PACT Oliguria and Anuria

Intensive Care Training Program

Radboud University Medical Centre Nijmegen

Acute Kidney Injury

Exclude pre- and postrenal causes

RIFLE

RISK	↑ S creatinine ≥ 1.5× baseline	UP < 0.5 ml/kg/h for ≥ 6 hrs
Injury	↑ S creatinine ≥ 2× baseline	UP < 0.5 ml/kg/h for ≥ 12 hrs
Failure	↑ S creatinine ≥ 3× baseline or ≥ 354 µmol/l with acute ↑ 44 µmol/l	UP < 0.3 ml/kg/h for ≥ 24 hrs or anuria ≥ 12 hrs
LOSS	Complete loss kidney function > 4 weeks	
ESKD	End-stage kidney disease > 3 M	

Baseline creatinine < 1 week

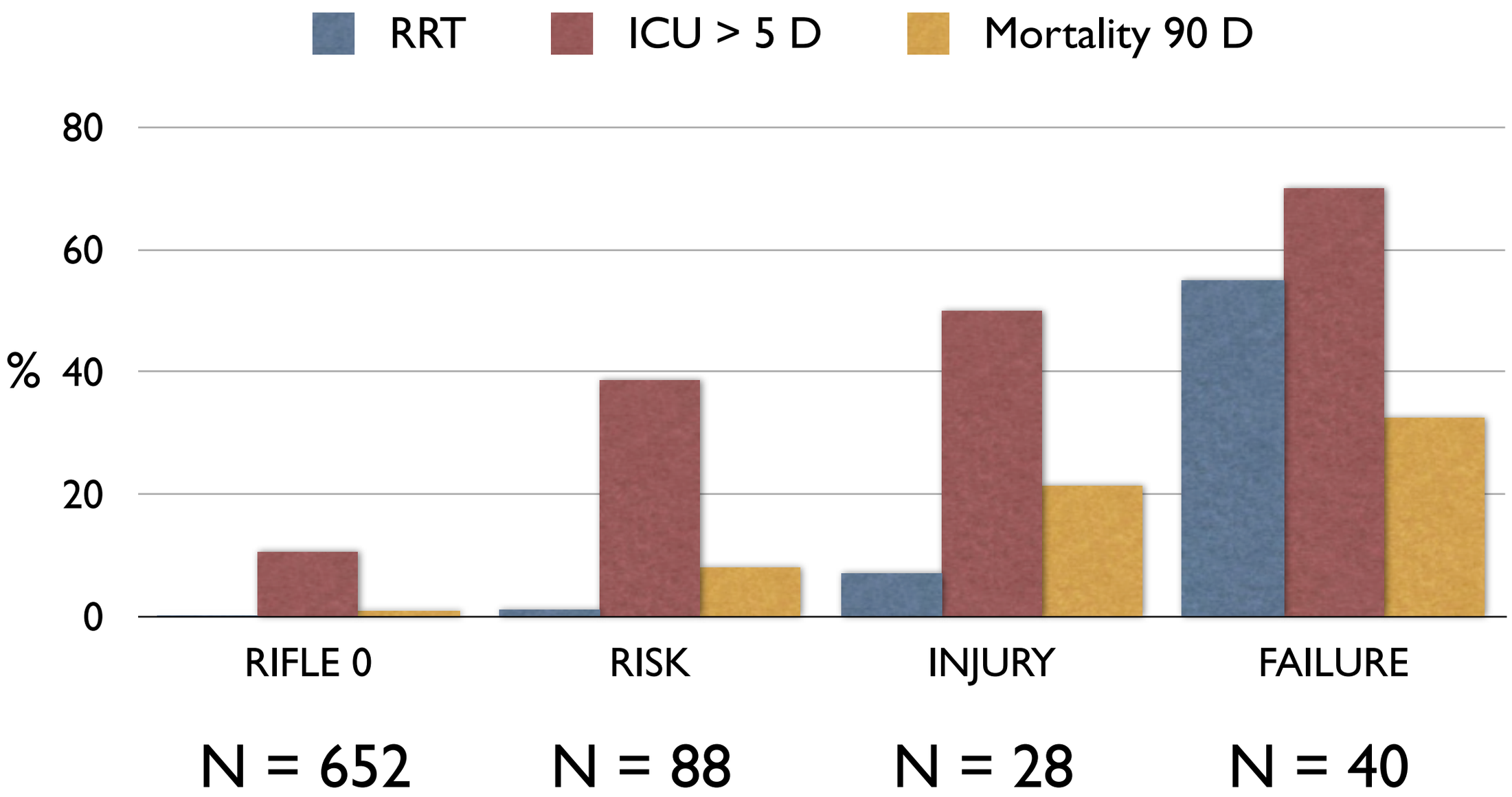
AKIN

Stage 1	↑ creatinine ≥ 1.5× or > 26.4 µmol/l baseline	UP < 0.5 ml/kg/h for ≥ 6 hrs
Stage 2	↑ creatinine ≥ 2× baseline	UP < 0.5 ml/kg/h for ≥ 12 hrs
Stage 3	↑ creatinine ≥ 3× baseline or ≥ 354 µmol/l with acute ↑ 44 µmol/l or RRT	UP < 0.3 ml/kg/h for ≥ 24 hrs or anuria ≥ 12 hrs

