AKI Post Open Cardiac Surgery

Magdy Mamdouh Atallah , MD

Professor of Intensive Care & Chief of Anesthesia

Cardiothoracic Unit

Clinical Fellowship Toronto University , Canada

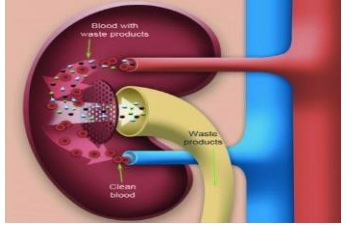
Mansoura University

[2024]

Objectives

- Epidemiology.
- What is AKI.
- Risk factors and Pathophysiology
- Highlight strategies for Prevention & Management
- Take home message.

Epidemiology



- More than **2millions** cardiac surgery/y. CSA-AKI is **the 2nd most common cause of AKI in the intensive care .**
- Mortality of AKI in ICU up to **23%.**
- Incidence Post cardiac Surgery **11-30% .**
- **7%** of hospital admission & **30%** of ICU admission. **(Goyal et al.2023)**
- **3-5%** of AKI end with long term RRT.
- The kidneys are **less than 0.5% of body wt.** , receive **20%** of COP with **less O2 extraction 7-10%.**

Do not forget

eGFR levels and stages of chronic kidney disease

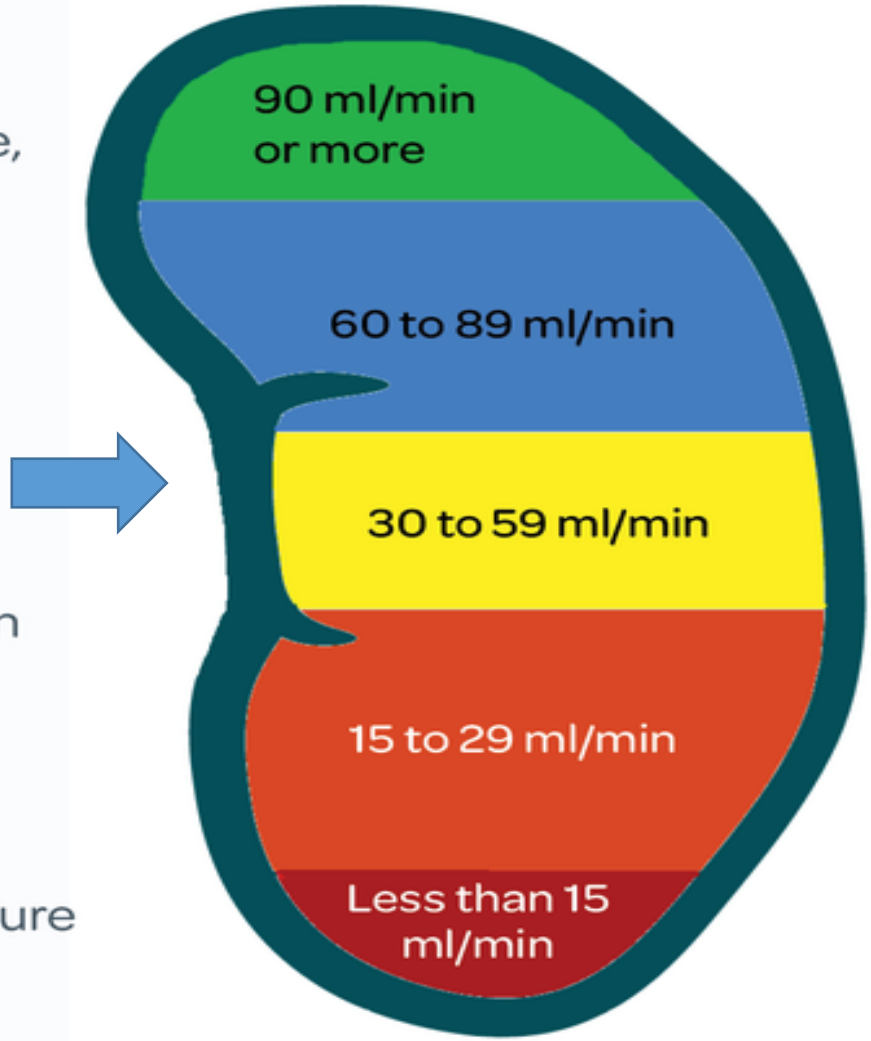
Stage 1
eGFR remains within a normal range, but other test results suggest signs of kidney damage

Stage 2
Slightly reduced kidney function with other tests suggesting kidney damage

Stage 3
Moderately reduced kidney function

Stage 4
Severely reduced kidney function

Stage 5
Very severe or end-stage kidney failure



What is AKI

Definition:

To date, no consensus definition ,however , several different criteria have been used. Among these Kidney disease Improving Global Outcomes. **KDIGO** reported any :

1.Increase creatinine by 0.3mg/dl within 48 hours.

