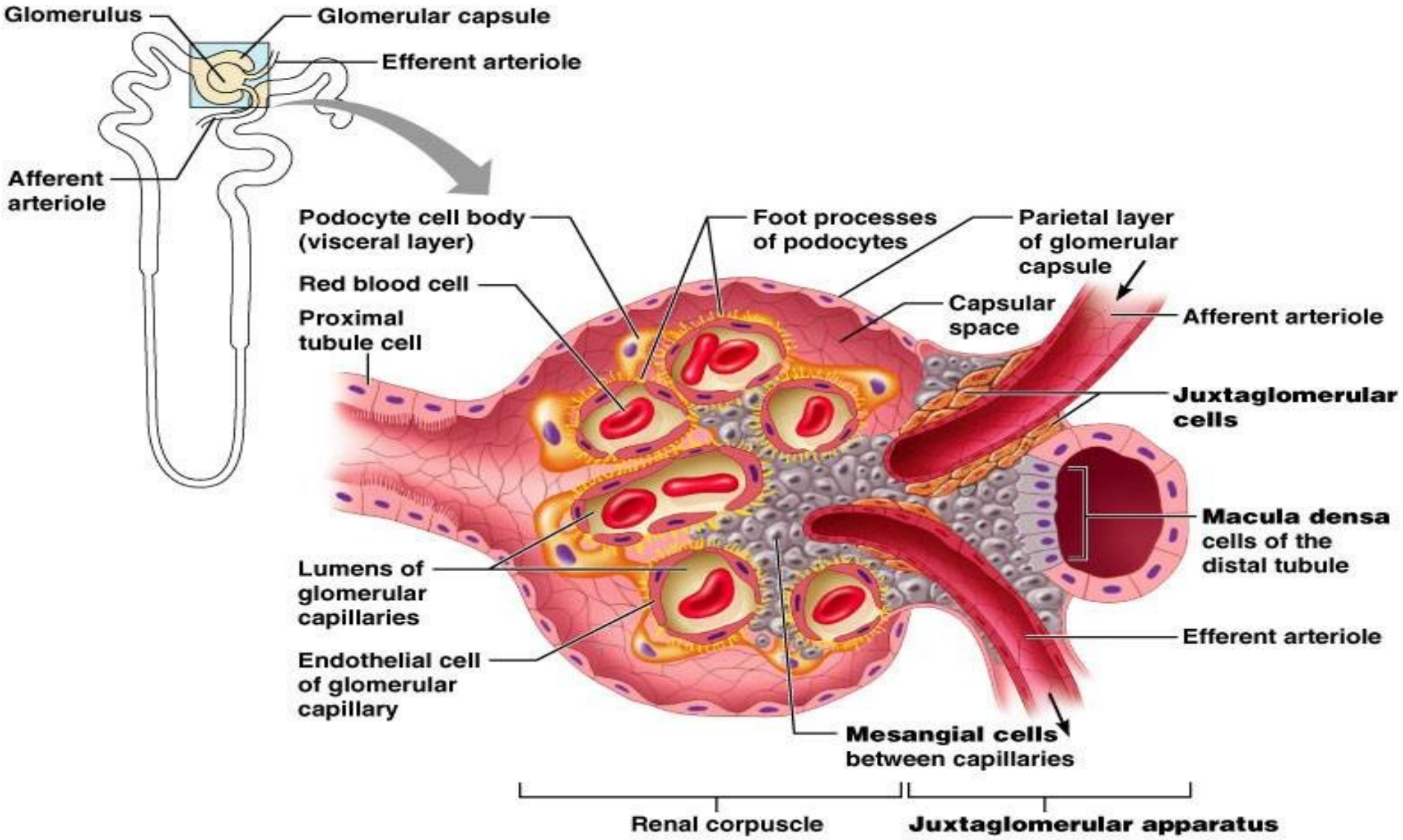
Renal failure post cardiac surgery

Sotiris Papaspyros

August 2010

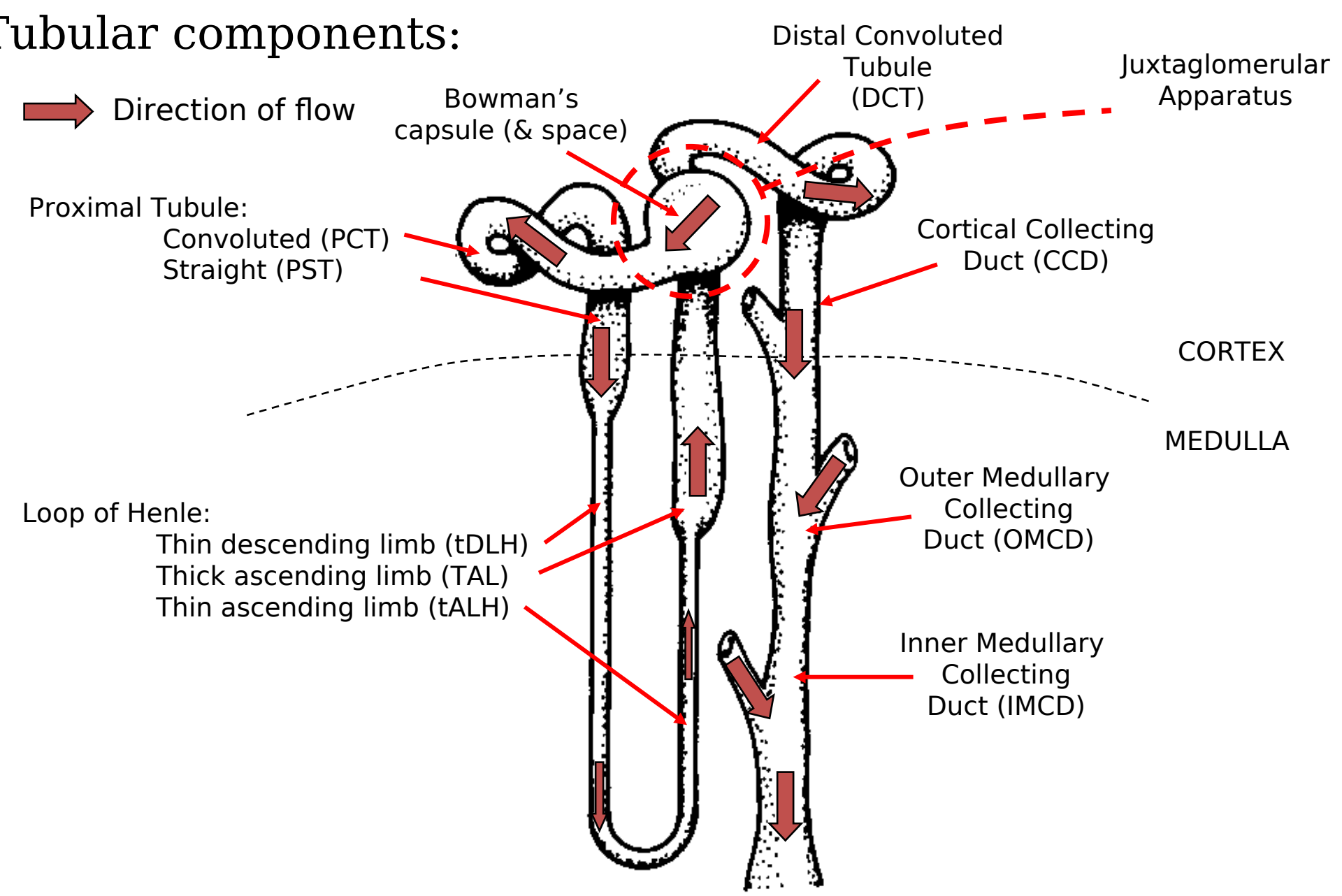
Contents

- Anatomy and physiology overview.
- Acute renal failure definition and management.
- Literature review 2010 – 1990 EJCTS, ATS, ICVTS, NEJM, Circulation.



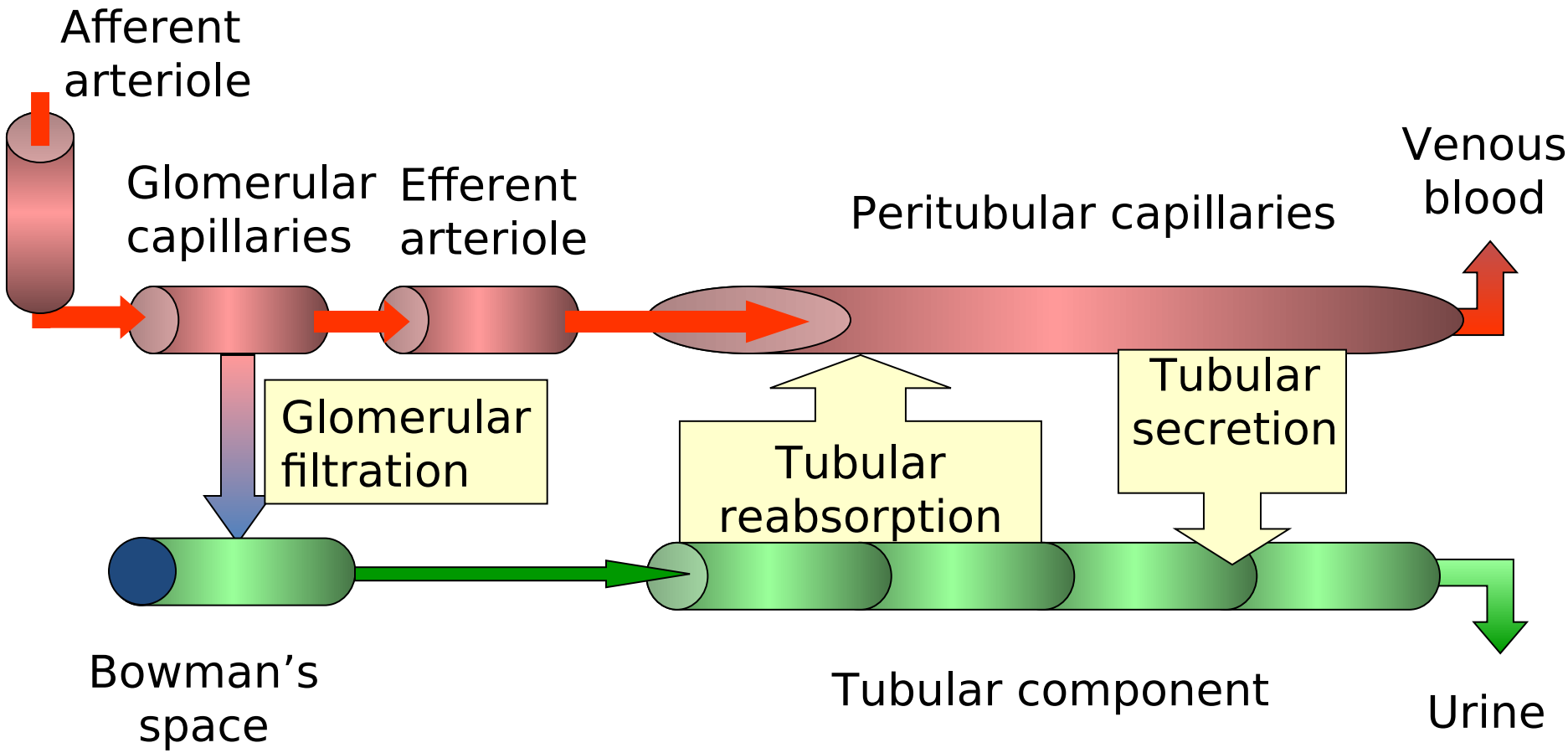
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Tubular components:

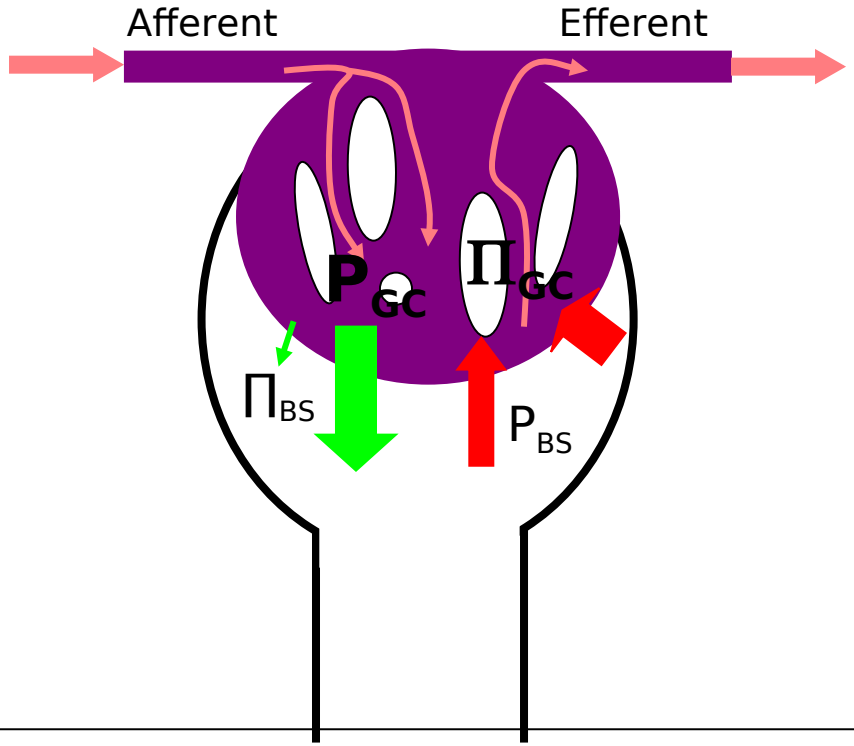


- Each segment is functionally specialised

Three basic processes underlie the formation of urine:



Forces (Starling's) determining filtration:



Favouring filtration:

- Hydrostatic pressure in the glomerular capillaries ($P_{GC\sim48mmHg}$)
- Oncotic pressure in Bowman's space (Π_{BS}) ~ negligible

Opposing filtration:

- Oncotic pressure in the glomerular capillaries ($\Pi_{GC\sim25mmHg}$)
- Hydrostatic pressure in Bowman's space ($P_{BS\sim10mmHg}$)

Determinants of filtration rate:

Ultra filtration pressure (P_{UF})

$$GFR = K_f.[(P_{GC} - P_{BS})-(\pi_{GC})]$$

Ultrafiltration coefficient

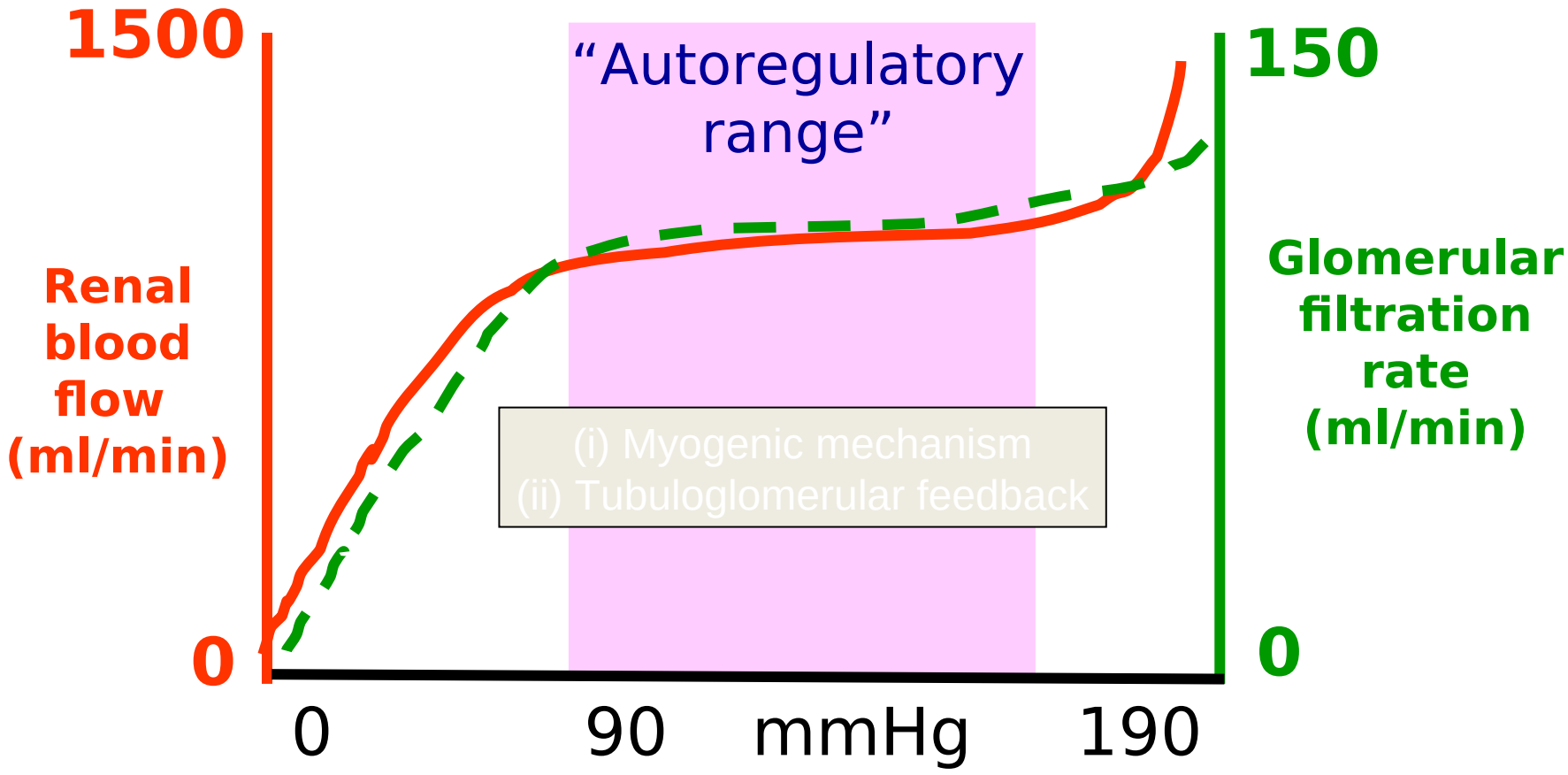
$L_p.S_f$

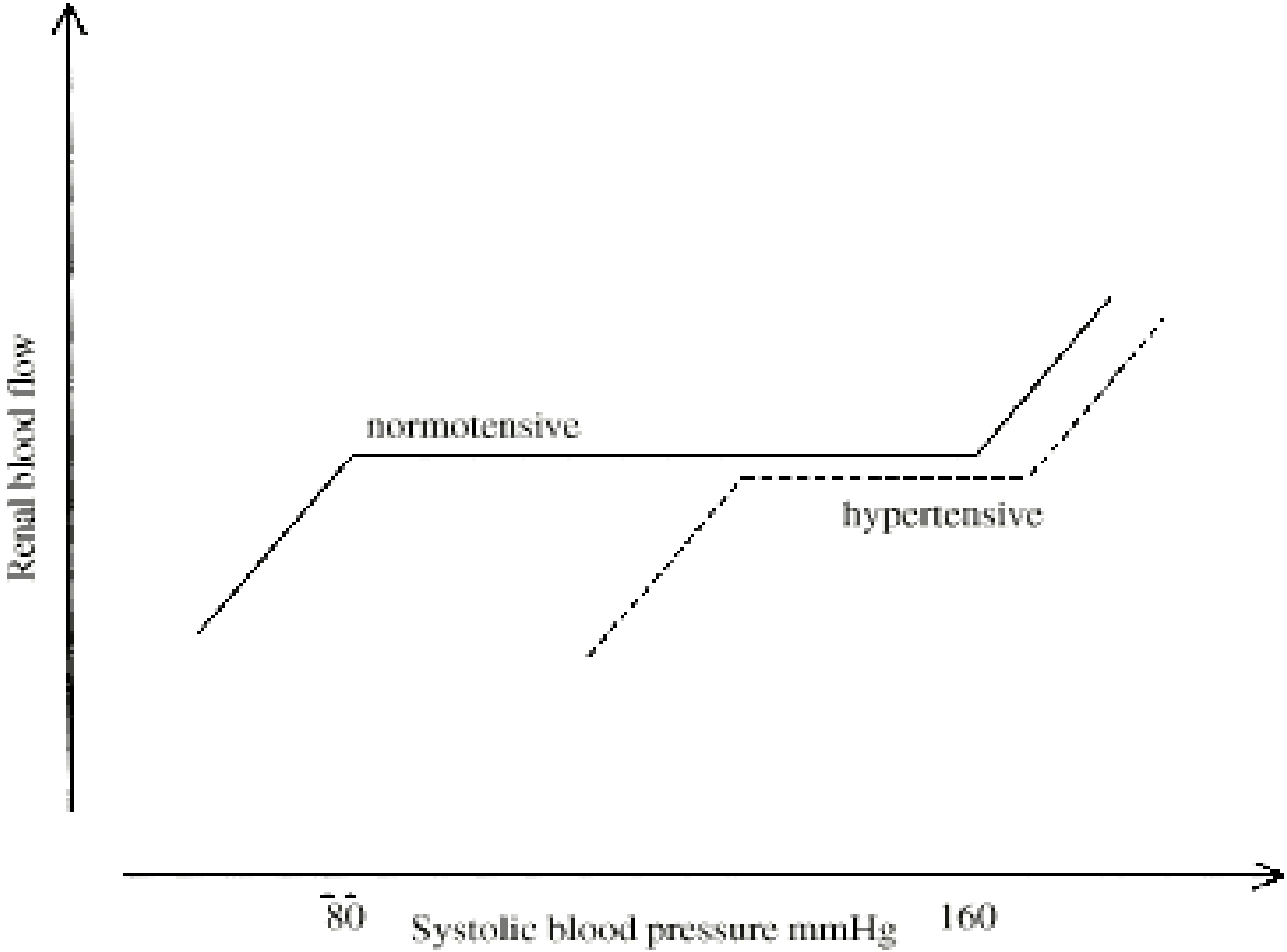
L_p = hydraulic conductivity

S_f = area available for filtration

- K_f ~X10 that of other systemic capillary beds.

Autoregulation of blood flow and GFR:




Renal blood flow
normotensive
hypertensive
80
Systolic blood pressure mmHg
160

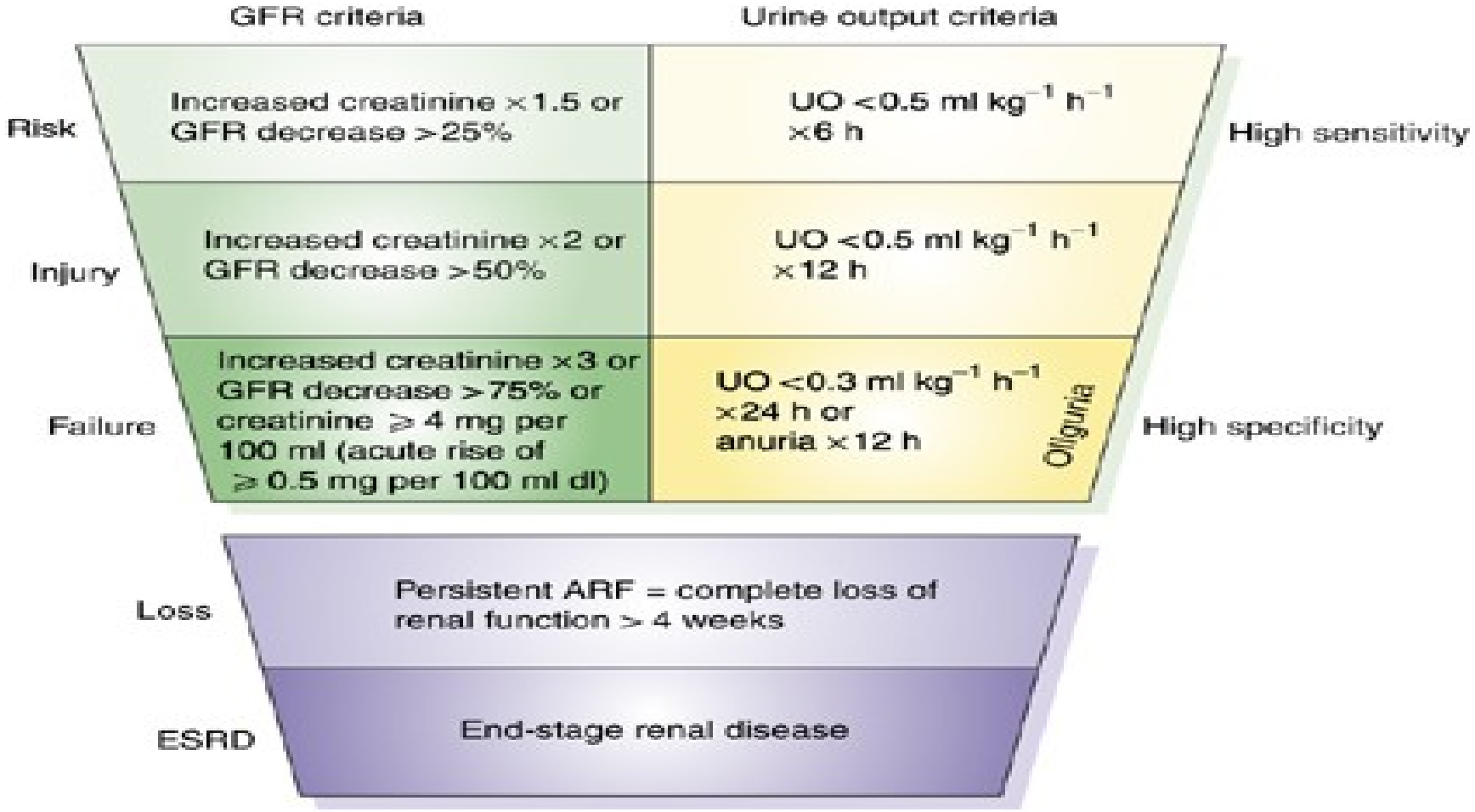
Acute Kidney Injury

Table 1 – Proposed classification for acute kidney injury – RIFLE

RIFLE classification	GFR criterion	Urine output criterion
Risk	SCr increase x 1.5 or GFR reduced > 25%	diuresis < 0.5mL/Kg/h in 6h
Injury	SCr increase x 2 or TFG reduction > 50%	diuresis < 0.5mL/Kg/h in 12h
Failure	SCr increase x 3 or GFR reduction > 75% or SCr > 4mg/dL	diuresis < 0.3mL/Kg/h in 24h ou anuria for 12h
Loss	completely loss renal function > 4 weeks	
End-stage kidney disease	RRT needed > 3 months	

RIFLE - Risk Injury Failure Loss End; GFR - glomerular filtration rate; SCr – serum creatinine; RRT – renal replacement therapy.
Adapted from: Bellomo R, Ronco C, Kellum JA, Mehta RL, Palevsky P, Acute Dialysis Quality Initiative workgroup. Acute renal failure - definition, outcome measures, animal models, fluid therapy and information technology needs: the Second International Consensus Conference of the Acute Dialysis Quality Iniciative (ADQI) Group. Crit Care. 2004;8(4):R204-12.