Baseline creatinine < 48 hours

Estimate with MDRD criteria

RIFLE criteria in cardiac surgery

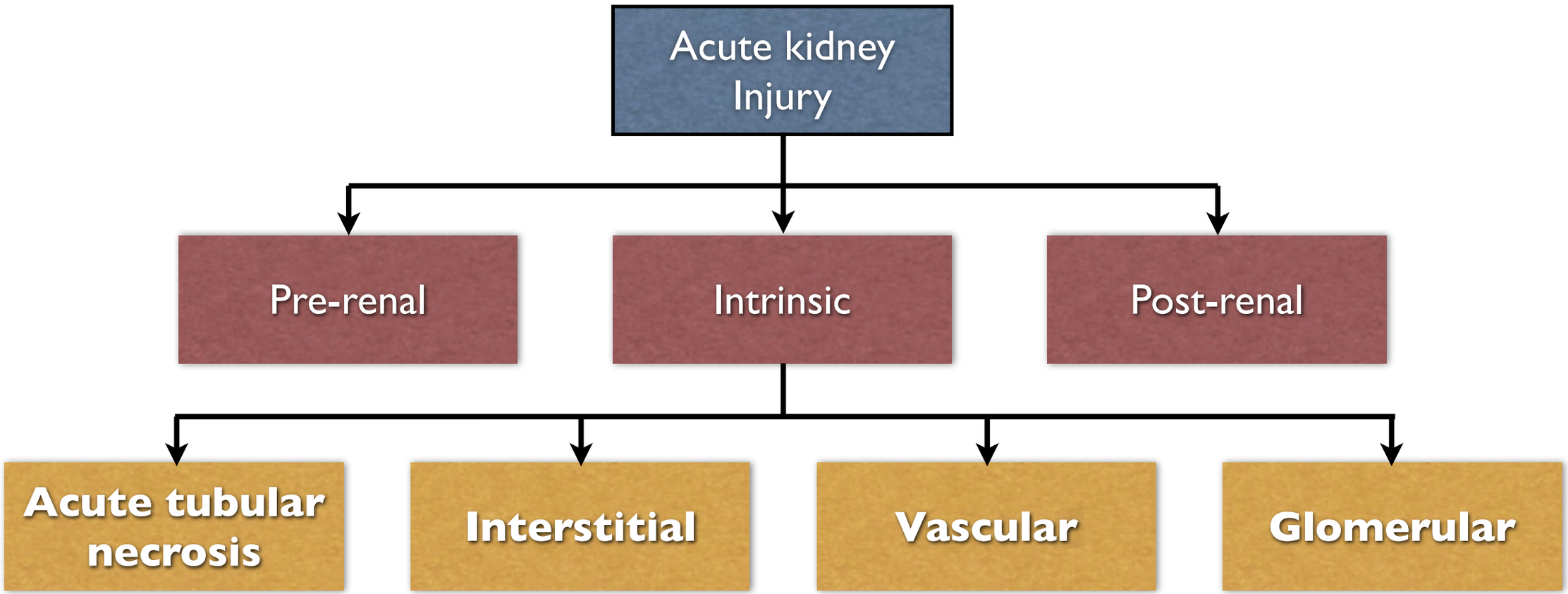


Kuitunen A. Ann Thorac Surg 2006;81:542-546

RIFLE criteria in the general ICU

	No AKI	Risk	Injury	Failure
Incidence %	65.6	19.1	3.8	12.5
Age	60.5	62.1	60.4	61.1
ICU mortality	10.7	20.1	25.9	49.6
Hospital mortality	16.9	29.9	35.8	57.9
ICU length of stay	2	5	8	9

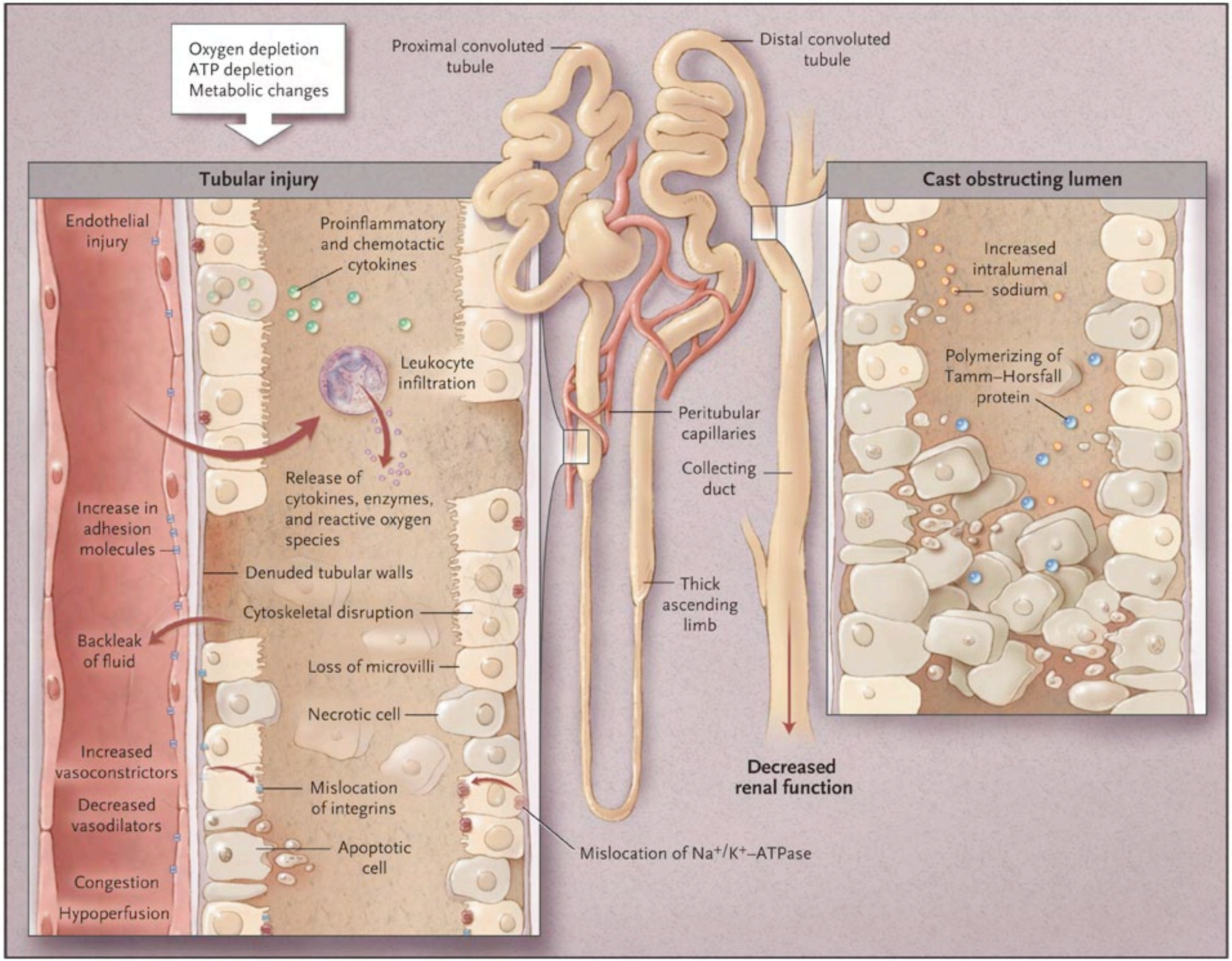
Acute Kidney Injury



In the ICU > 90% intrinsic due to hypoperfusion and/or sepsis

Pre-renal versus intrinsic

Test	Pre-renal	Intrinsic
Urine osmolarity (mOsm/kg)	> 500	< 400
Urine Sodium (mEq/l)	< 20	> 40
Urine/Plasma Creatinine	> 40	< 20
Fractional Sodium excretion (%)	< 1	> 2
Sediment	Normal, sometimes hyalin or granular casts	Renal tubular cells, (brown) granular casts