2.Increase creatinine 1.5 times within one week.

3.Urine output less than 0.5 ml/kg/h.

Pathophysiology:

1.Prerenal.

2.Renal.

3.Postrenal.

Cardiac Surgery &AKI

- **Renal hypoperfusion:** due to **hypotension, anemia ,atheroembolism ,reperfusion injury . decreased cardiac output, sympathetic stimulation**, the administration of **vasoconstrictive** medications, and activation of **the renin-angiotensin-aldosterone** system.
- Acute kidney injury (AKI) affects 30–50% of high-risk cardiac surgery patients.
- **Re-exploration** increased risk of AKI.
- Associated with **2–8 folds increased mortality risk**.
- Leads to **prolonged ICU stay, dialysis dependency, and higher costs**.

Pathophysiology & CPB

****Hemodynamic Factors:****

- Renal hypoperfusion due to low cardiac output, systemic hypotension, Reperfusion , atheromatous plaques, and non-pulsatile flow during CPB.
- Venous congestion impairs renal filtration.

****Ischemia-Reperfusion Injury:****

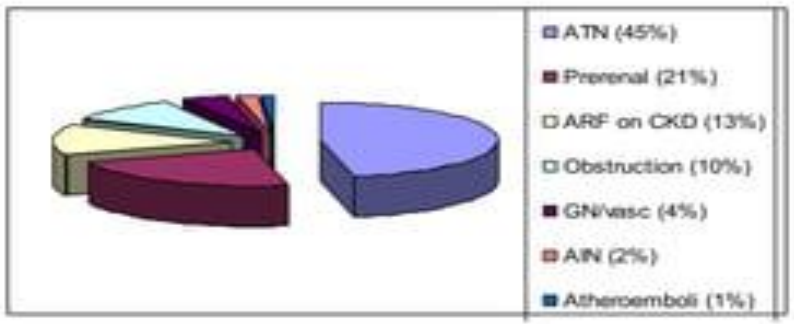
- Temporary oxygen deprivation damages tubular cells.
- Reperfusion causes oxidative stress and inflammation.