Renal failure definition RIFLE



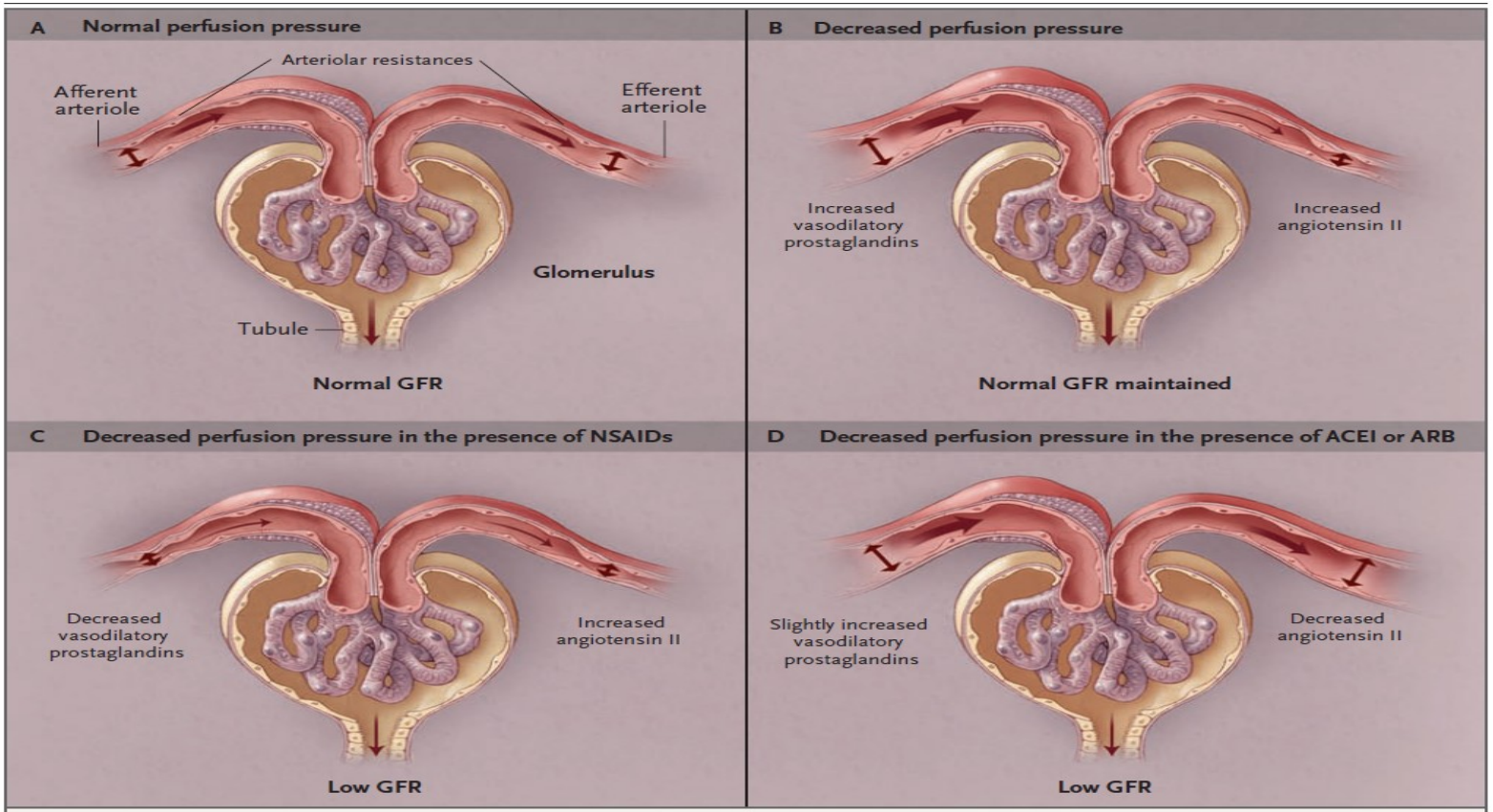


Figure 2. Intrarenal Mechanisms for Autoregulation of the Glomerular Filtration Rate under Decreased Perfusion Pressure and Reduction of the Glomerular Filtration Rate by Drugs.

Panel A shows normal conditions and a normal glomerular filtration rate (GFR). Panel B shows reduced perfusion pressure within the autoregulatory range. Normal glomerular capillary pressure is maintained by afferent vasodilatation and efferent vasoconstriction. Panel C shows reduced perfusion pressure with a nonsteroidal antiinflammatory drug (NSAID). Loss of vasodilatory prostaglandins increases afferent resistance; this causes the glomerular capillary pressure to drop below normal values and the GFR to decrease. Panel D shows reduced perfusion pressure with an angiotensin-converting–enzyme inhibitor (ACEI) or an angiotensin-receptor blocker (ARB). Loss of angiotensin II action reduces efferent resistance; this causes the glomerular capillary pressure to drop below normal values and the GFR to decrease.

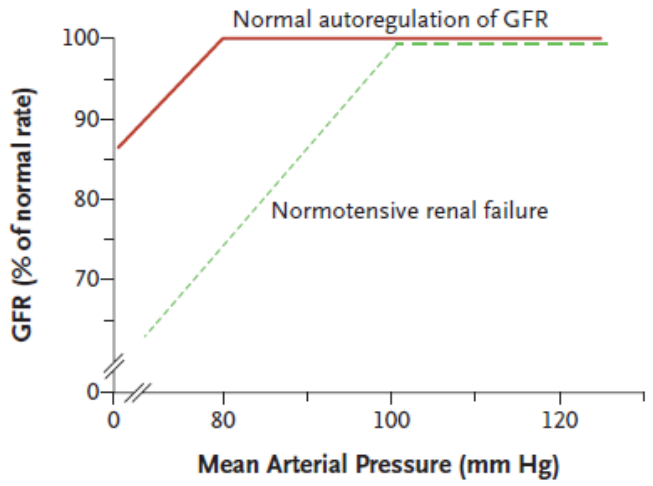


Figure 1. Normal and Impaired Autoregulation of the Glomerular Filtration Rate during Reduction of Mean Arterial Pressure.

In normal autoregulation, the glomerular filtration rate (GFR) is maintained until the mean arterial pressure falls below 80 mm Hg. However, in patients with impaired autoregulation, the GFR falls below normal values while the mean arterial pressure remains within the normal range, resulting in normotensive ischemic acute renal failure.

Table 1. Factors Increasing Susceptibility to Renal Hypoperfusion.

Failure to decrease arteriolar resistance
Structural changes in renal arterioles and small arteries
Old age
Atherosclerosis
Chronic hypertension
Chronic kidney disease
Malignant or accelerated hypertension
Reduction in vasodilatory prostaglandins
Nonsteroidal antiinflammatory drugs
Cyclooxygenase-2 inhibitors
Afferent glomerular arteriolar vasoconstriction
Sepsis
Hypercalcemia
Hepatorenal syndrome
Cyclosporine or tacrolimus
Radiocontrast agents
Failure to increase efferent arteriolar resistance
Angiotensin-converting–enzyme inhibitors
Angiotensin-receptor blockers
Renal-artery stenosis

Aetiology / classification

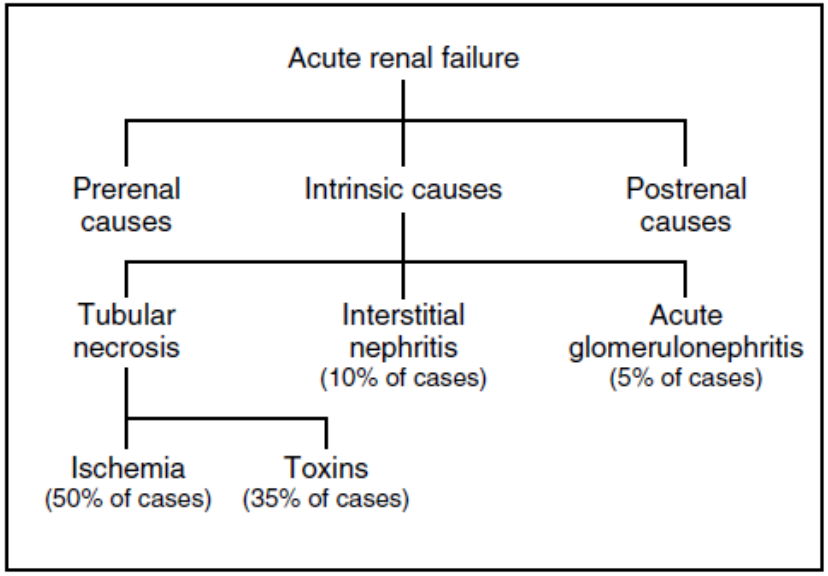


Figure 1. Main Categories of Acute Renal Failure.

The causes of acute renal failure can be categorized as prerenal, intrinsic, and postrenal. Once prerenal and postrenal causes have been excluded, one is left with intrinsic causes, which are associated with high rates of morbidity and mortality. The percentages listed reflect our experience; proportions may vary from institution to institution and from country to country.

- **Prerenal** — as an adaptive response to severe volume depletion and hypotension, with structurally intact nephrons
- **Intrinsic** — in response to cytotoxic, ischemic, or inflammatory insults to the kidney, with structural and functional damage
- **Postrenal** — from obstruction to the passage of urine.

Many **pathophysiologic features are shared** among the different categories.

Patients who develop AKI can be oliguric or nonoliguric, have a rapid or slow rise in creatinine levels, and may have qualitative differences in urine solute concentrations and cellular content. This lack of a uniform clinical presentation reflects the **variable nature of the injury**.

Classifying AKI as oliguric or nonoliguric based on daily urine excretion has **prognostic value**.

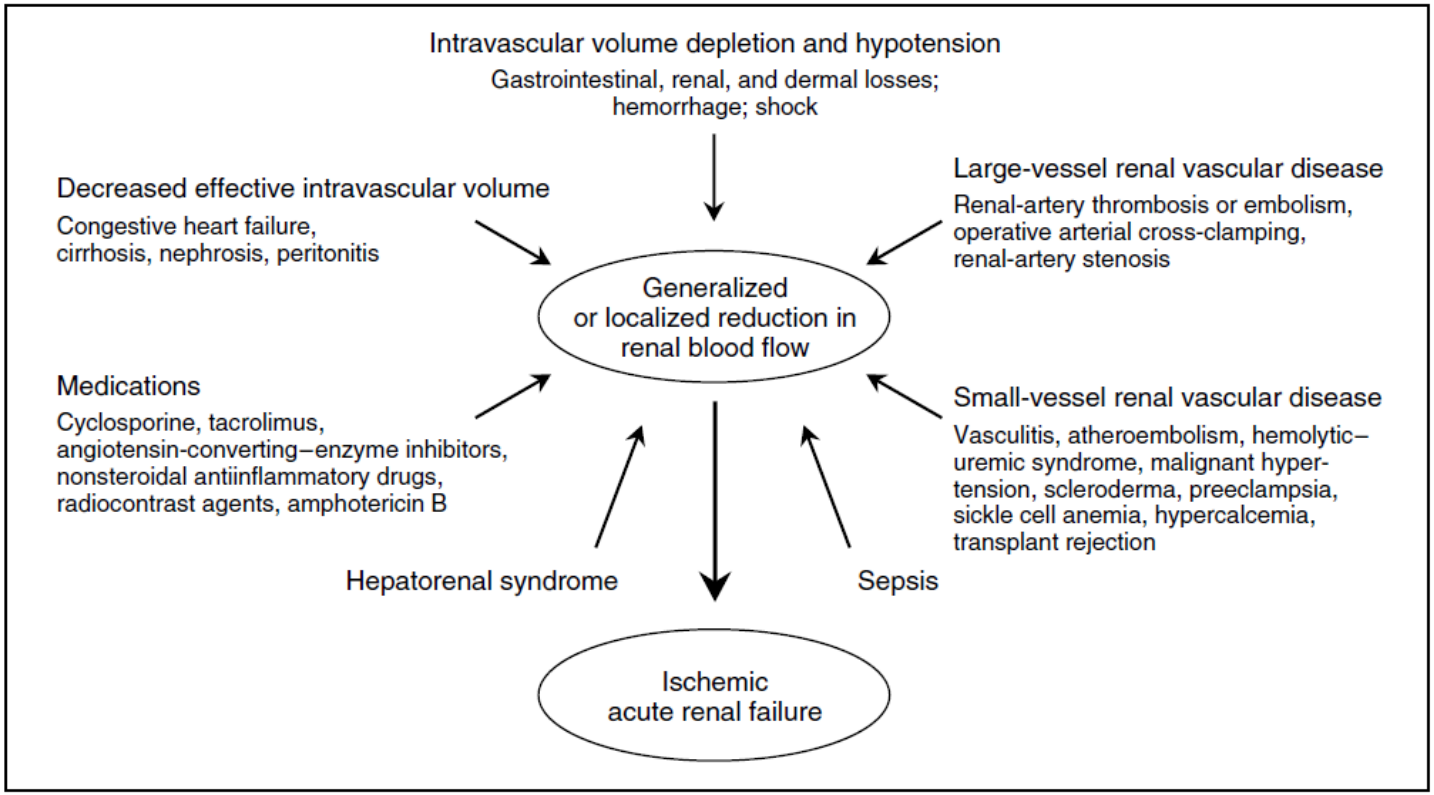


Figure 2. Conditions That Lead to Ischemic Acute Renal Failure.