Oxygen depletion
ATP depletion
Metabolic changes
Proximal convoluted tubule
Distal convoluted tubule
Tubular injury
Cast obstructing lumen
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
Mislocation of integrins
Decreased vasodilators
Apoptotic cell
Congestion
Hypoperfusion
Peritubular capillaries
Collecting duct
Thick ascending limb
Mislocation of Na+/K+–ATPase
Increased intralumenal sodium
Polymerizing of Tamm–Horsfall protein
Decreased renal function

Acute tubular necrosis

- Frequently - proximal tubular cell necrosis is absent during on histopathology
- Concept of sublethal cell injury with proximal tubule cell dysfunction

Immunology

- ANCA (ANCA-associated vasculitis)
- Anti-GBM (Goodpasture's Syndrome)
- ANA (lupus nephritis)
- Complement (lupus nephritis, infectious endocarditis)
- Serum electrophoresis & urine Bence Jones protein (myeloma)

Urine

- Legionella antigen

Arterial blood gases (↑ lactate with liver failure, ischaemic bowel, metformin)

Creatine kinase

- rhabdomyolysis

LDH

- HUS/TTP

Blood film

- schistocytes with HUS/TTP

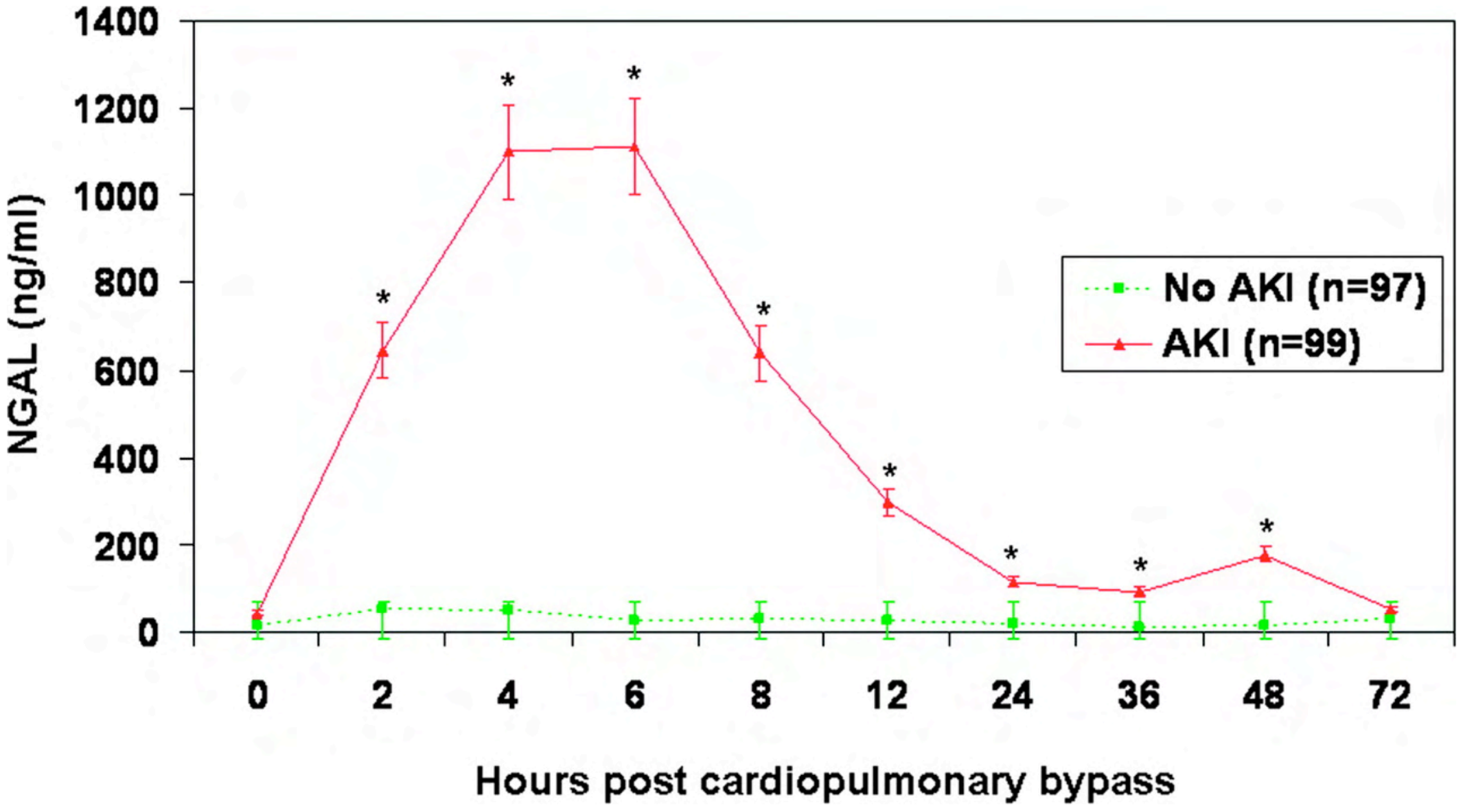
Toxicology screen

- if overdose suspected

Renal biopsy

- if there is suspicion of treatable glomerular or interstitial process

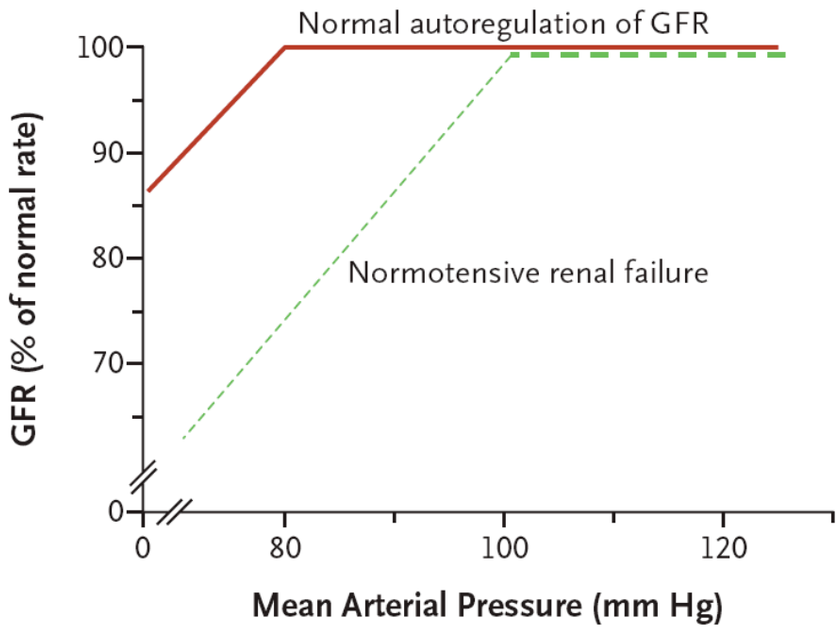
NGAL and AKI after cardiac surgery

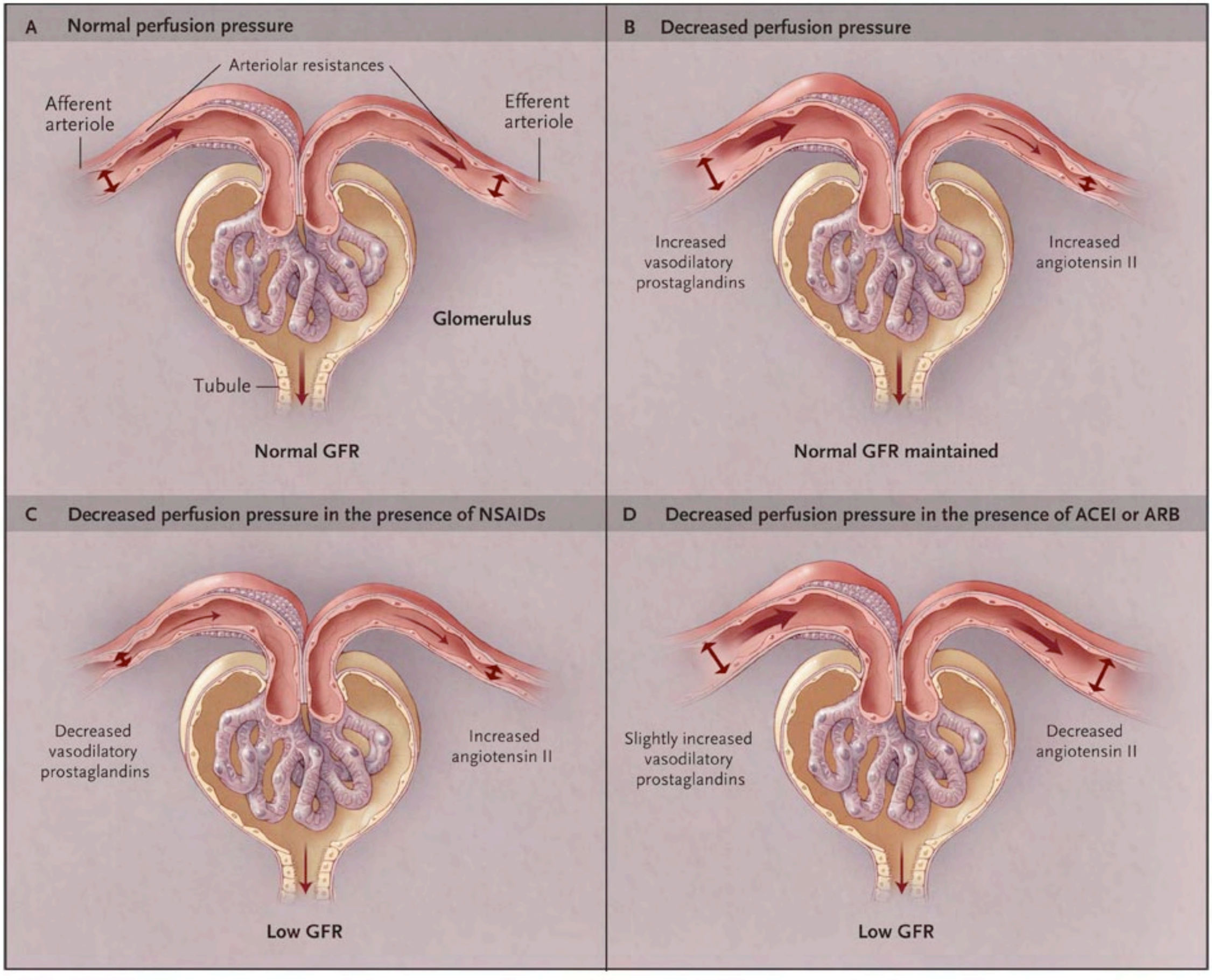


Bennett M. CJASN 2008;3:665-673

Prevention

- Maintain adequate circulating volume
- Maintain adequate perfusion pressure
- Avoid additional insults

