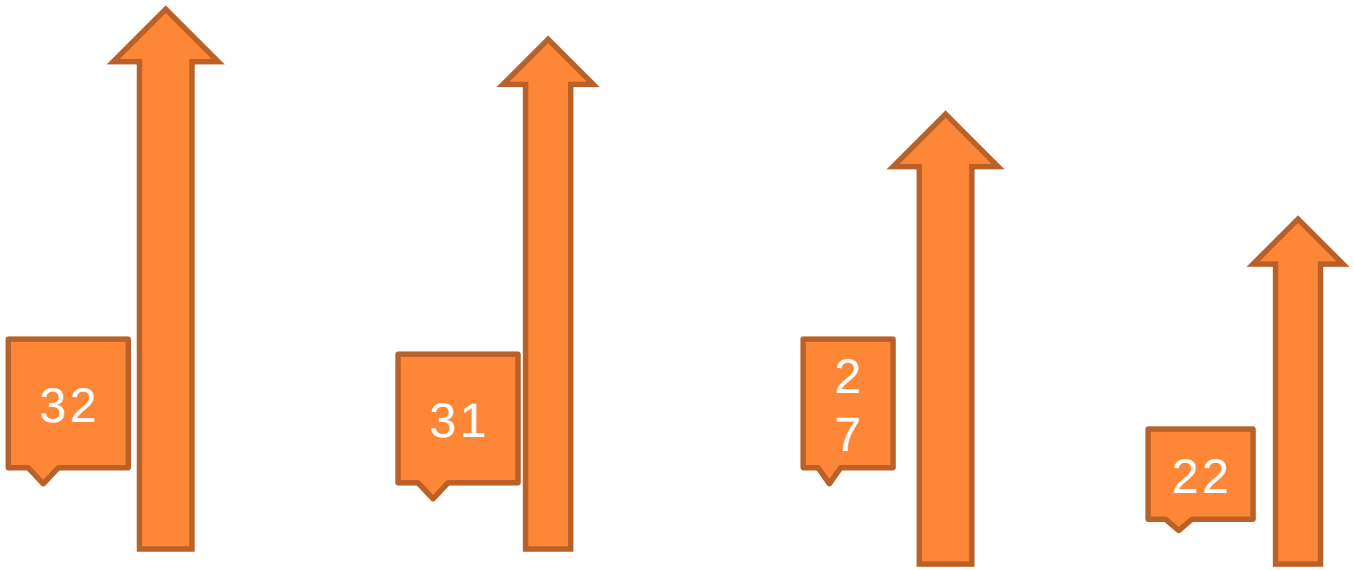
# HEMODIAFILTRACE



# Efficacy of the metods

(clearance of urea , Q 100ml/ min, ultrafiltrate 2L / hr )