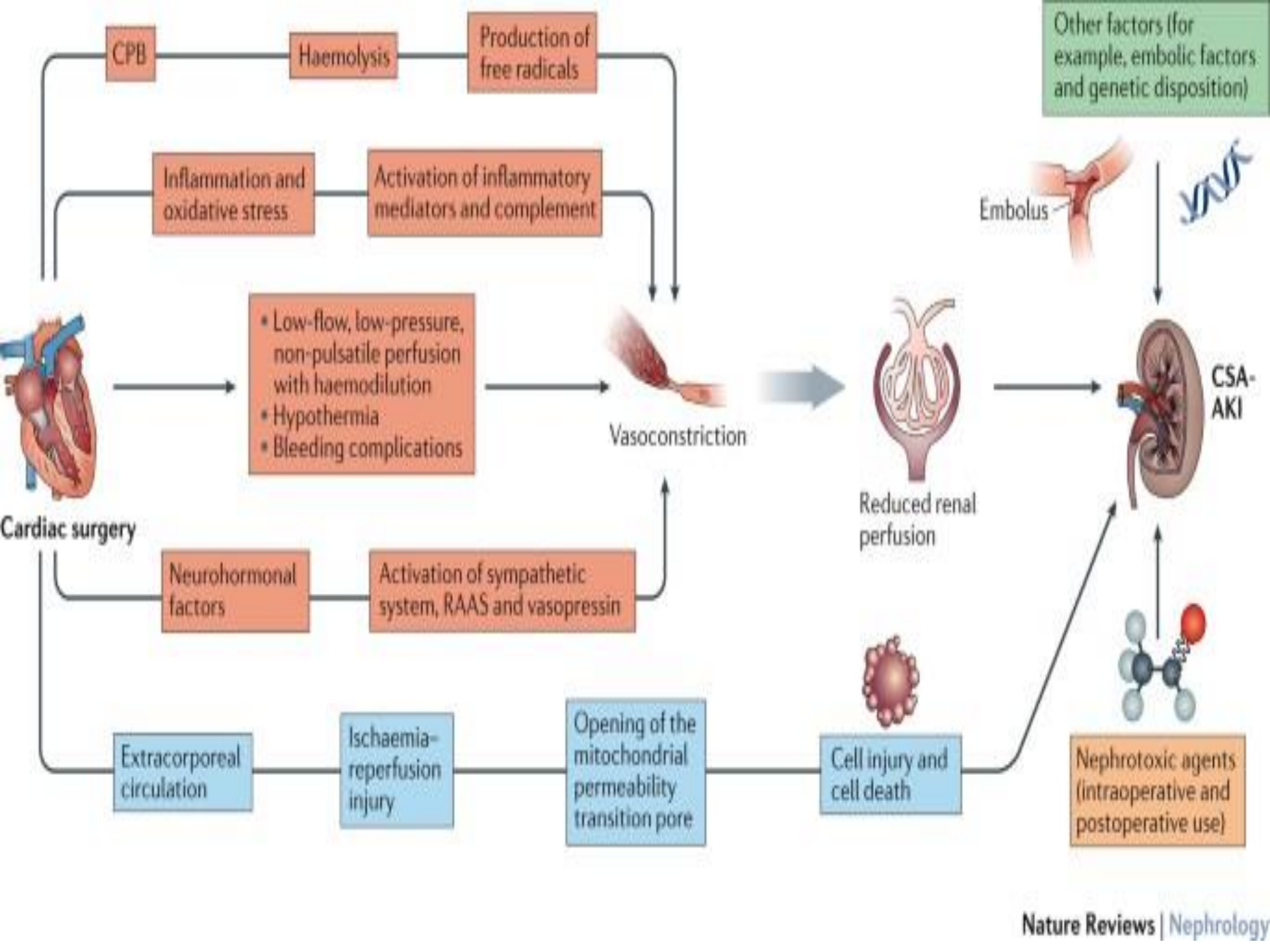
****Inflammat**

- CPB activa ments, leading to systemic
- Lysis of RI

****Direct Tul**

- Nephrotoxi antibiotics.
- Oxidative




CPB
Haemolysis
Production of free radicals
Other factors (for example, embolic factors and genetic disposition)
Inflammation and oxidative stress
Activation of inflammatory mediators and complement
Embolus
• Low-flow, low-pressure, non-pulsatile perfusion with haemodilution
• Hypothermia
• Bleeding complications
Vasoconstriction
Reduced renal perfusion
CSA-AKI
Cardiac surgery
Neurohormonal factors
Activation of sympathetic system, RAAS and vasopressin
Extracorporeal circulation
Ischaemia–reperfusion injury
Opening of the mitochondrial permeability transition pore
Cell injury and cell death
Nephrotoxic agents (intraoperative and postoperative use)

Risk Factors

Medication	Mechanism for Nephrotoxicity
Angiotensin-converting enzyme inhibitors and angiotensin receptor blockers	Functional renal insufficiency (hypotension)
Nonsteroidal anti-inflammatory drugs	Reduction in prostaglandin synthesis
Antibiotics (vancomycin, aminoglycosides and β-lactams)	Acute tubular necrosis, acute interstitial nephritis, crystal-induced acute kidney injury
Intravenous contrast agents	Acute tubular necrosis
Diuretics	Hypovolemia and hypotension

Clinical Prediction Scores

Cleveland Clinic Score

Derivation Cohort: 15,838 cardiac surgery patients, Single U.S. Center, 1993–2002

Validation Cohort: 17,379 cardiac surgery patients from the same center and time period

Variable	Points
Female sex	1
Congestive heart failure	1
Left ventricular ejection fraction < 35%	1
Preoperative intra-aortic balloon pump	2
Chronic obstructive pulmonary disease	1
Insulin-dependent diabetes	1
Previous cardiac surgery	1
Emergency surgery	2
Type of surgery	0–2
Preoperative serum creatinine	0–5
Score range	0–17

Mehta Score

Derivation Cohort: 449,524 cardiac surgery patients, database of > 600 centers, 2002–2004

Validation Cohort: 86,009 cardiac surgery patients from the same database, 2005

Variable	Points
Age ≥ 55	0–10
Non-White race	2
Preoperative serum creatinine	5–40
New York Heart Association Class IV heart failure	3
Diabetes treated with oral medications	2
Insulin-dependent diabetes	5
Chronic obstructive pulmonary disease	3
Recent myocardial infarction	3
Previous cardiac surgery	3
Cardiogenic shock	7
Type of surgery	0–7
Score range	0–85