A wide spectrum of clinical conditions can result in a generalized or localized reduction in renal blood flow, thus increasing the likelihood of ischemic acute renal failure. The most common condition leading to ischemic acute renal failure is severe and sustained prerenal azotemia. Kidney ischemia and acute renal failure are often the result of a combination of factors.

Pathophysiology

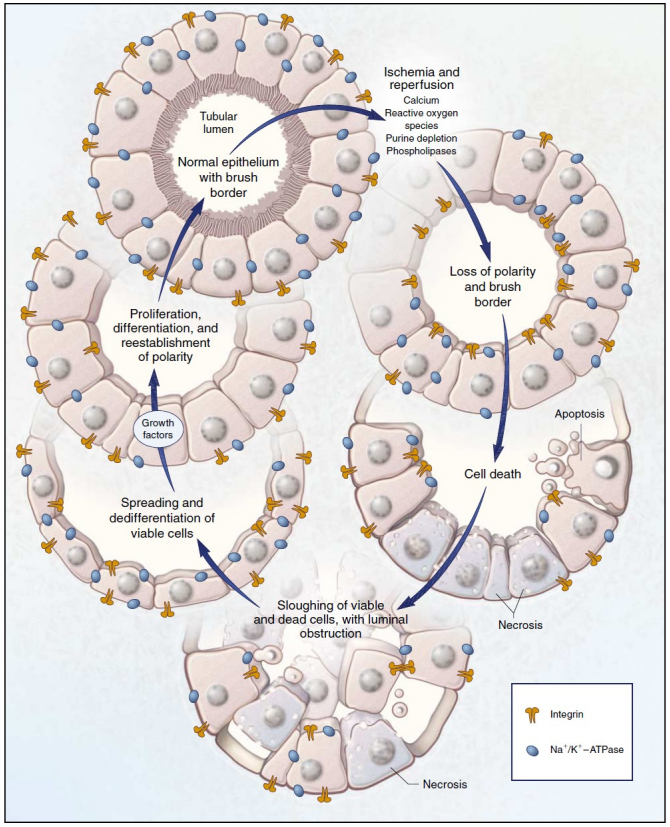


Figure 3. Tubular-Cell Injury and Repair in Ischemic Acute Renal Failure.

After ischemia and reperfusion, morphologic changes occur in the proximal tubules, including loss of the brush border, loss of polarity, and redistribution of integrins and Na^+/K^+–ATPase to the apical surface. Calcium, reactive oxygen species, purine depletion, and phospholipases probably have a role in these changes in morphology and polarity as well as in the subsequent cell death that occurs as a result of necrosis and apoptosis. There is a sloughing of viable and nonviable cells into the tubular lumen, resulting in the formation of casts and luminal obstruction and contributing to the reduction in the glomerular filtration rate. The severely damaged kidney can completely restore its structure and function. Spreading and dedifferentiation of viable cells occur during recovery from ischemic acute renal failure, which duplicates aspects of normal renal development. A variety of growth factors probably contribute to the restoration of a normal tubular epithelium.

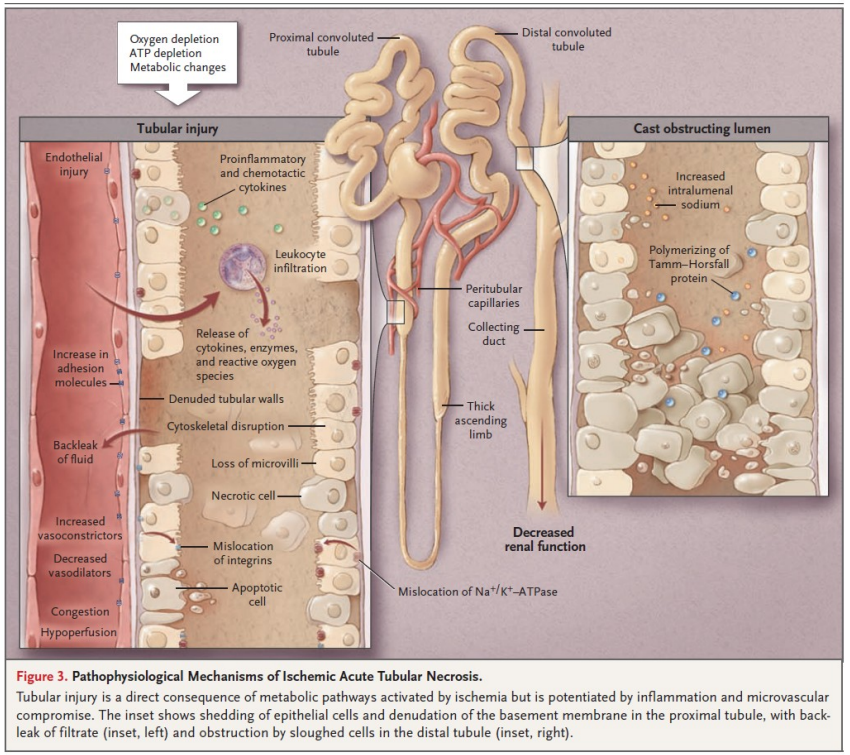
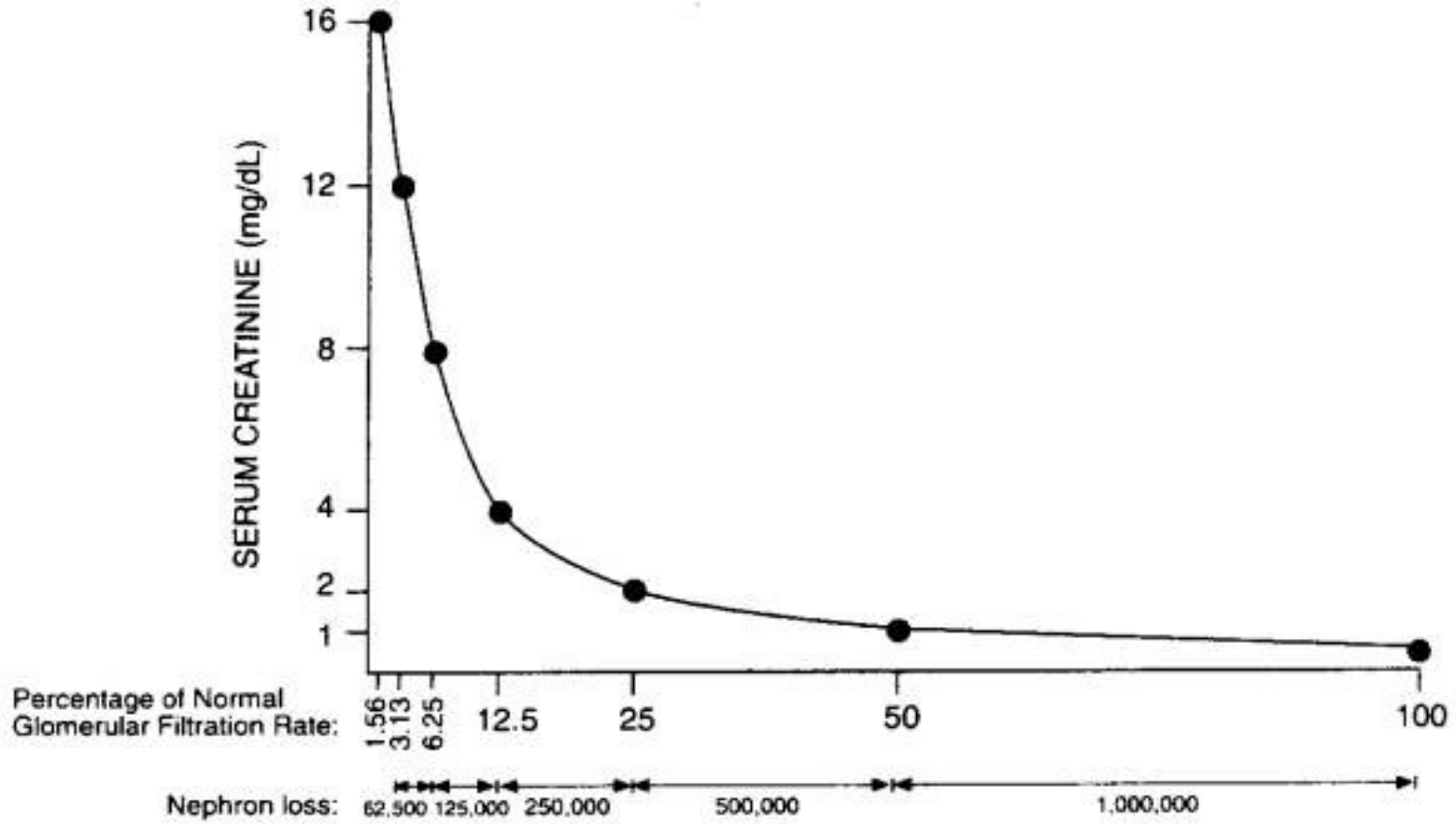


Figure 3. Pathophysiological Mechanisms of Ischemic Acute Tubular Necrosis.

Tubular injury is a direct consequence of metabolic pathways activated by ischemia but is potentiated by inflammation and microvascular compromise. The inset shows shedding of epithelial cells and denudation of the basement membrane in the proximal tubule, with backleak of filtrate (inset, left) and obstruction by sloughed cells in the distal tubule (inset, right).

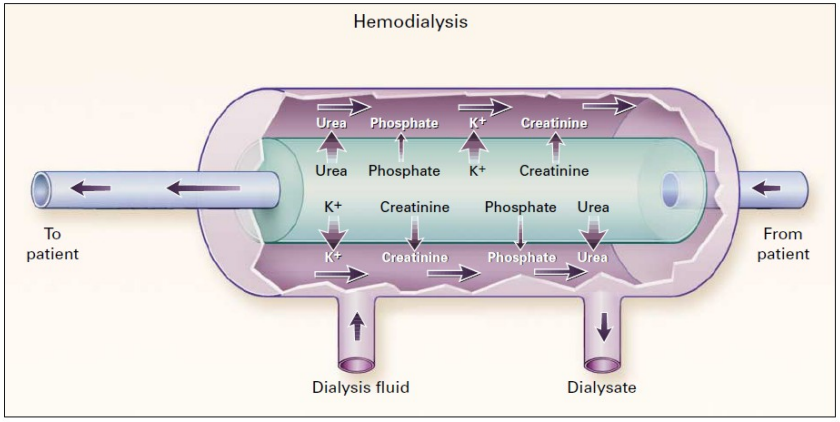
Management strategy/goals

- Measures to correct underlying causes of AKI should begin at the earliest indication of renal dysfunction.



- **Maintenance of volume homeostasis** and **correction of biochemical abnormalities** remain the primary goals of treatment.
- **Correct severe acidosis** with bicarbonate administration. Important as a bridge to dialysis.
- **Hyperkalemia,**
  - decrease the intake of potassium in **diet** or tube feeds,
  - exchange potassium across the gut lumen using **potassium-binding resins**,
  - promote intracellular shifts in potassium with **insulin and dextrose** solutions, and
  - institute **dialysis**.
- **Correct hematologic abnormalities** (eg, anemia, uremic platelet dysfunction).
- **The Acute Renal Failure Trial Network (ATN) Study** completed in 2008 was designed to compare clinical outcomes between patients allocated to an **intensive dose versus a less-intensive dose of renal replacement therapy**.

