Avoiding Kidney Injury: Cardiac Surgery

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Objectives

- Discuss incidence and impact of cardiac surgery-associated acute kidney injury (CSA-AKI) & Chronic Kidney Disease in patients undergoing cardiac surgery
- Review general guidelines based on the recommendations from the Society of Thoracic Surgeons/Cardiovascular Anesthesiologists Practice Guidelines
- Review the pathophysiology related to cardiac surgery and risk for developing AKI
- Summarize recommendations supported by the literature for recognizing and preventing CSA-AKI

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Additional Resources

- For a more in-depth overview of kidney disease, including staging definitions, please reference: MPOG Avoiding Kidney Injury - Overview, Pathophysiology, Definitions
- AKI-02
- For other specialty specific recommendations, reference the following sections of the toolkit:
  - Avoiding Kidney Injury - Pediatrics
  - Avoiding Kidney Injury - Obstetrics
  - Avoiding Kidney Injury - Recommendations for Adult Surgical Patients

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Incidence of Cardiac Surgery - Acute Kidney Injury

Acute kidney injury (AKI) is a common complication after cardiac surgery and occurs in 20-30% of pateints [1]

The Society of Thoracic Surgeons defines AKI as a 3-fold increase in serum creatinine, creatinine more than 4 mg/dL, or initiation of dialysis after cardiac surgery. [1]

- **28%** (287/1030) patients: 2013 single-center registry, AKIN criteria [2]
- **36%** (819/2,284) patients: 2018 single-center prospective cohort study, KDIGO criteria [3]
- **36%** (931/2,575) patients: 2017 single-center retrospective analysis, KDIGO criteria [4]
- **50%** (221/443) patients: 2015 single-center retrospective study, RIFLE definition [5]

References:

1. Cheruku,S., Raphael, J., Javier N, Fox, A. Acute Kidney Injury after Cardiac Surgery: Prediction, Prevention, and Management. *Anesthesiology* 2023; 139:880–898 doi: https://doi.org/10.1097/ALN.0000000000004734
2. Hansen MK, Gammelager H, Mikkelsen MM, Christiansen, CF. Et al.: Post-operative acute kidney injury and five-year risk of death, myocardial infarction, and stroke among elective cardiac surgical patients: a cohort study. Crit Care 2013; 17:R292
3. Howitt SH, Grant SW, McCollum, C. Et al.: The KDIGO acute kidney injury guidelines for cardiac surgery patients in critical care: a validation study. BMC Nephrol 2018; 19:149
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Incidence of Cardiac Surgery - Acute Kidney Injury

RIFLE			AKIN			KDIGO		
Class	**Creatinine Criteria**	**Urine Output Criteria**	**Stage**	**Creatinine Criteria**	**Urine Output Criteria**	**Stage**	**Creatinine Criteria**	**Urine Output Criteria**
Risk	Serum creatinine ≥ 1.5 times baseline OR glomerular filtration rate decline ≥ 25%	< 0.5 $ml \cdot kg^{-1} \cdot h^{-1}$ for ≥ 6 h	Stage 1	Serum creatinine ≥ 1.5 times baseline or increase by 0.3 mg/dl within 48 h	< 0.5 $ml \cdot kg^{-1} \cdot h^{-1}$ for ≥ 6 h	Stage 1	Serum creatinine increase by 0.3 mg/dl within 48 h OR Serum creatinine ≥ 1.5–1.9 times baseline within 7 days	< 0.5 $ml \cdot kg^{-1} \cdot h^{-1}$ for ≥ 6 h
Injury	Serum creatinine ≥ 2 times baseline OR glomerular filtration rate decline ≥ 50%	< 0.5 $ml \cdot kg^{-1} \cdot h^{-1}$ for ≥ 12 h	Stage 2	Serum creatinine ≥ 2 times baseline	< 0.5 $ml \cdot kg^{-1} \cdot h^{-1}$ for ≥ 12 h	Stage 2	Serum creatinine ≥ 2.0–2.9 times baseline within 7 days	< 0.5 $ml \cdot kg^{-1} \cdot h^{-1}$ for ≥ 12 h
Failure	Serum creatinine ≥ 3 times baseline or increase by 0.5 mg/dl to ≥ 4 mg/dl OR glomerular filtration rate decline ≥75% OR renal replacement therapy initiation	< 0.3 $ml \cdot kg^{-1} \cdot h^{-1}$ for 24 h OR anuria for 12 h	Stage 3	Serum creatinine ≥ 3 times baseline or increase by 0.5 mg/dl to ≥ 4 mg/dl OR renal replacement therapy initiation	< 0.3 $ml \cdot kg^{-1} \cdot h^{-1}$ for 24 h OR anuria for 12 h	Stage 3	Serum creatinine ≥ 3 times baseline or increase by 0.5 mg/dl to ≥ 4 mg/dl OR renal replacement therapy initiation	< 0.3 Anuria for 24 h OR anuria for 12 h
Loss	Loss of renal function for ≥ 4 weeks							
End-stage	Loss of renal function for ≥ 3 months							