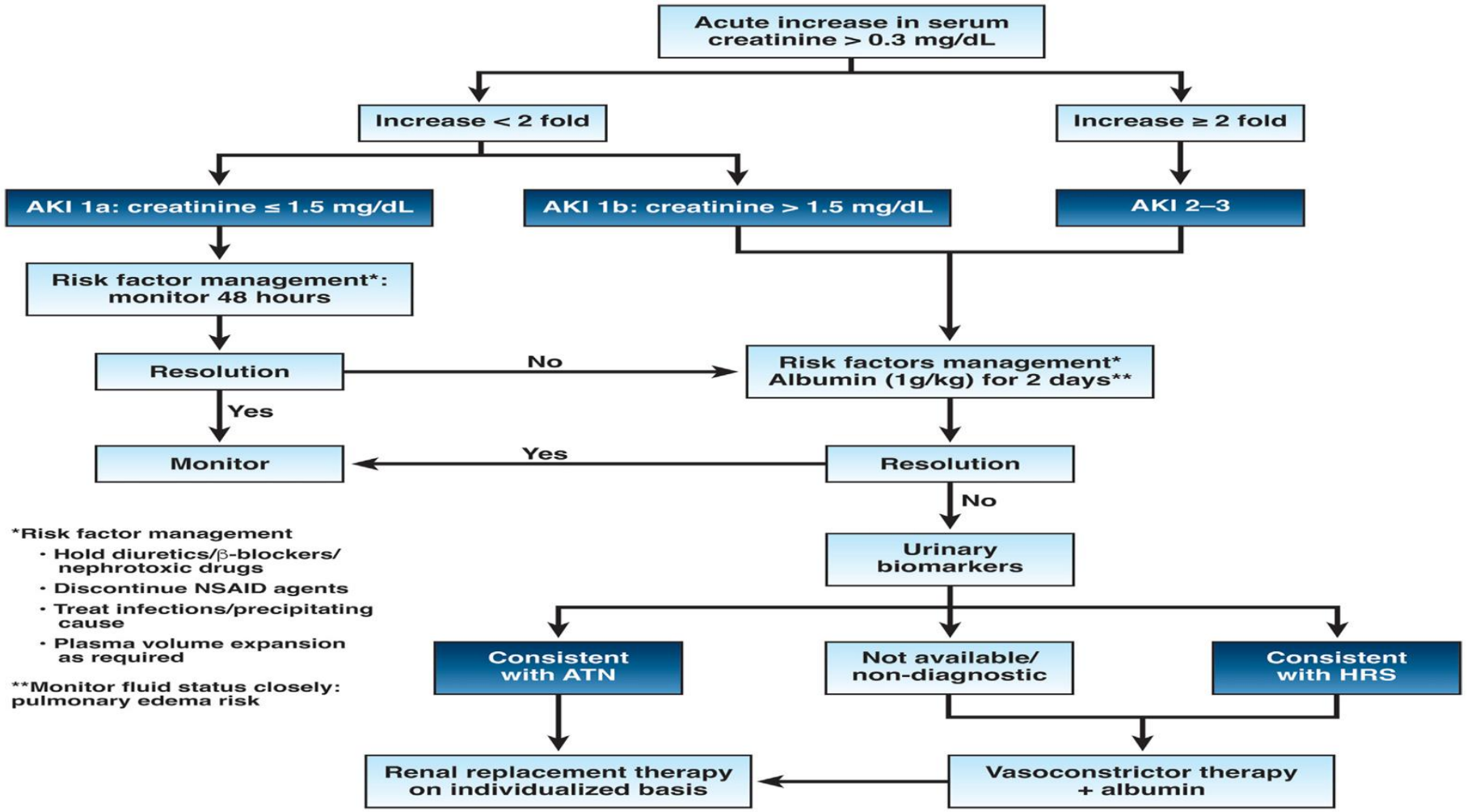
Simplified Renal Index

Derivation Cohort: 10,751 cardiac surgery patients, single Canadian center, 1999–2004