Renal replacement therapy



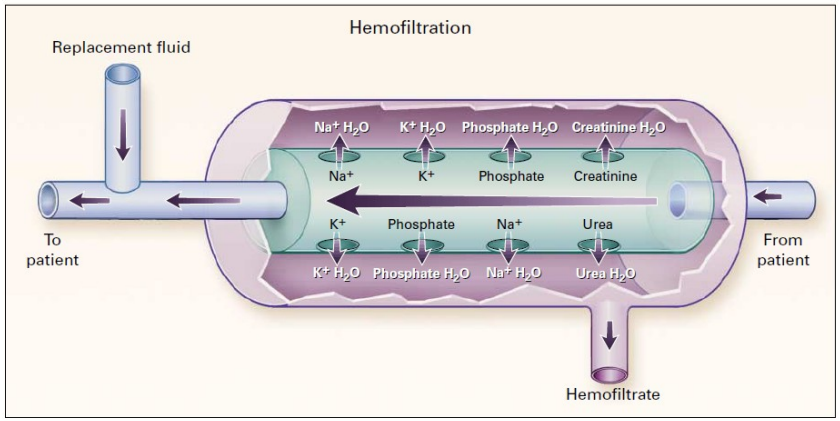


Figure 1. Hemodialysis and Hemofiltration.
The arrows that cross the membrane indicate the predominant direction of movement of each solute through the membrane; the relative size of the arrows indicates the net amounts of the solute transferred. Other arrows indicate the direction of flow.

TABLE 2. TYPES OF RENAL-REPLACEMENT THERAPY FOR ACUTE RENAL FAILURE.

TYPE	COMPLEXITY	EFFICIENCY	COST	ANTI-COAGULANT THERAPY	RISK OF HEMORRHAGE	RISK OF INFECTION	EXTRA-CELLULAR-FLUID VOLUME CONTROL	USE IN HYPO-TENSION
Peritoneal dialysis	Low	Moderate	Moderate	No	Low	High	Moderate	Yes
Intermittent hemodialysis	Moderate	High	Low	Yes	Moderate	Low	Intermittent	No
Continuous arteriovenous hemofiltration	Moderate	Low and variable	Moderate	Yes	Moderate	Low	Good	No
Continuous arteriovenous hemodialysis with filtration	High	Moderate and variable	High	Yes	Moderate	Low	Good	Variable
Continuous venovenous hemofiltration	Moderate	High	Moderate	Yes	Moderate	Low	Good	Yes
Continuous venovenous hemodialysis with filtration	High	High	High	Yes	Moderate	Low	Good	Yes

Frusemide

- **Diuretics**
- Although diuretics seem to have no effect on the outcome of established AKI, they appear useful in fluid homeostasis and are used extensively.
- The only therapeutic or preventive intervention that has an established beneficial effect in the management of AKI is administration of isotonic sodium chloride solution to keep the patient euvolemic or even hypervolemic.
- Increases excretion of water by interfering with chloride-binding cotransport system, which, in turn, inhibits sodium and chloride reabsorption in the thick ascending loop of Henle and the distal renal tubule. Potent and rapid-acting agent with peak action at 60 min and lasting 6-8 h.
- In renal failure, higher doses must be used for greater diuretic effects. Doses as high as 600 mg/d may be needed under monitored conditions.
- Frequently, IV doses are needed in AKI to maintain urine output. IV infusions are often helpful in ICU settings, in which larger doses are necessary. This method promotes a sustained natriuresis with reduced ototoxicity compared to conventional intermittent bolus dosing.

Dopamine

- **Vasodilators**
- Dopamine in small doses (eg, 1-5 mcg/kg/min) causes selective dilatation of the renal vasculature, enhancing renal perfusion. Dopamine also reduces sodium absorption, thereby decreasing the energy requirement of the damaged tubules. This enhances urine flow, which, in turn, helps prevent tubular cast obstruction. Most clinical studies have failed to establish this beneficial role of renal-dose dopamine infusion.

- Stimulates both adrenergic and dopaminergic receptors. Hemodynamic effect is dose-dependent. Lower doses predominantly stimulate dopaminergic receptors, which, in turn, produce renal and mesenteric vasodilation. Cardiac stimulation and renal vasodilation produced by higher doses.

Nifedipine

- **Calcium channel blockers**
- Effective in animal models but efficacy not proven in humans. Effects are believed to be mediated through vasodilation, and calcium channel blockers increasingly are used to enhance the function of transplanted kidneys.

- Relaxes smooth muscle and produces vasodilation, which, in turn, improves blood flow and oxygen delivery.

N-acetylcysteine

- Used for prevention of contrast toxicity in susceptible individuals such as those with diabetes mellitus.

- May provide substrate for conjugation with toxic metabolites.

Prognosis

- The prognosis of patients with AKI is directly related to the cause of renal failure and, to a great extent, to the duration of renal failure prior to therapeutic intervention.
- However, even if renal failure is mild, the mortality rate is 30-60%. If these patients need dialytic therapy, the mortality rate is 50-90%.
  - The mortality rate is 31% in patients with normal urine sediment test results and is 74% in patients with abnormal urine sediment test results.
  - The survival rate is nearly 0% among patients with AKI who have an Acute Physiology and Chronic Health Evaluation II (APACHE II) score higher than 40; the survival rate is 40% in patients with APACHE II scores of 10-19.
  - Other prognostic factors include the following:
    - Older age
    - Multiorgan failure (ie, the more organs that fail, the worse the prognosis)
    - Oliguria
    - Hypotension
    - Vasopressor support
    - Number of transfusions
    - Noncavitary surgery

Literature review

Bedside Tool for Predicting the Risk of Postoperative Dialysis in Patients Undergoing Cardiac Surgery

Rajendra H. Mehta, MD, MS; Joshua D. Grab, MS; Sean M. O'Brien, PhD; Charles R. Bridges, MD; James S. Gammie, MD; Constance K. Haan, MD; T. Bruce Ferguson, MD; Eric D. Peterson, MD, MPH; for the Society of Thoracic Surgeons National Cardiac Surgery Database Investigators

Background—Estimation of an individual patient's risk for postoperative dialysis can support informed clinical decision making and patient counseling.

Methods and Results—To develop a simple bedside risk algorithm for estimating patients' probability for dialysis after cardiac surgery, we evaluated data of 449 524 patients undergoing coronary artery bypass grafting (CABG) and/or valve surgery and enrolled in >600 hospitals participating in the Society of Thoracic Surgeons National Database (2002–2004). Logistic regression was used to identify major predictors of postoperative dialysis. Model coefficients were then converted into an additive risk score and internally validated. The model also was validated in a second sample of 86 009 patients undergoing cardiac surgery from January to June 2005. Postoperative dialysis was needed in 6451 patients after cardiac surgery (1.4%), ranging from 1.1% for isolated CABG procedures to 5.1% for CABG plus mitral valve surgery. Multivariable analysis identified preoperative serum creatinine, age, race, type of surgery (CABG plus valve or valve only versus CABG only), diabetes, shock, New York Heart Association class, lung disease, recent myocardial infarction, and prior cardiovascular surgery to be associated with need for postoperative dialysis (*c* statistic=0.83). The risk score accurately differentiated patients' need for postoperative dialysis across a broad risk spectrum and performed well in patients undergoing isolated CABG, off-pump CABG, isolated aortic valve surgery, aortic valve surgery plus CABG, isolated mitral valve surgery, and mitral valve surgery plus CABG (*c* statistic=0.83, 0.85, 0.81, 0.75, 0.80, and 0.75, respectively).

Conclusions—Our study identifies the major patient risk factors for postoperative dialysis after cardiac surgery. These risk factors have been converted into a simple, accurate bedside risk tool. This tool should facilitate improved clinician–patient discussions about risks of postoperative dialysis. (***Circulation***. **2006;114:2208-2216.**)

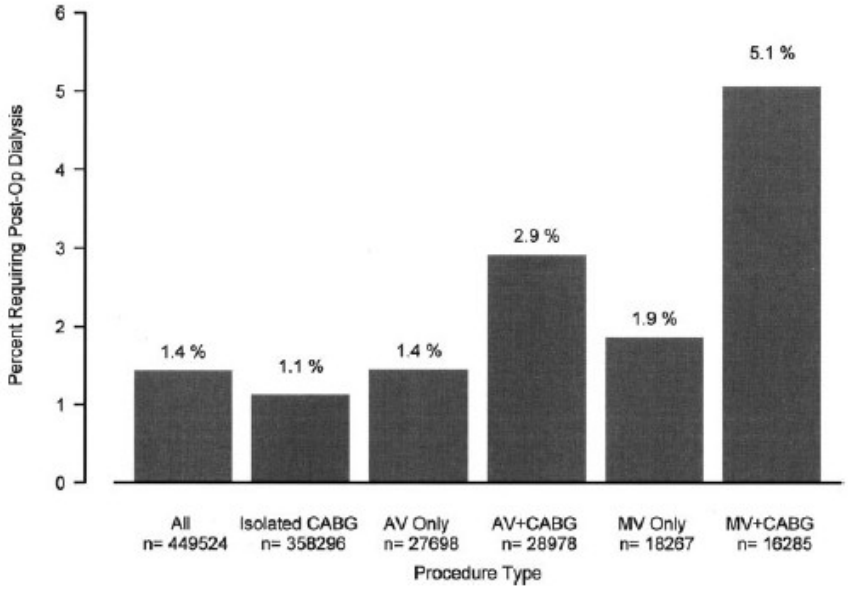


Figure 1. Postoperative dialysis frequency by procedure type. AV indicates aortic valve surgery; MV, mitral valve surgery.

Valvular Heart Operation Is an Independent Risk Factor for Acute Renal Failure

Antony D. Grayson, Magdy Khater, FRCA, Mark Jackson, PhD, and Mark A. Fox, FRCA

Departments of Research and Development and Cardiothoracic Anaesthesia, The Cardiothoracic Centre, Liverpool, United Kingdom

Background. Acute renal failure (ARF) after cardiac operation with cardiopulmonary bypass is associated with a high mortality rate. The purpose of this study was to determine and quantify whether valvular heart operation is an independent risk factor for developing ARF.

Methods. We retrospectively analyzed 5,132 consecutive patients who underwent cardiac operation involving cardiopulmonary bypass between April 1997 and March 2001. Patients with significant renal impairment (preoperative serum creatinine > 200 μmol/L) were excluded. A multivariable logistic regression model was constructed to identify independent risk factors for the postoperative development of ARF.

Results. In 151 (2.9%) patients ARF developed before hospital discharge. The crude incidence of ARF for isolated coronary artery bypass grafting, isolated valve(s) operation, and valve(s) with coronary artery bypass grafting operation was 1.9%, 4.4%, and 7.5%, respectively ($p < 0.001$). The results of the logistic regression analysis found that valve operation with or without coronary artery bypass grafting was an independent risk factor for the development of postoperative ARF (odds ratio 2.68, 95% confidence interval 1.89 to 3.79; $p < 0.001$). Other independent predictors of ARF were increased preoperative serum creatinine levels, urgent or emergent operation, insulin-dependent diabetes, and increased cardiopulmonary bypass time.

Conclusions. Valve operation is an independent risk factor for postoperative ARF. This risk is further increased by prolonged cardiopulmonary bypass.