- CVVHDF postdiluce
- CVVH postdiluce
- CVVHDF prediluce
- CVVH prediluce



# Methods used

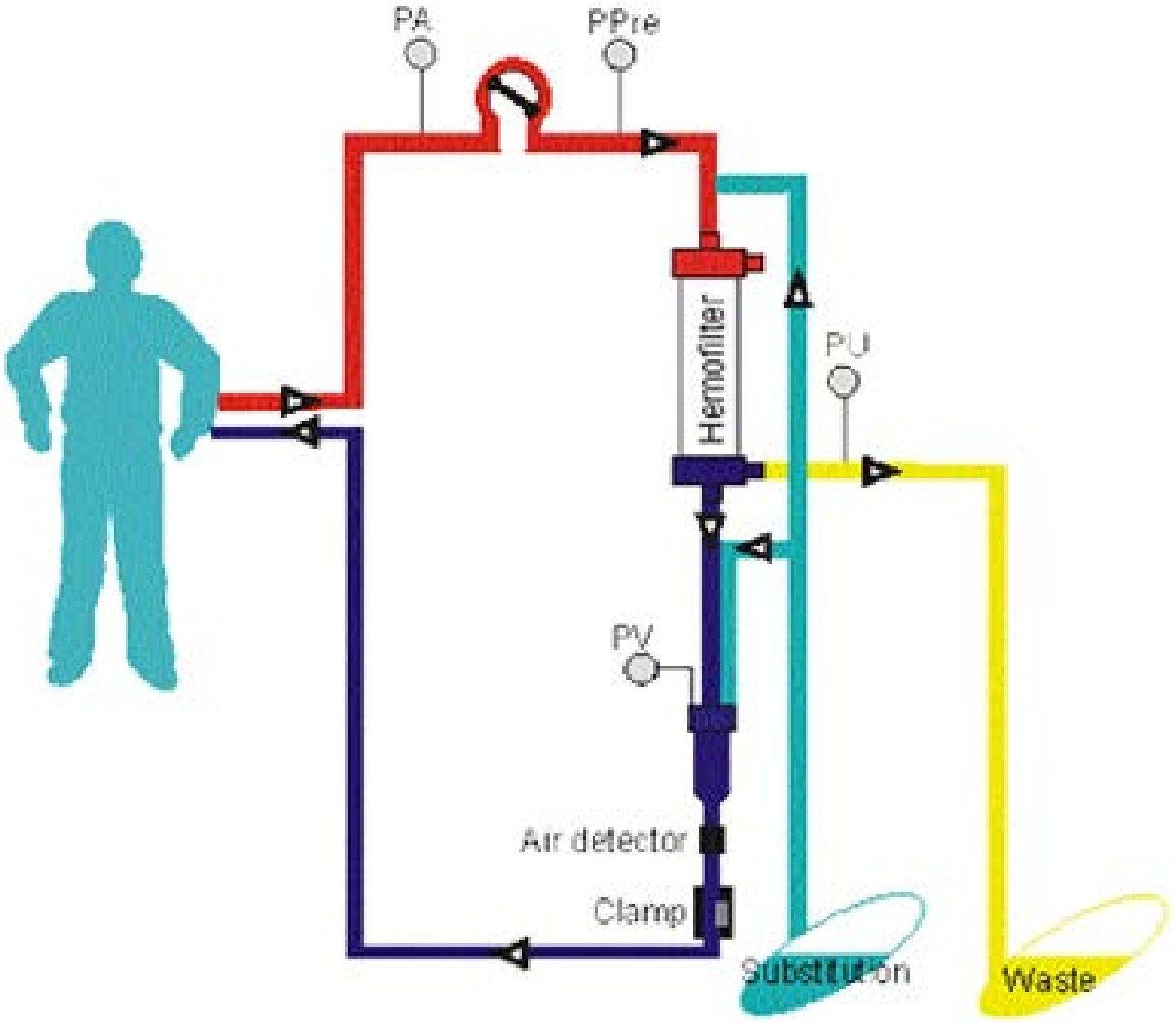
CVVHDF –

CVVH –

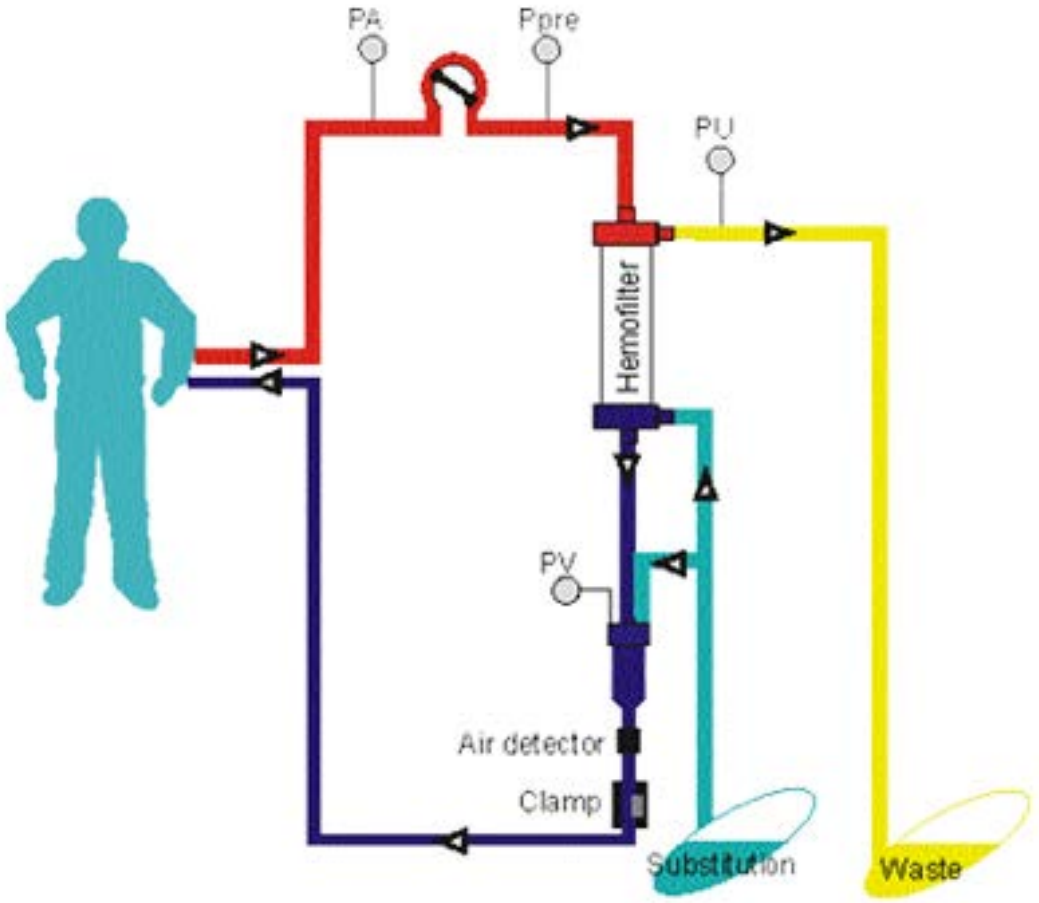
CVVHD -

SCUF – slow continuos ultrafiltration

# CVVH


PA
PPre
Hemofilter
PU
PV
Air detector
Clamp
Substitution
Waste

# CVVHDF


PA
Ppre
PU
Hemofilter
PV
Air detector
Clamp
Substitution
Waste

# Parameters of CRRT

- How long? Time to reach desired results
- Rate of Fluid elimination
- Predilution – „dilution“of blood (part of UF)
- Postdilution – repacement of UF fluid
- Dialysis fluid speed
- Blood flow – according to method (120-180 ml/min)

# ANTIGOAGULATION

- Heparin
- Heparin – Protamin
- LMWH
- Citrate - Ca++

# Dialyzační přístroje



# Conclusion

- Think about who might be vulnerable to acute renal failure
- Think twice before initiating therapy that may cause ARF
- Think about it as a diagnosis – don't look/won't find

# Acknowledgements


- Powerpoint Harvard learning – Malcolm Cox – Acute renal failure
- Royal Perth Hospital teaching powerpoints
- Acute renal failure powerpoint – Anthony Mato
- Acute renal failure ppt Dr Cherelle Fitzclarence
- May 2010
- Acute renal failure in intensive care, ppt – Prikrylova, Petruska, March 2008

- NB – above mentioned slides were freely used with thanks to the authors