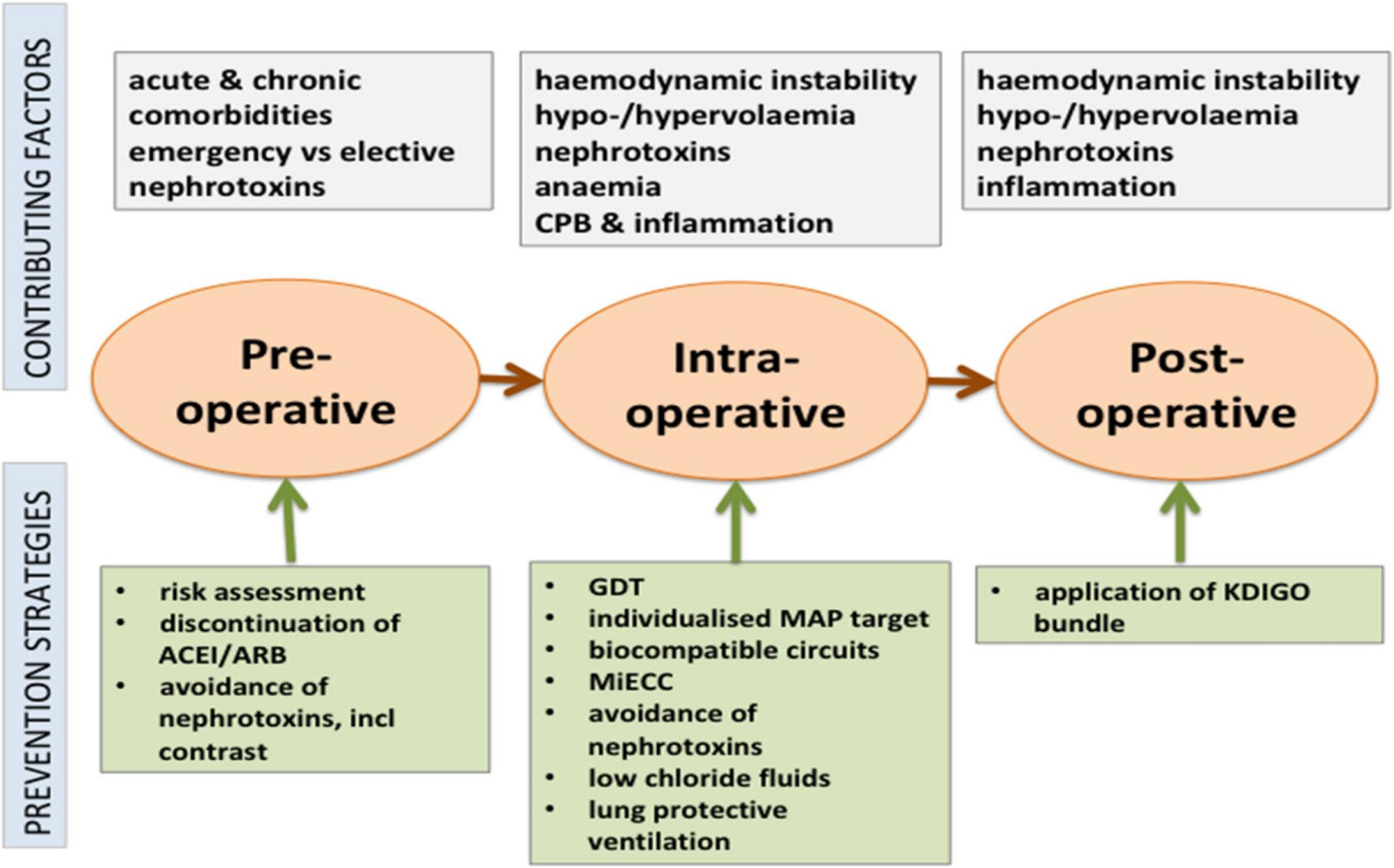
Validation Cohort: 9,380 cardiac surgery patients, two Canadian centers, 1999–2003

Variable	Points
Preoperative glomerular filtration rate	1–2
Diabetes requiring medications	1
Left ventricular ejection fraction ≤40%	1
Previous cardiac surgery	1
Preoperative intra-aortic balloon pump	1
Nonelective surgery	1
Type of surgery	0–1
Score range	0–8