(Ann Thorac Surg 2003;75:1829–35)

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TABLE 1. Patient Characteristics

Characteristics	Overall	No Postoperative Dialysis	Postoperative Dialysis	*P*
Sample size, n (%)	449 524 (100)	443 073 (98.6)	6451 (1.4)	
Demographics				
Age, median (IQR), y	67 (58–74)	66 (58–74)	73 (65–79)	<0.0001
Female, %	30.4	30.2	39.5	<0.0001
White, %	88.1	88.1	85.0	<0.0001
BMI, median (IQR), m^2	28.2 (25.2–32.0)	28.2 (25.2–32.0)	28.4 (25.0–33.3)	<0.0001
BSA, median (IQR), m^2	2.0 (1.8–2.1)	2.0 (1.8, 2.1)	1.9 (1.8–2.1)	<0.0001
Medical history, %				
Hypertension	75.2	75.1	83.6	<0.0001
Diabetes	33.2	33.0	48.9	<0.0001
Current smoker	21.4	21.5	15.3	<0.0001
Obesity	11.3	11.3	15.8	<0.0001
Hypercholesterolemia	68.7	68.7	65.7	<0.0001
Chronic lung disease	19.6	19.5	31.1	<0.0001
Preoperative renal failure	4.2	3.8	27.6	<0.0001
Stroke	7.3	7.2	13.6	<0.0001
Infectious endocarditis	0.9	0.9	2.3	<0.0001
Immunosuppressive treatment	2.0	2.0	4.4	<0.0001
Peripheral vascular disease	14.6	14.5	25.9	<0.0001
Cerebrovascular disease	13.8	13.7	24.0	<0.0001
Preoperative cardiac status, %				
Prior CABG	6.0	5.9	12.7	<0.0001
Prior PCI	19.6	19.6	20.1	0.0863
Prior valve surgery	2.3	2.3	4.0	<0.0001
LVEF, median (IQR)	51	51	45	<0.0001
Mitral regurgitation	23.3	23.0	41.6	<0.0001
Left main disease >50%	22.9	22.8	26.7	<0.0001
Myocardial infarction <3 wk	22.9	22.7	36.6	<0.0001
Congestive heart failure	19.6	19.1	48.1	<0.0001
Cardiogenic shock	1.9	1.8	10.3	<0.0001
NYHA class IV	20.4	20.1	38.4	<0.0001
Preoperative IABP	6.5	6.4	17.0	<0.0001
Inotropic support	2.1	2.0	9.7	<0.0001
Operative details				
Surgery type				
CABG only, %	78.6	78.6	62.6	<0.0001
Aortic valve surgery only, %	6.2	6.2	6.2	0.8546
CABG plus aortic valve surgery, %	6.5	6.4	13.1	<0.0001
Mitral valve surgery only, %	4.1	4.1	5.3	<0.0001
CABG plus mitral valve surgery, %	3.6	3.5	12.8	<0.0001
Elective surgery, %	53.6	53.8	38.5	<0.0001
Urgent surgery, %	42.3	42.2	48.9	<0.0001
Emergent surgery, %	3.8	3.7	10.9	<0.0001
Emergent salvage surgery, %	0.3	0.2	1.6	<0.0001
Intraoperative IABP, %	2.1	1.9	11.8	<0.0001
Perfusion time, median >90th percentile, %	5.4	5.2	18.8	<0.0001
Cross-clamp time, median (IQR), min	69 (51–93)	69 (51–93)	85 (60–117)	<0.0001

IQR indicates interquartile range; BMI, body mass index; BSA, body surface area; PCI, percutaneous coronary intervention; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; and IABP, intra-aortic balloon pump.

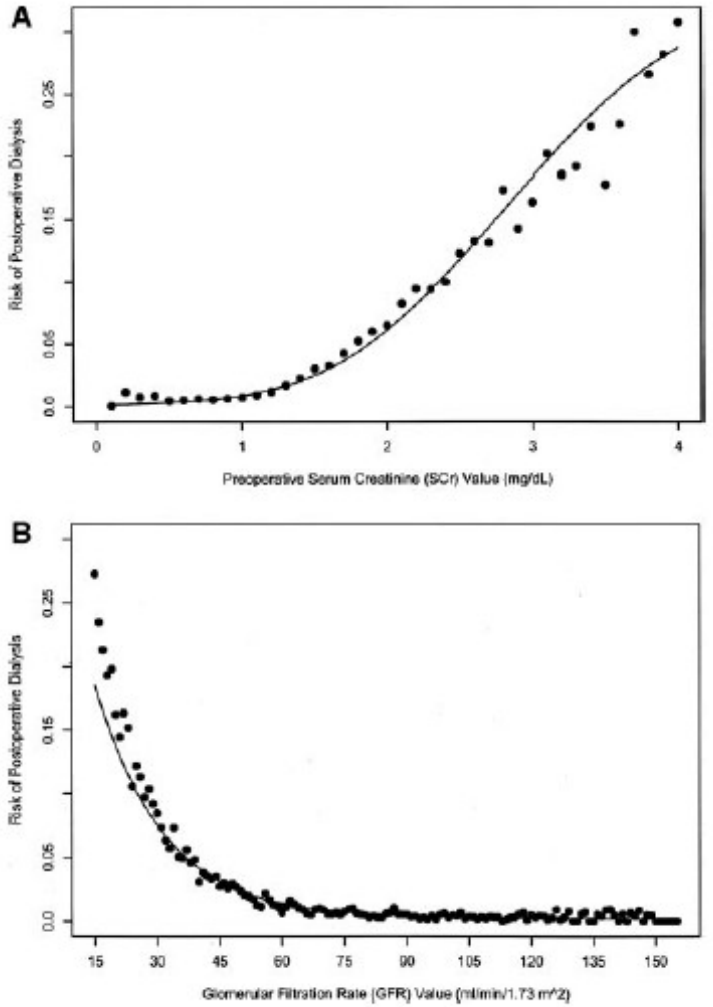


Figure 2. A, Risk of dialysis based on preoperative serum creatinine demonstrating a direct relationship between the preoperative serum creatinine and the need for postoperative dialysis. B, Similarly, the inverse relationship between preoperative GFR and the need for postoperative dialysis. Each data point represents >1 patient with same serum creatinine value.

TABLE 3. Independent Correlates of the Need for Postoperative Dialysis After Cardiac Surgery Using Preoperative Serum Creatinine

	Full Model		Simplified Model Approximation	
Variables	OR	95% CI	OR	95% CI
GFR, mL/min per 1.73 m^2				
30 vs 90	9.85	8.89–10.90	...	...
45 vs 90	4.51	4.10–4.96	...	...
60 vs 90	2.07	1.85–2.31	...	...
Serum creatinine	...	...	4.62	4.34–4.92
Aortic valve surgery	1.45	1.24–1.69	1.44	1.29–1.60
Aortic valve surgery plus CABG	1.94	1.70–2.22	2.14	1.97–2.32
Mitral valve surgery	2.01	1.72–2.34	2.00	1.77–2.26
Mitral valve surgery plus CABG	2.57	2.29–2.88	3.12	2.87–3.39
Age (in 5-y increments starting at age <50 y)	1.14	1.13–1.16	1.23	1.21–1.24
Diabetes treated with insulin	1.86	1.74–2.00	2.17	2.03–2.33
Diabetes treated with oral agents	1.32	1.23–1.41	1.42	1.33–1.51
Chronic lung disease	1.45	1.37–1.54	1.57	1.49–1.66
Myocardial infarction in last 3 wk	1.36	1.28–1.45	1.44	1.36–1.53
Cardiogenic shock	1.92	1.71–2.16	2.36	2.10–2.64
NYHA class IV	1.41	1.33–1.49	1.49	1.41–1.58
Race (nonwhite vs white)	1.39	1.29–1.49	1.28	1.19–1.38
Prior CV surgery	1.55	1.44–1.67	1.63	1.51–1.75
Variables in the full model that were excluded from the simplified model approximation				
Female	0.83	0.77, 0.90	...	...
Peripheral or cerebrovascular disease	1.23	1.17, 1.30	...	...
Body surface area	0.78	0.62, 0.99	...	...
Left ventricular ejection fraction	0.99	0.99, 0.99	...	...
Emergent status, salvage/resuscitation vs elective/urgent	2.19	1.71, 2.81	...	...
Emergent status, emergent (no salvage) vs elective/urgent	1.7	1.53, 1.90	...	...
Triple-vessel disease	1.25	1.17, 1.34	...	...
Left main disease	1.12	1.06, 1.20	...	...
Prior percutaneous coronary interventions	1.64	1.34, 2.01	...	...
Hypertension	1.15	1.08, 1.24	...	...
Immunosuppressive treatment	1.4	1.23, 1.59	...	...
Aortic stenosis	1.24	1.09, 1.40	...	...
Mitral insufficiency	1.18	1.08, 1.30	...	...

OR indicates odds ratio; CI, confidence interval; NYHA, New York Heart Association; and CV, cardiovascular.

Dialysis risk post cardiac surgery

										Score
Last Creatinine	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0 and higher		
Points (Creatinine * 10)	5	10	15	20	25	30	35	40		
Age	<55	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95–99	100+	
Points	0	1	2	3	4	5	6	7	8	9	10	
Surgery	CABG Only	AV Only	AV + CABG	MV Only	MV + CABG	
Points	0	2	5	4	7	
Diabetes	No Diabetes	Controlled Orally	Insulin Dependent	
Points	0	2	5	
MI Recent	No Recent MI	Within Last 3 weeks	
Points	0	3	
Race	White	Non-White	
Points	0	2	
Chronic Lung Disease	No	Yes	
Points	0	3	
Reoperation	No Prior CV Surgery	Prior CAB or Other CV Surgery	
Points	0	3	
NYHA Class	I,II,III	IV	
Points	0	3	
Cardiogenic Shock	No	Yes	
Points	0	7	
									Total Score:	

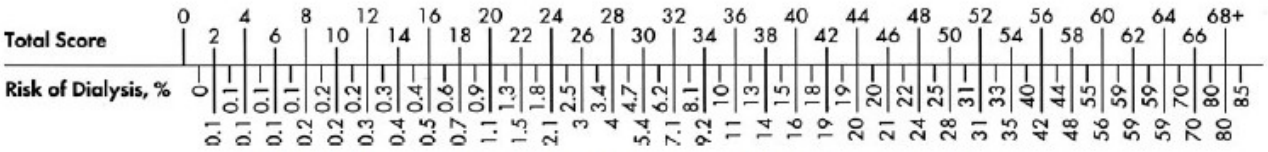


Figure 4. Nomogram to predict postoperative renal dysfunction needing dialysis.

A Clinical Score to Predict Acute Renal Failure after Cardiac Surgery

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The risk of mortality associated with acute renal failure (ARF) after open-heart surgery continues to be distressingly high. Accurate prediction of ARF provides an opportunity to develop strategies for early diagnosis and treatment. The aim of this study was to develop a clinical score to predict postoperative ARF by incorporating the effect of all of its major risk factors. A total of 33,217 patients underwent open-heart surgery at the Cleveland Clinic Foundation (1993 to 2002). The primary outcome was ARF that required dialysis. The scoring model was developed in a randomly selected test set (n = 15,838) and was validated on the remaining patients. Its predictive accuracy was compared by area under the receiver operating characteristic curve. The score ranges between 0 and 17 points. The ARF frequency at each score level in the validation set fell within the 95% confidence intervals (CI) of the corresponding frequency in the test set. Four risk categories of increasing severity (scores 0 to 2, 3 to 5, 6 to 8, and 9 to 13) were formed arbitrarily. The frequency of ARF across these categories in the test set ranged between 0.5 and 22.1%. The score was also valid in predicting ARF across all risk categories. The area under the receiver operating characteristic curve for the score in the test set was 0.81 (95% CI 0.78 to 0.83) and was similar to that in the validation set (0.82; 95% CI 0.80 to 0.85; P = 0.39). In conclusion, a score is valid and accurate in predicting ARF after open-heart surgery; along with increasing its clinical utility, the score can help in planning future clinical trials of ARF.

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Table 4. ARF score[a]

Risk Factor	Points
Female gender	1
Congestive heart failure	1
Left ventricular ejection fraction <35%	1
Preoperative use of IABP	2
COPD	1
Insulin-requiring diabetes	1
Previous cardiac surgery	1
Emergency surgery	2
Valve surgery only (reference to CABG)	1
CABG + valve (reference to CABG)	2
Other cardiac surgeries	2
Preoperative creatinine 1.2 to <2.1 mg/dl (reference to 1.2)	2
Preoperative creatinine ≥2.1 (reference to 1.2)	5

[a]Minimum score, 0; maximum score, 17.

Validation of a clinical score to determine the risk of acute renal failure after cardiac surgery

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Received 31 March 2009; received in revised form 6 July 2009; accepted 7 July 2009; Available online 27 August 2009

Abstract

Objective: Preoperative assessment of risk factors for postoperative acute renal failure (ARF) is a key point in the management of cardiac surgery patients. A reliable evaluation of individual risk permits the efficient application of prophylactic and therapeutic measures to patients with increased risk of ARF. In 2005, Thakar published a scoring system to determine the ARF risk prior to surgery. The score allowed calculation of the incidence of postoperative ARF requiring dialysis (ARF-D) with a high level of precision. **Methods:** In order to examine the reproducibility of the results on different patient populations, we retrospectively applied the scoring system to 3508 cardiac surgery patients at the Goettingen University Hospital. **Results:** We found a qualitative correlation between the score value and ARF-D, but prognostic significance, when judged by the area under the receiver operating characteristic (ROC) curve, was considerably reduced. Also, the incidence of ARF-D in the Goettingen population was remarkably higher than the incidence shown by Thakar for patients with the same score. **Conclusions:** The correlation between score values and incidence of ARF-D shows that the Thakar score is qualitatively transferable to cardiac surgery patients from other centres. Though the score allows the discrimination between patients with higher or lower risks of ARF-D within the Goettingen collective, it was not suitable to estimate the real incidence of postoperative ARF-D with sufficient precision.
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Early hemofiltration improves survival in post-cardiotomy patients with acute renal failure☆

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Abstract

Objective: The application and timing of hemofiltration (continuous veno-venous hemofiltration, CVVH) in patients with acute renal failure (ARF) post cardiac surgery has been called into question because of uncertain short-term outcome. The aim of the present study was to identify how the timing of introduction of hemofiltration affects the morbidity and mortality in patients with ARF after cardiac surgery. **Methods**: 1264 consecutive patients who underwent adult cardiac surgical procedures performed between January 2002 and January 2003 were audited. Out of these, case notes of 64 patients who required renal supportive intervention were reviewed. Statistical significance was accepted at a level of $P<0.05$. **Results**: Of the 64 (5%) patients, who developed ARF and required CVVH, there were 48 males and 16 females. Mean age was 70 ± 6.8 years. The hospital mortality was 43% (12 patients) in Group-I and 22% (8) in Group-II ($P<0.05$), giving an overall 1.5% mortality associated with ARF. The mean time between the operation and the initiation of CVVH was 2.55 ± 2.2 days in Group-I and 0.78 ± 0.2 days in Group-II ($P<0.001$). The mean duration of CVVH was 4.57 ± 11.4 days in Group-I and 4.61 ± 2.0 days in Group-II ($P=$NS). Older age ($P=0.013$), elevated preoperative creatinine ($P=0.002$), postoperative pulmonary oedema ($P=0.01$), sepsis ($P=0.001$), multiple organ failure ($P=0.031$), hypotension ($P=0.031$) and preoperative renal failure ($P<0.05$) were the independent factors influencing the poor postoperative outcome and cardiac instability. **Conclusion**: Early and aggressive use of CVVH is associated with better than expected survival in severe ARF after cardiac operations.