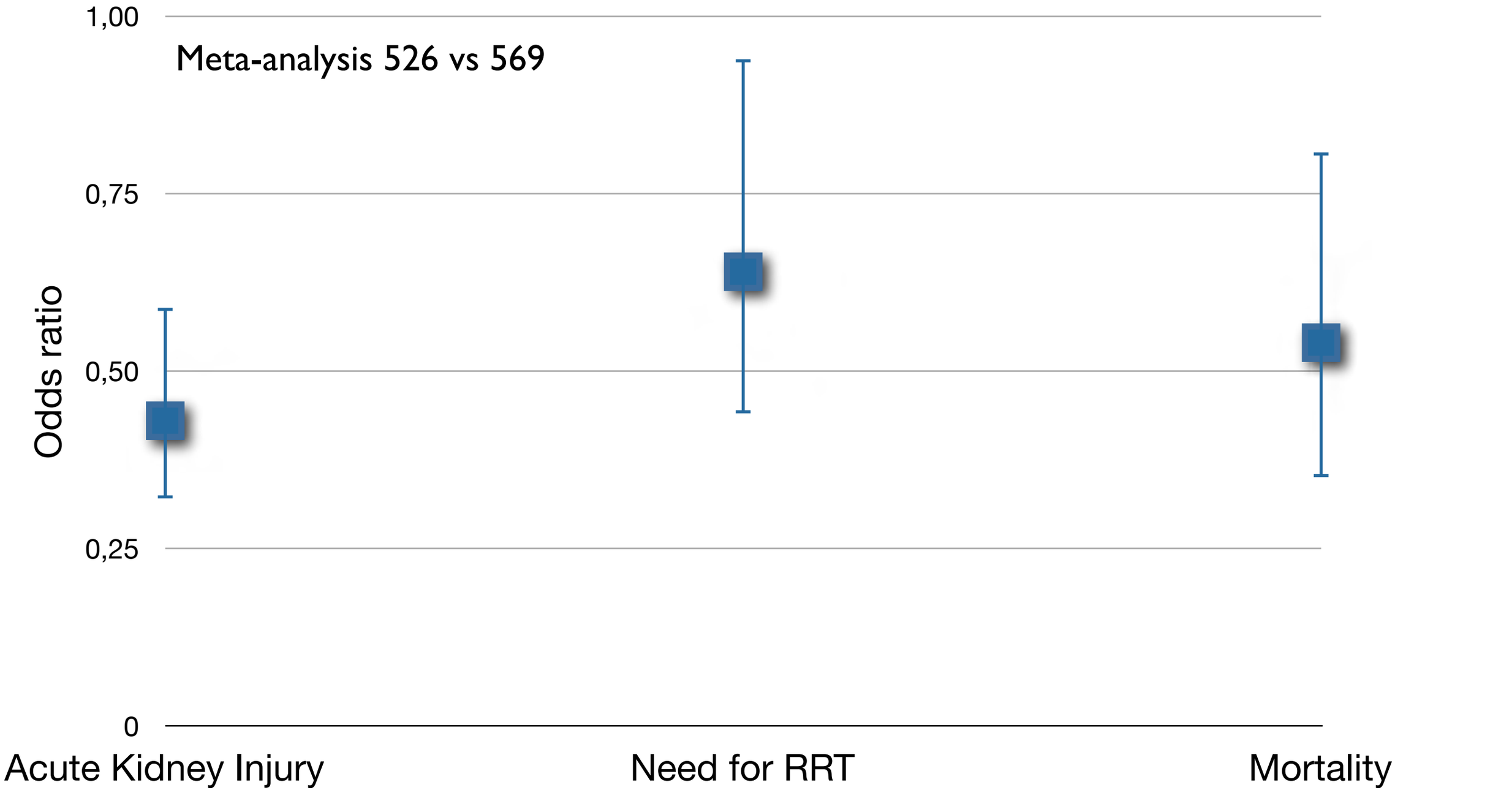



A Normal perfusion pressure
Arteriolar resistances
Afferent arteriole
Efferent arteriole
Glomerulus
Tubule
Normal GFR
B Decreased perfusion pressure
Increased vasodilatory prostaglandins
Increased angiotensin II
Normal GFR maintained
C Decreased perfusion pressure in the presence of NSAIDs
Decreased vasodilatory prostaglandins
Increased angiotensin II
Low GFR
D Decreased perfusion pressure in the presence of ACEI or ARB
Slightly increased vasodilatory prostaglandins
Decreased angiotensin II
Low GFR

Other medications to avoid

- Aminoglycosides
- Amphotericin B
- Radiocontrast

Fenoldopam prevention



Landoni G. Am J Kid Dis 2007;49:56-68

Glomerular Hemodynamics

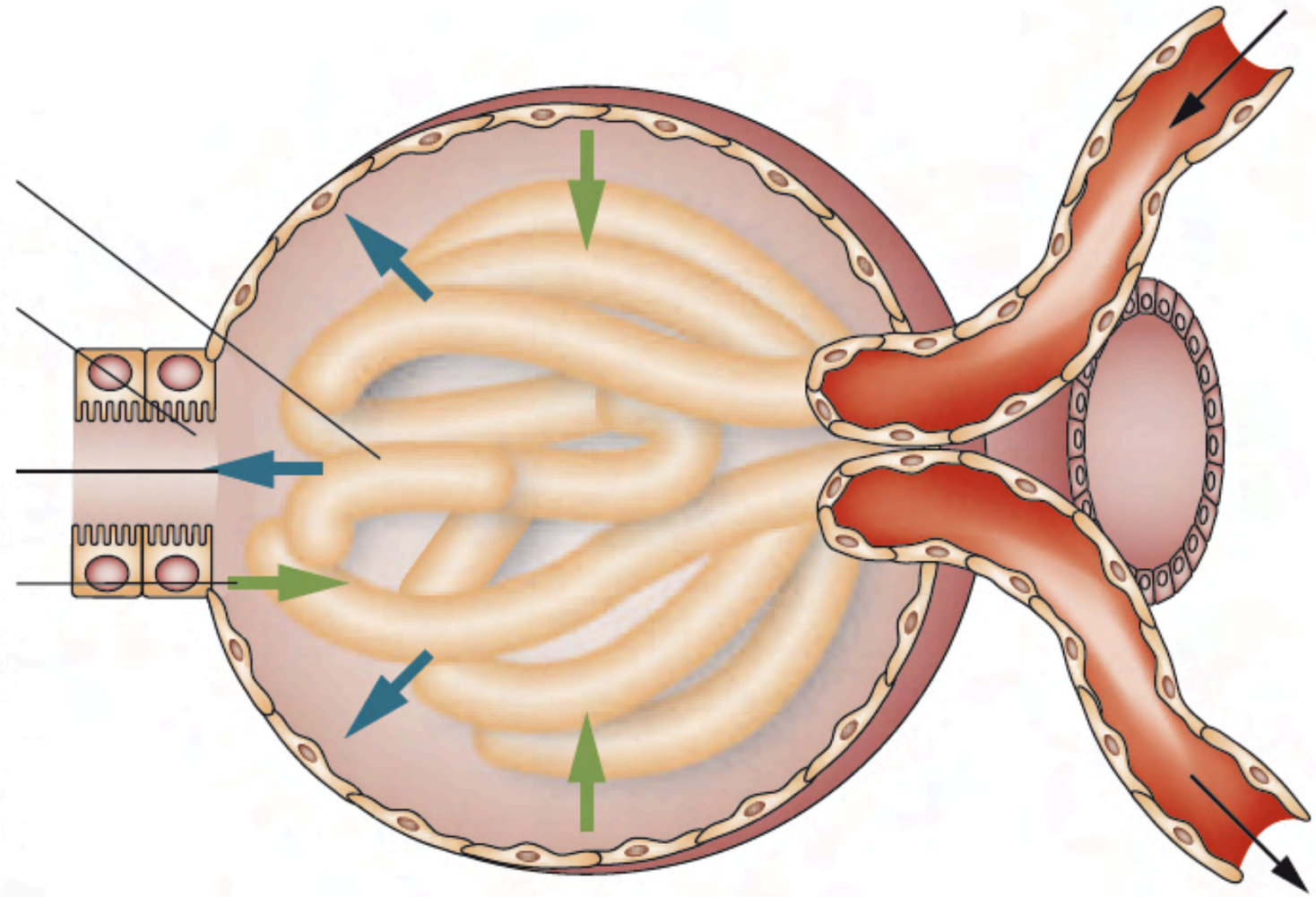
Mean glomerular capillary pressure:
45 mmHg