Algorithm of AKI



Summary of Management



Diagnosis and Monitoring

Biomarker	Source	Pathophysiology	Utility in Cardiac Surgery	Limitations
Neutrophil gelatinase-associated lipocalin	Blood, urine	Upregulated in the proximal tubules after ischemic or nephrotoxic injury to the kidneys	Early detection of AKI	More specific in children and adults without chronic kidney disease.
Cystatin C	Blood	Functional biomarker with decreased clearance in AKI	Early detection of AKI Unaffected by differences in muscle mass.	Some studies have indicated that Cystatin C has lower predictive value.
Interleukin-18	Urine	Mediates ischemic and inflammatory kidney injury in the proximal tubules	Early detection of AKI	Some studies have indicated that interleukin-18has lower predictive value.
Kidney injury molecule-1	Urine	Rapidly expressed in proximal tubular cells after ischemic kidney injury	Early detection of AKI	Some studies have indicated that it peaks up to 2–3 days after kidney injury.
[Tissue inhibitor of metalloproteinase]x[insulin-like growth factor-binding protein 7]	Urine	Induces cell cycle arrest in renal tubular cells	Early detection of AKI Better sensitivity and specificity in predicting AKI.	Some studies have indicated that these biomarkers have lower specificity.
C-C motif chemokine ligand 14	Urine	Mediates inflammatory kidney injury in the proximal tubules	Predicts persistent AKI and the need for renal replacement therapy- and can be used as a marker for progression of AKI to chronic kidney disease	Does not provide early detection of AKI

AKI, acute kidney injury

Prevention Strategies till 2011

Pre-operative:*

- ❑ Risk assessment (e.g., EuroSCORE).
- ❑ Optimize volume & nutritional status.

Intra-operative:*

- ❑ Limit CPB& ischemic time.
- ❑ Maintain hemodynamic stability.
- ❑ Avoid nephrotoxins.
- ❑ Biocompatible circuit & reperfusion time.

Post-operative:*

- ❑ Monitor renal function regularly.
- ❑ Early identification (Biomarkers) and intervention.

KIDGO bundle 2024

Rewarming Temperature on Cardiopulmonary Bypass: (rewarming from 32° to 37°C in a 10- to 15-min period resulted in an increased incidence of AKI Vs. rewarming to 34°C; however, that sustained mild hypothermia did not have a nephron protective effect.

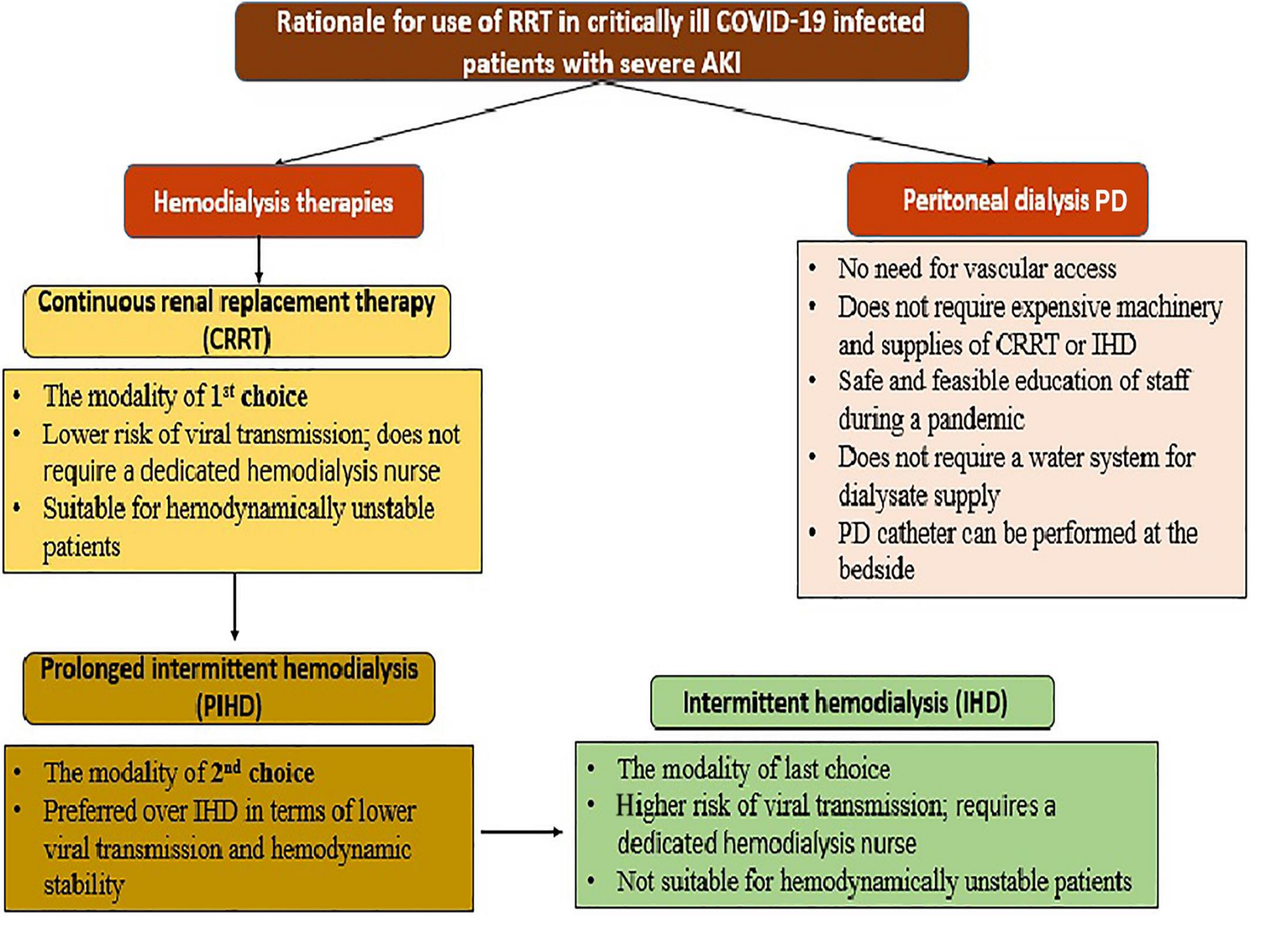
Goal-directed Oxygen Delivery &NO on Cardiopulmonary Bypass