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Does furosemide prevent renal dysfunction in high-risk cardiac surgical patients? Results of a double-blinded prospective randomised trial☆,☆☆

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Abstract

Objective: Renal dysfunction following cardiac surgery is more apparent in high-risk patients with pre-existing renal dysfunction, diabetes and impaired left-ventricular function, and following complicated procedures involving prolonged cardiopulmonary bypass (CPB). The aim of this prospectively randomised double-blinded placebo-controlled study was to evaluate reno-protective effect of low-dose furosemide infusion in this high-risk group. **Methods:** Patients with preoperative serum creatinine >130 μmol/l (1.4 mg/dl), left-ventricular ejection fraction <50%, congestive heart failure, diabetes, or procedures involving prolonged CPB were randomised to receive either saline at 2 ml/h ($n = 21$), or furosemide at 4 mg/h ($n = 21$). Infusion was commenced after induction of anaesthesia and continued for 12 h postoperatively. Renal dysfunction was defined as >50% increase in serum creatinine postoperatively, or >130 μmol/l (1.4 mg/dl), or requirement for haemodialysis, or all of these. In patients with preoperative serum creatinine >130 μmol/l, >50% increase over preoperative levels was used to define postoperative renal dysfunction. **Results:** Following cardiac surgery, patients receiving furosemide had a *higher* urine output (3.4 ± 1.2 ml/kg/h in furosemide group and 1.2 ± 0.5 ml/kg/h in placebo group; $p < 0.001$), *higher* postoperative fluid requirement (4631 ± 1359 ml in furosemide group and 3714 ± 807 ml in placebo group, $p = 0.011$), and *lower* urinary-creatinine (2 ± 1.3 μmol/l in furosemide group and 5.9 ± 2.5 μmol/l in placebo group $p < 0.001$). Both groups had significant *increase* in retinol binding protein/creatinine ratio (7.2 ± 6 to 3152 ± 1411 in furosemide group; 4.9 ± 2.1 to 2809 ± 1125 in placebo group; $p < 0.001$) and peak serum creatinine (98 ± 33 to 177 ± 123 μmol/l in furosemide group; 96 ± 20 to 143 ± 87 μmol/l in placebo group; $p < 0.001$), and a significant *decrease* in peak creatinine-clearance (64.3 ± 29.4 to 39.1 ± 16.6 ml/min in furosemide group; 65.5 ± 38.6 to 41.8 ± 17.8 ml/min in placebo group; $p < 0.001$) following cardiac surgery, implying significant renal injury following cardiac surgery. Peak creatinine levels (177 ± 123 μmol/l in furosemide group and 143 ± 87 μmol/l in placebo group; $p = 0.35$) and peak creatinine-clearance (39.1 ± 16.6 ml/min in furosemide group and 41.8 ± 17.8 ml/min in placebo group; $p = 0.61$) were similar in the two groups. Importantly, there was *no difference* in incidence of renal dysfunction between the furosemide group (9/21) and the control group (8/21) (relative risk 1.1, 95% confidence interval 0.6—2.2; $p = 0.99$). **Conclusions:** Our randomised trial did not demonstrate any benefit of furosemide-infusion postoperatively in high-risk cardiac surgical patients. Although urinary output increased with furosemide, there was no decrease in renal injury, and no decrease in incidence of renal dysfunction.

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Mannitol, Furosemide, and Dopamine Infusion in Postoperative Renal Failure Complicating Cardiac Surgery

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Background. Acute renal failure occurring in the postoperative period, requiring dialysis after cardiac surgery is an important risk factor for an early mortality, and the overall mortality of this complication is as high as 40% to 60%. Dialysis in the early postoperative period is often complicated by acute hemodynamic, metabolic, and hematologic effects that adversely affect cardiopulmonary function in patients stabilizing from recent surgery. The purpose of this study was to avoid the need for dialysis by infusion of the solution of mannitol, furosemide, and dopamine in the early postoperative period in oliguric renal failure.

Methods. One hundred patients with postoperative oliguric or anuric renal failure despite adequate postoperative cardiac output and hemodynamic function were randomized. Forty patients (group A) were given intermittent doses of diuretics (furosemide, bumetadine, and ethracrynic acid) and fluids. Sixty patients (group B) were given continuous infusion of the solution of mannitol, furosemide, and dopamine; the infusion was started within 6 hours (mean 3.5 hours) in subgroup B1 (n = 30), and later than 6 hours (mean 7.5 hours) in subgroup B2 (n = 30) after the onset of renal failure.

Results. Diuresis occurred in 93.3% of group B (n = 56) versus 10% in group A (n = 4; patients with preop normal renal function). Ninety percent of group A (n = 36) required dialysis versus only 6.7% of group B (n = 4; patients with preexisting renal disease of subgroup B2). Renal function returned to preoperative normal (serum creatinine 0.9 ± 0.05, $p < 0.0001$) or baseline value (serum creatinine 2.5 ± 0.01, $p < 0.0001$) after first postoperative week in subgroup B1 and third postoperative week in subgroup B2.

Conclusions. Infusion of solution of mannitol, furosemide, and dopamine promoted diuresis in patients with acute postoperative renal failure with adequate postoperative cardiac output and had decreased the need for dialysis in the majority of patients. Early administration of this solution in acute renal failure caused early restoration of renal function to normal or baseline status. It remains to be determined whether routine administration of this solution in the early postoperative period for oliguric renal failure influences the long-term mortality and morbidity in those patients who do require dialysis.

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Long and short-term outcomes in patients requiring continuous renal replacement therapy post cardiopulmonary bypass

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Abstract

Objective: The development of acute renal failure following cardiac surgery is a rare but devastating complication with high morbidity and mortality. This study aimed to assess the incidence of acute renal failure necessitating continuous renal replacement therapy (CRRT) in patients who required cardiopulmonary bypass, to determine the factors associated with mortality and to evaluate long-term outcome. **Methods:** Patients who underwent cardiac surgery between October 1997 and 2003 and treated with CRRT were included ($n=98$). Six patients were then excluded (already in established renal failure pre-operatively) and one patient lost to follow-up. A retrospective analysis was carried out. **Results:** Overall CRRT was used in 2.9% (92/3172). The mean (SD) age of patients was 68 (10) years. Their mean pre-operative creatinine level and duration of cardiopulmonary bypass were 154 (87) micromol/l and 160 (84) min, respectively. Mean duration from surgery to establishment of CRRT was 50 (42) h. Mean creatinine level prior to hospital discharge was 168 (93) micromol/l. Thirty-day mortality was 42%. Significant risk factors for death were complex procedures (odds ratio=9.9), gastro-intestinal complications (OR=7.2), cross-clamp time over 88 min (OR=5.9), re-exploration (OR=4.0) and patients age over 75 years (OR=3.3). Actuarial 1 and 5-year survivals (95% CI) were 53 (43, 63) % and 52 (42, 62) %, respectively. Only 2 (2.2%) patients required long term renal support. **Conclusions:** Acute renal failure necessitating the use of CRRT is a rare but serious complication post cardiopulmonary bypass. In the long-term, surviving patients are not likely to require further renal support.
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Best evidence topic - Cardiac general

Does the use of non-steroidal anti-inflammatory drugs after cardiac surgery increase the risk of renal failure?

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Summary

A best evidence topic in cardiac surgery was written according to a structured protocol. The question addressed was whether the use of non-steroidal anti-inflammatory drugs (NSAIDs) for pain relief postcardiac surgery increases the risk of renal failure. Altogether 53 papers were found using the reported search, of which 11 represented the best evidence to answer the clinical question. The authors, journal, date and country of publication, patient group studied, study type, relevant outcomes and results of these papers are tabulated. We identified 11 studies, comprising one meta-analysis, seven randomised controlled trials, and three retrospective studies. The meta-analysis of 1065 patients across 20 RCTs established that the risk of renal failure was not significantly higher with perioperative NSAID usage [odds ratio (OR) 0.95, 95% confidence interval (CI) 0.37–2.46]. Furthermore, there was no statistically significant difference in serum creatinine levels between NSAID and control groups. Six RCTs agreed that postoperative NSAID therapy was not associated with an elevation in serum creatinine levels suggestive of renal failure. One of these RCTs was conducted in a paediatric population undergoing congenital heart surgery, and achieved equivalent results. Another large RCT found a non-significant increase in the incidence of renal failure/dysfunction in patients receiving the cyclo-oxygenase 2 (COX-2) selective drugs parecoxib and valdecoxib vs. placebo (placebo vs. parecoxib and valdecoxib: relative risk (RR) 2.4, 95% CI 0.6–9.2, $P=0.20$) whilst highlighting the potential adverse vascular effects of this drug class. In contrast, one RCT assessing these COX-2 inhibitors detected a significant increase in the incidence of oliguria in this group compared to controls (parecoxib/valdecoxib: 14.5%, controls: 9.9%, $P=0.187$) as well as renal dysfunction (parecoxib/valdecoxib: 1.9%, controls: 0%, $P=0.184$). Three retrospective studies within paediatric populations, including one cohort study and two chart reviews, found various parameters of renal function, such as serum creatinine and blood urea nitrogen, to be similar between ketorolac and control groups. We conclude that NSAIDs are not associated with an increased risk of renal failure after cardiac surgery when administered at optimal 'renal' doses, within early postoperative settings, to patients at low-risk of renal dysfunction in whom NSAIDs are not contraindicated.
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Author Proof

The effect of cardiac angiography timing, contrast media dose, and preoperative renal function on acute renal failure after coronary artery bypass grafting

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Objective: Our objective was to assess the effect of the timing of cardiac angiography, contrast media dose, and preoperative renal function on the prevalence of acute renal failure after cardiac surgery.

Methods: Data on 395 consecutive patients who underwent coronary artery bypass grafting were prospectively collected. Creatinine clearance was estimated by the Cockcroft–Gault equation. Patients were divided into 3 groups according to the time between cardiac angiography and surgery (group A, $\leq$ 1 day; group B, $>$ 1 day and $\leq$ 5 days; group C, $>$ 5 days). Patients who underwent a salvage operation or were receiving dialysis before surgery were excluded. Acute renal failure was defined as 25% decrease from baseline of estimated creatinine clearance and estimated creatinine clearance of 60 mL/min or less on postoperative day 3. Owing to differences in preoperative characteristics between groups, propensity score analysis was used to adjust those differences.

Results: Acute renal failure developed in 13.6% of patients. Hospital mortality was 3.3% and was higher in patients in whom acute renal failure developed (22%) versus those in whom it did not (0.3%; $P < .001$). Multivariable analysis identified preoperative estimated creatinine clearance of 60 mL/min or less (odds ratio [OR], 7.1), operation within 24 hours of catheterization (OR = 3.7), use of more than 1.4 mL/kg of contrast media (OR = 3.4), lower hemoglobin level (OR = 1.3), older age (OR = 1.1), and lower weight (OR = 0.95) as independent predictors of postoperative acute renal failure. Analysis of interaction between contrast dose and time of surgery revealed that high contrast dose (>1.4 mL/kg) predicted acute renal failure if surgery was performed up to 5 days after angiography.

Conclusions: Whenever possible, coronary bypass grafting should be delayed for at least 5 days in patients who received a high contrast dose, especially if they also have preoperative reduced renal function. (J Thorac Cardiovasc Surg 2010;139:1539-44)

Renal Failure After Cardiac Surgery: Timing of Cardiac Catheterization and Other Perioperative Risk Factors

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Background. The incidence of acute renal failure after cardiac surgery remains high, and the ability to predict renal failure using well-defined baseline risk factors is important. The relationship between the timing of preoperative cardiac catheterization and the incidence of postoperative renal failure has not been previously described.