– Intracapsular pressure:
10 mmHg

Mean hydrostatic pressure gradient:
35 mmHg

– Mean colloid pressure:
25 mmHg

Mean pressure driving ultrafiltration:
10 mmHg



Decreased GRF in patients with AKI

Table 1 | Reasons for decreased glomerular ultrafiltration in patients with acute kidney injury

Abnormality	Physiological effect	Consequence
Low systemic blood pressure Afferent arteriole vasoconstriction Efferent arteriole vasodilatation	Low glomerular hydrostatic pressure	Decreased glomerular filtration
Renal interstitial edema Extrinsic compression Tubular obstruction Failure of downstream tubular reabsorption	High intracapsular pressure	Decreased glomerular filtration
Low renal plasma flow	Rapid rise in oncotic pressure	Decreased glomerular filtration

Overzealous fluid resuscitation

- Renal excretion of exogenous sodium is slow even in healthy individuals and is further impaired in acute illness
- Hyperchloremia reduces renal blood flow and impairs sodium excretion

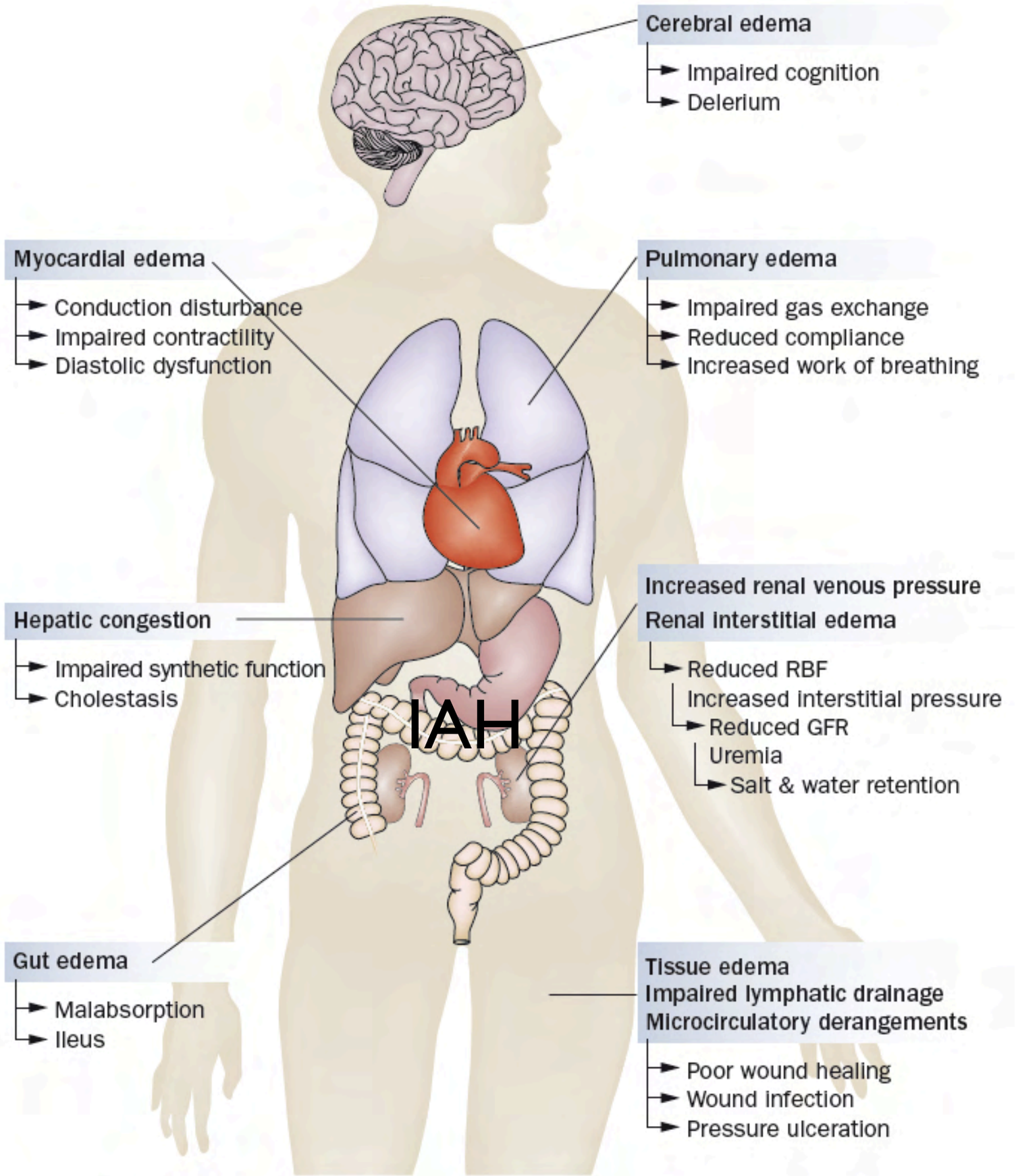


Figure 2 | Pathological sequelae of fluid overload in organ systems. Abbreviations: GFR, glomerular filtration rate; RBF, renal blood flow.

Table 2 | Publications describing two groups of critically ill patients with differing fluid balances where a renal outcome was reported*

Reference	Study type	Population	*n*	Average fluid balance in less-positive group	Average fluid balance in more-positive group	Renal function measure	Renal outcome with more-restrictive fluid balance strategy	Principal outcome with more-restrictive fluid balance strategy
ARDS Clinical Trials Network (2006)[88]	Multicenter RCT	ARDS	1,000	–136 ml on day 7	+6,992 ml on day 7	Need for RRT; change in creatinine	No difference P = 0.06	Shorter duration of ventilation and ICU stay
Martin *et al.* (2005)[86]	Single-center RCT	Mixed ALI	40	–5,480 ml on day 5	–1,490 ml on day 5	Change in creatinine	No difference	Improved oxygenation
Martin *et al.* (2002)[85]	Single-center RCT	ALI after trauma	37	–3,300 ml on day 5	+500 ml on day 5	Change in creatinine	No difference	Improved oxygenation
Mitchell *et al.* (1992)[127]	Single-center RCT	Mixed ICU needing PAC	102	+142 ml	+2,239 ml	Change in creatinine	Small rise in creatinine	Shorter duration of ventilation and ICU stay
Bouchard *et al.* (2009)[25]	Retrospective observational	Mixed ICU with AKI	542	<10% rise	>10% rise	Dialysis independence	Improved	Decrease in mortality
Payen *et al.* (2008)[6]	Retrospective observational	Mixed ICU with or without AKI	3,147	–1,000 ml	+3,000 ml	Renal SOFA score	Improved	Decrease in mortality in patients with AKI
Vidal *et al.* (2008)[72]	Prospective observational	Mixed ICU with elevated or normal IAP	83	+5,000 ml	+9,000 ml	Renal SOFA score	Improved	Normal IAP associated with less organ failure and shorter ICU stay
Adesanya *et al.* (2008)[128]	Retrospective observational	Surgical ICU	41	+5 kg	+8.3 kg	Change in creatinine	No difference	Shorter duration of ventilation and ICU stay
McArdle *et al.* (2007)[87]	Retrospective observational	Surgical ICU	100	+7,500 ml	+10,000 ml	Change in creatinine	No difference	Decrease in postoperative complications
Arlati *et al.* (2007)[99]	Prospective observational	Burns ICU	24	+7,500 ml	+12,000 ml	Urine output	No difference	Decrease in organ dysfunction score