Vasopressors &Perioperative Hypotension: Patients who received *Vasopressin vs. NE* as a first-line agent had a significantly lower incidence of moderate to severe AKI and a lower mortality.

Anemia , Hemolysis and Transfusion: multimodal preoperative anemia management with *oral iron therapy, erythropoietin administration in patients with iron deficiency anemia, and supplementation with vitamin B12 and folate for B12* and folate deficiency anemia.

Intravenous Fluids: **Ringer's lactate vs Na Chloride** have been associated with a lower risk of AKI. Hydroxy-ethyl starch should be avoided

Early Renal Replacement Therapy


Rationale for use of RRT in critically ill COVID-19 infected patients with severe AKI
Hemodialysis therapies
Peritoneal dialysis PD
Continuous renal replacement therapy (CRRT)
The modality of 1st choice
Lower risk of viral transmission; does not require a dedicated hemodialysis nurse
Suitable for hemodynamically unstable patients
No need for vascular access
Does not require expensive machinery and supplies of CRRT or IHD
Safe and feasible education of staff during a pandemic
Does not require a water system for dialysate supply
PD catheter can be performed at the bedside
Prolonged intermittent hemodialysis (PIHD)
Intermittent hemodialysis (IHD)
The modality of 2nd choice
Preferred over IHD in terms of lower viral transmission and hemodynamic stability
The modality of last choice
Higher risk of viral transmission; requires a dedicated hemodialysis nurse
Not suitable for hemodynamically unstable patients

Management of AKI in Recent Studies

- **Corticosteroids**: Corticosteroids can down regulate pro-inflammatory cytokines, up regulate anti-inflammatory cytokines.
- **Albumin**.
- **Erythropoietin**.
- **Statins**.
- **N-acetylcysteine**.
- **Sodium bicarbonate**.
- **Intra-Aortic Balloon Pump ???.**

Outcomes and Prognosis

Short-term: Increased ICU, hospital length of stay , and total cost.

Long-term: Risk of CKD and ESRD.

Mortality: 30–50% in severe AKI cases.