Methods. Perioperative variables for 649 patients over 12 months were prospectively collected. Variables included medical comorbidities, preoperative glomerular filtration rate calculated using the simplified Modification of Diet in Renal Disease equation, and date of cardiac catheterization. Endpoints were (A) renal failure defined as a rise in serum creatinine greater than 25% by the third postoperative day or renal dysfunction requiring the initiation of dialysis, and (B) hospital mortality.

Results. The incidence of renal failure and renal failure requiring dialysis were 24.0% and 4.2%, respectively. After multivariate analysis, age, cardiopulmonary bypass time, baseline glomerular filtration rate less than 60 mL/min (odds ratio [OR] 1.69; 95% confidence interval [CI]: 1.09 to 2.62; $p = 0.047$), and cardiac catheterization performed within 5 days before operation (OR 1.82; 95% CI: 1.17 to 2.84; $p = 0.010$) were independently associated with acute renal failure. Developing postoperative renal failure was independently related to hospital mortality (OR 3.70; 95% CI: 1.59 to 9.09; $p = 0.003$).

Conclusions. Cardiac catheterization performed within 5 days before operation, baseline glomerular filtration rate less than 60 mL/min, and prolonged cardiopulmonary bypass duration are significant risk factors for acute renal failure after cardiac surgery. Acute renal failure after cardiac surgery is a significant predictor of hospital mortality.

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Does Off-Pump Coronary Surgery Reduce Postoperative Acute Renal Failure? The Importance of Preoperative Renal Function

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Background. Off-pump was compared with on-pump coronary artery bypass graft surgery to evaluate the impact of cardiopulmonary bypass on the incidence of postoperative acute renal failure (ARF).

Methods. From November 1994 to December 2001, 2,943 patients having multivessel surgical disease underwent myocardial revascularization. Ninety patients were excluded because of incompleteness of data, intraoperative death, or preoperative chronic dialysis. The analysis was split: one analysis included 1,724 (862 each group) of 2,618 patients with normal preoperative creatinine (<1.5 mg/dL), and the second analysis included 160 (80 each group) of 215 patients with preoperative abnormal renal function; in both analyses matched groups were selected applying propensity score.

Results. In the group with normal preoperative creatinine, the incidence of 30-day ARF was 5.4% (2.9% off-pump versus 7.9% on-pump; $p < 0.001$). Stepwise logistic regression confirmed that cardiopulmonary bypass was an independent variable for increased postoperative ARF incidence (odds ratio, 3.3), as well as age and reduced left ventricular ejection fraction. Receiver operating characteristic curves showed that cardiopulmonary bypass duration was a predictor of higher ARF incidence (area under the curve, 0.79) with a cutoff value of 66 minutes. In the patients with abnormal renal function preoperatively, the incidence of ARF was similar between the groups (16.3% on-pump versus 12.5% off-pump; $p = 0.499$). Acute renal failure had an important impact on early (odds ratio, 3.6) and late mortality (hazard ratio, 4.1).

Conclusions. Off-pump surgery plays an important renoprotective role and provides better early and late outcome in patients with normal preoperative creatinine. When the preoperative creatinine is abnormal, the surgical strategy does not seem to have any influence. The occurrence of ARF significantly impairs early and long-term mortality, and the surgical strategy does not improve outcomes.

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On-Pump Versus Off-Pump Coronary Artery Bypass Grafting: Impact on Postoperative Renal Failure Requiring Renal Replacement Therapy

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Background. Despite refinements in perioperative patient management postoperative renal failure requiring hemofiltration or dialysis is still a common complication after coronary artery bypass grafting associated with impaired patient outcome.

Methods. Prospective data on 9,631 patients receiving myocardial revascularization with (coronary artery bypass grafting [n = 8,870]) or without cardiopulmonary bypass (off-pump coronary artery bypass grafting [n = 761]) between April 1996 and August 2001 were evaluated by univariate and multivariate logistic regression analysis.

Results. Overall prevalence of postoperative continuous renal replacement therapy was 4.1% (coronary artery bypass grafting, 4.3%; off-pump coronary artery bypass grafting, 1.8%; $p = 0.001$). Thirty of 40 selected preoperative and intraoperative patient and treatment related variables had a high association with the requirement for postoperative renal replacement therapy; fifteen of these variables were independent predictors in the whole study population. Off-pump coronary artery bypass surgery was identified as having a significantly lower predictive value for postoperative continuous renal placement therapy. In the subgroup of patients undergoing off-pump coronary artery bypass grafting surgery, a second multivariate logistic regression model revealed preoperative cardiogenic shock, urgent operation, intraoperative low cardiac output, and high transfusion requirement as independent predictors for postoperative renal replacement therapy.

Conclusions. Patients with preoperative nondialysis dependent renal insufficiency are at a high risk for further decline in renal function requiring postoperative continuous renal replacement therapy. Off-pump coronary artery bypass surgery is associated with a lower prevalence of postoperative renal replacement therapy after coronary artery bypass grafting.

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Acute Renal Failure in Coronary Artery Bypass Surgery: Independent Effect of Cardiopulmonary Bypass

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Background. Acute renal failure after cardiac surgery is associated with a high morbidity and mortality, particularly when associated with hemodialysis. The aim of the study was to investigate whether the use of cardiopulmonary bypass increased the risk of developing acute renal failure.

Methods. The 2199 consecutive patients undergoing isolated coronary artery bypass grafting between January 2000 and March 2002 were retrospectively analyzed. Patients with significant preoperative renal dysfunction (preoperative serum creatinine > 200 μmol/L) were excluded. A multivariate logistic regression model was constructed to identify independent risk factors for the development of acute renal failure.

Results. In the study, 53 patients (2.4%) developed acute renal failure before hospital discharge. The crude incidences of acute renal failure for isolated coronary artery bypass grafting in the on- and off- pump groups were 2.9% and 1.4%, respectively ($p = 0.031$). There were 1483 patients who underwent on-pump surgery whereas 716 patients were in the off-pump group. The two groups were broadly comparable on many variables. The off-pump group were slightly younger on average (63.6 versus 64.9 years old [$p = 0.017$]), but had more angina class IV patients (39.5% versus 28.9% [$p < 0.001$]) and a greater proportion of redo surgery (4.1% versus 1.6% [$p < 0.001$]). The on-pump group had more patients with three-vessel disease (82.8% versus 74.3% [$p < 0.001$]). The logistic regression model identified use of cardiopulmonary bypass as an independent risk factor for the development of acute renal failure (odds ratio 2.64 [95% confidence intervals 1.27 to 5.45]). Other independent predictors of acute renal failure were preoperative creatinine levels, diabetes, emergency operations, increasing age, increasing body mass index, and peripheral vascular disease.

Conclusions. Cardiopulmonary bypass is associated with significantly increased risk of acute renal failure following isolated coronary artery bypass surgery.

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Hemodilution during cardiopulmonary bypass is an independent risk factor for acute renal failure in adult cardiac surgery

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Background: This observational study sought to determine whether the degree of hemodilution during cardiopulmonary bypass is independently related to perioperative acute renal failure necessitating dialysis support.

Methods: Data were prospectively collected on consecutive patients undergoing cardiac operations with cardiopulmonary bypass from 1999 to 2003 at a tertiary care hospital. The independent relationship was assessed between the degree of hemodilution during cardiopulmonary bypass, as measured by nadir hematocrit concentration, and acute renal failure necessitating dialysis support. Multivariate logistic regression was used to control for variables known to be associated with perioperative renal failure and anemia.

Results: Of the 9080 patients included in the analysis, 1.5% (n = 134) had acute renal failure necessitating dialysis support. There was an independent, nonlinear relationship between nadir hematocrit concentration during cardiopulmonary bypass and acute renal failure necessitating dialysis support. Moderate hemodilution (nadir hematocrit concentration, 21%-25%) was associated with the lowest risk of acute renal failure necessitating dialysis support; the risk increased as nadir hematocrit concentration deviated from this range in either direction (P = .005). Compared with moderate hemodilution, the adjusted odds ratio for acute renal failure necessitating dialysis support with severe hemodilution (nadir hematocrit concentration <21%) was 2.34 (95% confidence interval, 1.47-3.71), and for mild hemodilution (nadir hematocrit concentration >25%) it was 1.88 (95% confidence interval, 1.02-3.46).

Conclusions: Given that there is an independent association between the degree of hemodilution during cardiopulmonary bypass and perioperative acute renal failure necessitating dialysis support, patient outcomes may be improved if the nadir hematocrit concentration during cardiopulmonary bypass is kept within the identified optimal range. Randomized clinical trials, however, are needed to determine whether this is a cause-effect relationship or simply an association.

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Oxygen Delivery During Cardiopulmonary Bypass and Acute Renal Failure After Coronary Operations

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Background. The degree of hemodilution during cardiopulmonary bypass has recently been identified as an independent risk factor for acute renal failure after cardiac operations. In this prospective observational study we have investigated the role of the lowest oxygen delivery, lowest hematocrit, and pump flow during cardiopulmonary bypass as possible risk factors for acute renal failure and renal dysfunction.

Methods. One thousand forty-eight consecutive patients undergoing coronary operations have been studied. For each patient we have recorded the lowest hematocrit on cardiopulmonary bypass, the correspondent lowest oxygen delivery, and the pump flow around the time of these determinations. The three variables have been explored in a multivariable model as possible risk factors for acute renal failure and postoperative serum creatinine levels increase. The role of transfusions in determining acute renal failure was subsequently included in the model.

Results. The best predictor for acute renal failure and peak postoperative serum creatinine levels was the lowest oxygen delivery, with a critical value at 272 $mL \cdot min^{-1} \cdot m^{-2}$. The lowest hematocrit was an independent risk factor with a lowest predictive value at a cutoff of 26%. When corrected for the need for transfusions, only the lowest oxygen delivery remained an independent risk factor.

Conclusions. A high degree of hemodilution during cardiopulmonary bypass is a risk factor for postoperative renal dysfunction; however, its detrimental effects may be reduced by increasing the oxygen delivery with an adequately increased pump flow.

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Institutional report - Cardiac general

Predictors of acute renal failure requiring renal replacement therapy post cardiac surgery in patients with preoperatively normal renal function☆

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Abstract

Acute renal failure requiring continuous renal replacement therapy post cardiac surgery carries a high mortality. Most studies have focused on patients with impaired renal function preoperatively but little is known about predictors of such a complication in patients with preoperatively normal renal function. This is a retrospective review of a prospective collected database. A total of 1609 patients underwent cardiac surgery over a 4-year period. Dialysis was required in 47 patients (2.9%). Univariate analysis identified the following as significant risk factors: age, female gender, chronic obstructive pulmonary disease, congestive cardiac failure, creatinine clearance, Euro, Parsonnet and Cleveland clinic scores, body mass index, non-isolated CABG, cardiopulmonary bypass time, extubation time and pulmonary complications ($P<0.05$). Multivariate analysis identified EuroSCORE, congestive cardiac failure, insulin-dependent diabetes, emergency surgery, post-operative extubation time and pulmonary complications as independent risk factors ($P<0.05$). In-hospital mortality and length of stay ($P<0.0001$) were higher in dialysis group. Acute renal failure requiring dialysis post cardiac surgery is associated with a higher mortality and prolonged hospital stay. By identifying higher risk patients, early planned preventative measures should be readily available to both reduce the incidence of such a complication and improve utilisation of hospital resources.
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Acute Renal Failure After Cardiac Surgery: Evaluation of the RIFLE Classification

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Background. Acute renal failure increases risk of death after cardiac surgery. However, the definition of acute renal failure is not standardized. The Acute Dialysis Quality Initiative Workgroup has outlined consensus criteria. The aim of the present study was to evaluate this determination of postoperative renal impairment in cardiac surgical patients, and its association with mortality.

Methods. The 813 consecutive patients undergoing cardiac surgery at Helsinki University Central Hospital were analyzed. According to the RIFLE classification (named by the severity of renal impairment: Risk, Injury, Failure, Loss, End-stage kidney disease) patients were divided into three levels based on either plasma creatine level or urine output.The discrimination with death within 90 days after surgery was determined.

Results. According to the RIFLE criteria, 19.3% of patients had renal impairment after cardiac surgery. Patients in the more severe category, RIFLE-F (failure), had a 90-day mortality rate of 32.5% compared with 8.0% for those in RIFLE-R (risk) and 21.4% for RIFLE-I (injury) patients. The RIFLE classification discriminated 90-day mortality quite well (area under curve 0.824) compared with the change of plasma creatinine and the change of estimated gromerular filtration rate (areas under curve 0.849 and 0.829, respectively). The results of the multivariate forward stepwise logistic regression analysis found that RIFLE classification was an independent risk factor for 90-day mortality ($p < 0.0001$), unlike change in glomerular filtration rate and change in plasma creatinine.

Conclusions. We propose that the RIFLE classification is a valuable method to evaluate acute renal failure after cardiac surgery. The severity of RIFLE classification may be associated with increased 90-day mortality rate.

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