*See Supplementary Information online for systematic search strategy. Abbreviations: AKI, acute kidney injury; ALI, acute lung injury; ARDS, acute respiratory distress syndrome; IAP, intra-abdominal pressure; ICU, intensive care unit; PAC, pulmonary artery catheter; RCT, randomized, controlled trial; RRT, renal replacement therapy; SOFA, sequential organ failure assessment.

RCT's with major differences in fluid balance

Reasonable guidelines

- Volume therapy should result in a reasonable cardiac output but should not compensate for excessive vasodilation
- This results in an earlier and greater use of vasopressors
- After 1 or 2 days thinks about prevention of further fluid overload and removal of excess salt and water
- If diuretics fail - otherwise early CRRT

Indications for Renal Replacement Therapy.[2]

Anuria/Oliguria (associated with deteriorating clinical condition)
- Urine output <200 ml 12 h^{-1}

Electrolyte/Acid-Base Abnormality
- pH <7.1
- *K* > 6.5 (refractory to medical therapy)
- *Na* <115 or >160 (correct gradually if chronic)

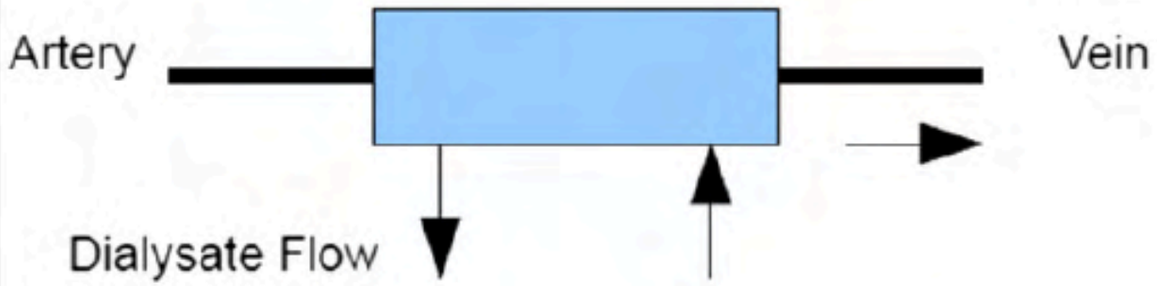
Uraemia & its complications
- Uraemia >30 mmol l^{-1} (associated with deteriorating clinical condition)
- Pericarditis
- Encephalopathy
- Neuropathy/Myopathy

Clinically significant organ oedema (particularly lung)