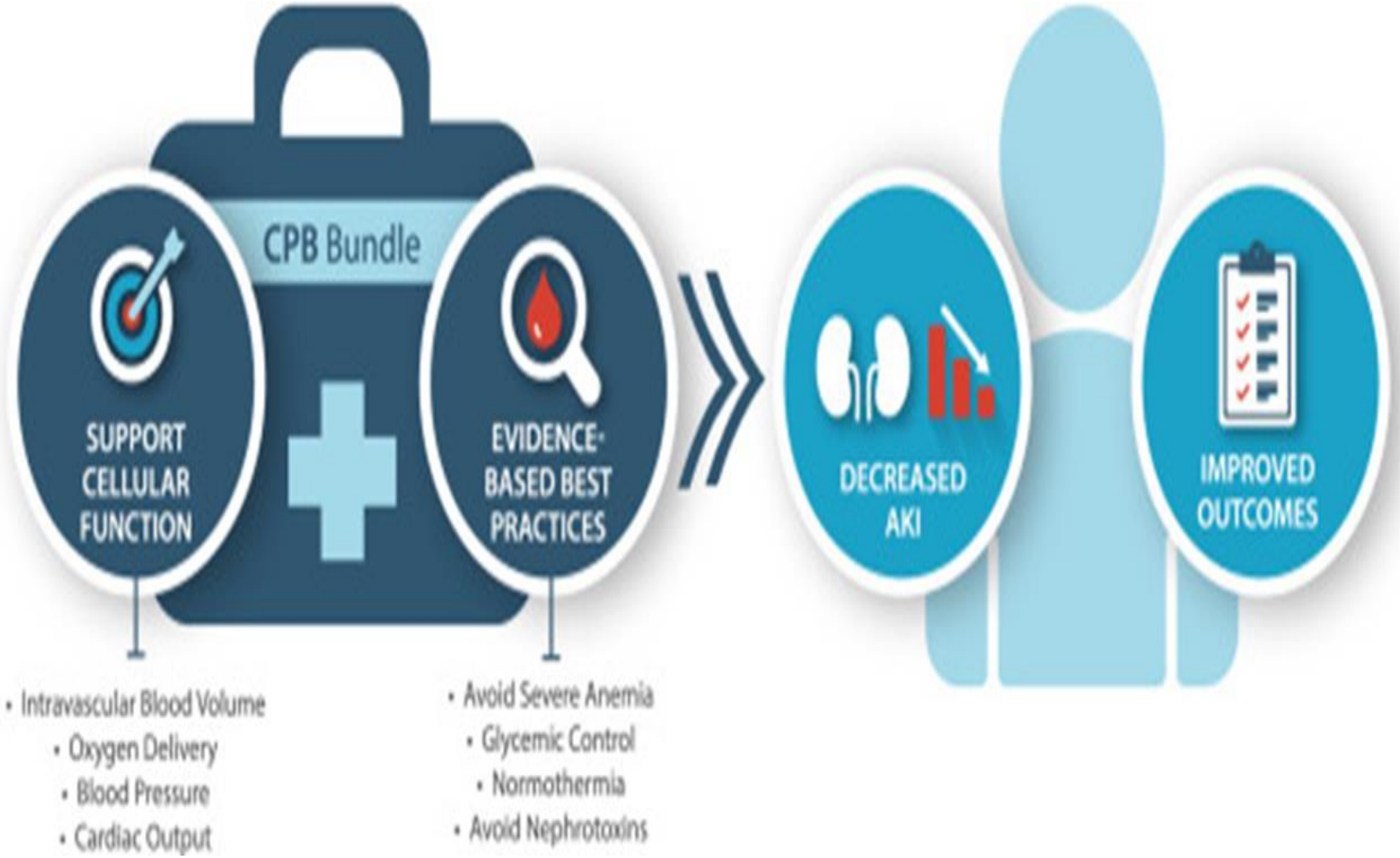
Recent Novel Exploratory Studies of Cardiac Surgery AKI Prevention in KIDGO 2024

- **Urine Oximetry**: (noninvasive urine oximetry is a novel concept for intraoperative and postoperative ICU).
- **Haptoglobin**: Administration(prevented circulating free hemoglobin-induced kidney injury.
- **Nitric Oxide:** administration of NO (40 ppm via the cardiopulmonary bypass circuit) was associated with a significant decrease in the incidence of cardiac surgery–associated AKI.
- **Acetaminophen:** anti-inflammatory and anti-oxidative preventing the conversion of iron from the ferric ion to its more inflammatory and nephrotoxic ferryl ion form

Recent Advances Under Researches

- Biomarkers for early detection.
- Machine learning for risk prediction.
- Novel therapies (e.g., stem cells).
- Enhanced recovery protocols ,fenoldopam ,dexmedetomidine , acitamenophen ,OpCAB ,Minimally invasive , perioperative clinical nutrition .

Take Home Message



Take Home Message

V:Preservation of adequate intravascular volume (grade B evidence; strong recommendation).

VI: **No use of excessive ultrafiltration** during cardiopulmonary bypass (grade C evidence; strong recommendation).

VII: Use of **POCU** to augment evaluation of postoperative intravascular volume status (grade C evidence; weak recommendation).

VIII: Use of a **Urinary biomarker-driven care bundle** to reduce CSA-AKI (grade C evidence; weak recommendation).

IX: **No prophylactic or otherwise routine use of diuretic** therapy (grade A evidence; strong recommendation).

X: Development of new **KDIGO stage 2** for long-term follow-up (grade A evidence; strong recommendation)

Conclusion

- Prevention and early intervention are key.
- Multidisciplinary care improves outcomes.
- Future research is essential for better management.
- Prevention and early detection must be the primary focus.
- **No reliable or effective treatment options to cure or reverse CSA-AKI**

Thank you