Hyperthermia

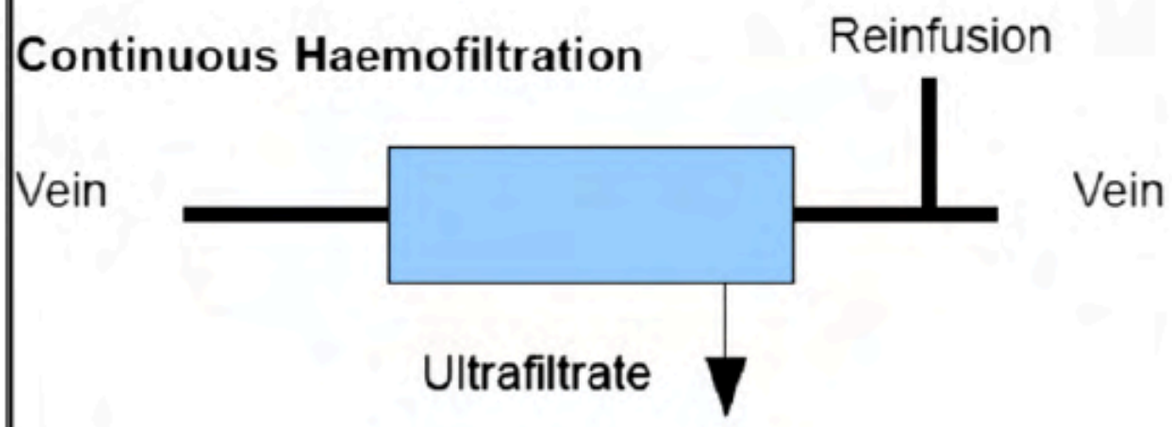
Drug overdose with a dialysable toxin

Intermittent haemodialysis

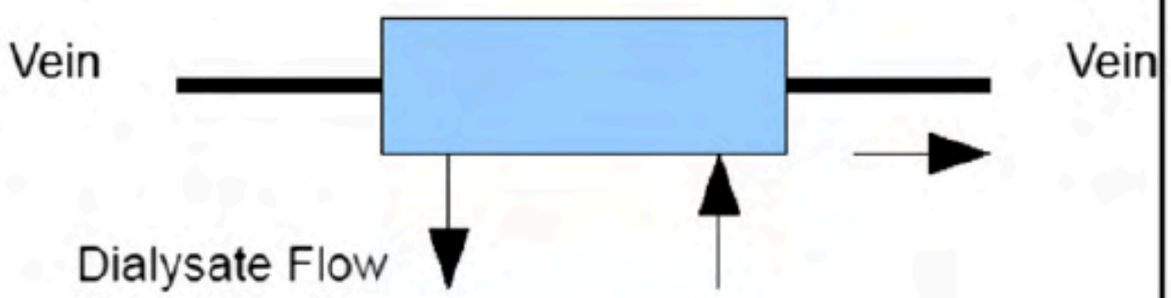


SCUF

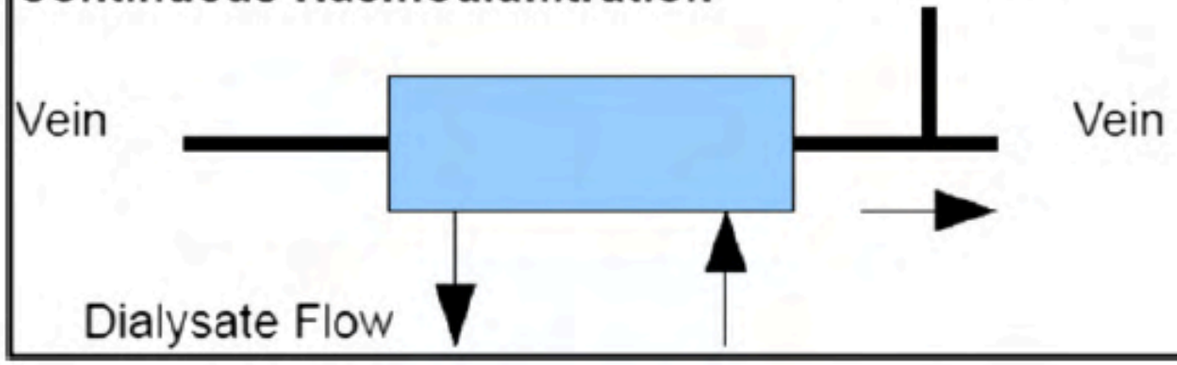
Continuous Haemofiltration



SLEDD



Continuous Haemodiafiltration



Flow rates in renal replacement therapy.[2,5,6]

Technique	Blood flow (mL min^{-1})	Dialysate flow (mL min^{-1})	Filtrate flow (mL min^{-1})	Replacement fluid
IHD	300–500	500	N/A	No
CHD	50–200	10–20	2–4	No
CVVHF	50–200	N/A	8–25	Yes
CVVHDF	50–200	10–20	8–12	Yes
SCUF	100	N/A	[a]	No
HVHF	300	N/A	100	Yes
SLEDD	100	200 mL	N/A	No

Critically ill
Age ≥ 18
Acute Kidney Injury

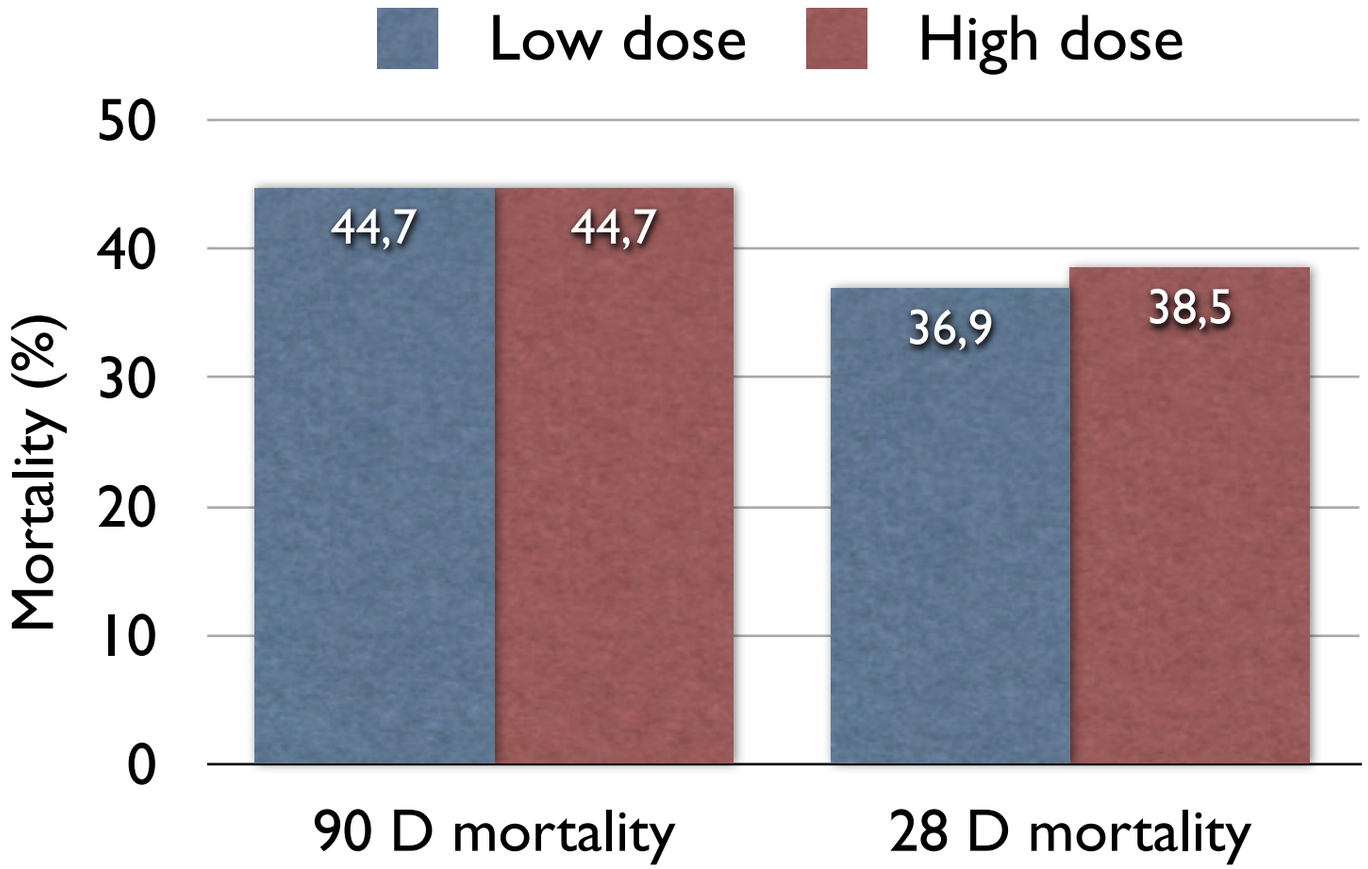
CVVH

Blood flow > 150 mL/min

40 mL/kg/hr — N = 721

25 mL/kg/hr — N = 743

No differences in baseline characteristics



	Low dose	High dose
0	46,2%	47,6%
1	35,4%	35,2%
2	14,7%	13,9%
3	3,4%	3,2%
4	0,4%	0,1%

No. of nonrenal organ failures (%)

No differences in need for RRT in survivors at day 28 and day 90

RENAL Replacement Therapy Study Investigators. N Engl J Med 2009;361:1627-1638