AKIN, Acute Kidney Injury Network; KDIGO, Kidney Disease: Improving Global Outcomes; RIFLE, Risk, Injury, Failure, Loss, and End-stage renal failure

References

1. Cheruku,S., Raphael, J., Javier N, Fox, A. Acute Kidney Injury after Cardiac Surgery: Prediction, Prevention, and Management. *Anesthesiology* 2023; 139:880–898 doi: https://doi.org/10.1097/ALN.0000000000004734

Impact of CSA-AKI

- 2-5% of cardiac surgery patients require renal replacement therapy postoperatively.[1]
- Five-year risk of death was 27% among cardiac surgery patients with AKI compared to 12.1% in patients without AKI.[2]
- In a study of valve and valve+CABG operations, postoperative renal injury of AKI stage 1 or higher found to be associated with an increase in long-term mortality (HR: 2.27 for valve; HR: 1.65 for valve+CABG; HR: 1.56 for CABG).[3]
- Further, an increase in creatinine by only 10% during the first week after valve operation is associated with an increased risk for long-term mortality[3]

References:

1. Howitt SH, Grant SW, Caiado C, Carlson E, Kwon D, Dimarakis I, Malagon I, McCollum C: The KDIGO acute kidney injury guidelines for cardiac surgery patients in critical care: a validation study. BMC Nephrol 2018; 19:149
2. Hansen MK, Gammelager H, Mikkelsen MM, Hjortdal VE, Layton JB, Johnsen SP, Christiansen CF: Post-operative acute kidney injury and five-year risk of death, myocardial infarction, and stroke among elective cardiac surgical patients: a cohort study. Crit Care 2013; 17:R292
3. Bouma HR, Mungroop HE, Geus AF de, Huisman DD, Nijsten MWN, Mariani MA, Scheeren TWL, Burgerhof JGM, Henning RH, Epema AH: Acute Kidney Injury Classification Underestimates Long-Term Mortality After Cardiac Valve Operations. Ann Thorac Surg 2018; 106:92–8

Impact of CSA-AKI

Table 7. Hospital Outcomes in Propensity-Matched Patients

Outcomes	No AKI (n = 833)	Stage I AKI (n = 833)	*p* Value
Intensive care unit stay, days	2.71 ± 3.89	5.28 ± 10.72	<0.0001
Length of ventilation, hours	19.31 ± 58.67	41.77 ± 125.0	<0.0001
Length of hospital stay, days	14.73 ± 18.31	17.95 ± 20.19	0.0007
CNS complications	68 (8.16)	127 (15.25)	<0.0001
Atrial fibrillation	67 (8.04)	140 (16.81)	<0.0001
Postoperative pneumonia	3 (0.36)	17 (2.04)	0.001
Sternal wound infection	5 (0.60)	27 (3.24)	<0.0001

Values are mean ± SD or n (%).

AKI = acute kidney injury; CNS = central nervous system.

Table 8. Predictors of Mortality

Predictors	OR	95% CI	*p* Value
Acute kidney injury	8.454	4.712–15.167	<0.0001
Preoperative creatinine	1.004	1.003–1.006	<0.0001
Preoperative hemoglobin	1.01	1.03–1.005	0.004
Hypertension	4.27	1.58–11.36	0.0009
Operative priority urgent	1.7	1.001–2.86	0.002
Operative priority emergent	2.464	1.121–5.414	0.002
CARE score	6.32	3.44–11.62	0.005

CARE = Cardiac Anesthesia Risk Evaluation; CI = confidence interval; OR = odds ratio.

Cardiac surgery patients who developed Stage 1 AKI also experienced increased hospital mortality, post-op complications, & longer length of stay. [1]

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Reference:

1. Elmistekawy, E., McDonald, B., Boodhwani, M. et al: Clinical impact of mild acute kidney injury after cardiac surgery. Ann Thorac Surg 2014; 98:815–22

Impact of CSA-AKI

- Mortality rates among cardiovascular patients requiring postoperative renal replacement therapy are between 40-70% [1]

- In a review of cases for 1,078,036 patients undergoing CABG, valve-replacement surgery or both from the Nationwide Inpatient Sample from 2008-2011 (United States only) [2]
  - 1 in every 10 patients developed AKI after cardiac operation
  - 10-fold greater in-hospital mortality
  - Twofold greater length of stay
  - On average, $36,453 greater index hospitalization costs

References:

1. Ishani A, Nelson D, Clothier B, Schult T, Nugent S, Greer N, Slinin Y, Ensrud KE: The magnitude of acute serum creatinine increase after cardiac surgery and the risk of chronic kidney disease, progression of kidney disease, and death. Arch Intern Med 2011; 171:226–33
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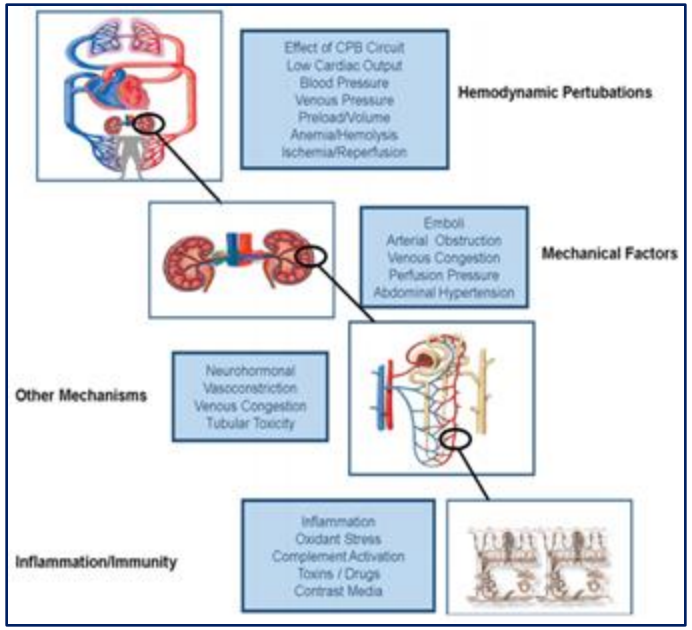
Pathophysiology of AKI related to Cardiopulmonary bypass and Cardiac Surgery



Variables associated with cardiac surgery & cardiopulmonary bypass that can contribute to acute kidney injury [1] :

- Nonpulsatile blood flow
- Hemodilution
- Transfusion load
- Release of free hemoglobin & free iron from hemolysis
- Prolonged hypothermia
- Inflammatory response
- Venous congestion
- Emboli
- Hypotension
- Ischemia and reperfusion

Reference

1. Nadim, M., F. LG, Bihorac, A., Kellum, J. et al: Cardiac and Vascular Surgery-Associated Acute Kidney Injury: The 20th International Consensus Conference of the ADQI (Acute Disease Quality Initiative) Group. J Am Heart Assoc 2018; 7

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CSA-AKI Risk Factors [1]

Preop	Intraop	Postop
Advanced Age	Complex surgery	Vasopressor exposure
Female	Cardiopulmonary bypass	Inotrope exposure
Hypertension	Low HCT in CPB	Blood transfusion
Hyperlipidemia	Aortic cross clamp time*	Anemia
Chronic Kidney Disease	Hypoperfusion	Hypovolemia
Liver Disease	Hypovolemia	Venous congestion
Peripheral Vascular Disease	Venous congestion	Cardiogenic shock
Previous Stroke	Emboli	
Smoking hx	Inotropes Exposure	
Diabetes		
Anemia		

* Cardiopulmonary bypass lasting 3 hours or longer was associated with a nearly fourfold elevated risk in renal dysfunction (unadjusted relative risk, 3.7 [CI, 2.8 to 4.9]) compared with cardiopulmonary bypass lasting less than 2 hours. [2]

References:

1. Romagnoli, S., Ricci, Z., Ronco, C.: Perioperative Acute Kidney Injury: Prevention, Early Recognition, and Supportive Measures. Nephron 2018; 140:105–10
2. Mangano, C., Diamondstone, L., Mangano, D. et al: Renal dysfunction after myocardial revascularization: risk factors, adverse outcomes, and hospital resource utilization. The Multicenter Study of Perioperative Ischemia Research Group. Ann Intern Med 1998; 128:194–203

Incidence of CKD after Cardiac Surgery

In a review of 29,388 cardiac surgery patients using the VASQIP registry: [1]

- 31% (9125) patients had CKD at time of surgery
- CKD defined as average eGFR <60mL/min/1.73m^2 for at least 3 months
- In remaining 20,263 patients without CKD at baseline:
  - 25% of patients with NO increase in postop creatinine developed CKD
  - 33% of patients with an increase of 1-24% in postop creatinine developed CKD
  - 44% of patients with an increase of 25-49% in postop creatinine developed CKD
  - 51% of patients with an increase of 50-99% in postop creatinine developed CKD
  - 53% of patients with an increase of ≥100% in postop creatinine developed CKD

Reference:

1. Ishani A, Nelson D, Clothier B, Schult T, Nugent S, Greer N, Slinin Y, Ensrud KE: The magnitude of acute serum creatinine increase after cardiac surgery and the risk of chronic kidney disease, progression of kidney disease, and death. Arch Intern Med 2011; 171:226–33

Considerations for Preventing CSA-AKI [1, 2]

Preop

- Assess Risk Factors
- Statin initiation: not supported
- Maintain normoglycemia
- Hold ACE inhibitors & Angiotensin Receptor Blockers (ARB)
- Treat anemia before elective cardiac surgery

Intraop

- Maintain Normoglycemia
- Avoid hydoxyethyl starch
- Use balanced crystalloid solutions to replace fluid losses
- Avoid hyperthermic perfusion during CPB- rewarming to > 37 C associated with higher incidence of CSA-AKI
- Avoid significant hemodilution during CPB & limit blood transfusions

Postop

- Avoid dopamine
- Discontinue ACEIs & ARBs for the first 48 hours after surgery
- Monitor sCr and urine output
- Maintain normoglycemia
- Avoid radiocontrast agents

References:

1. Cheruku,S., Raphael, J., Javier N, Fox, A. Acute Kidney Injury after Cardiac Surgery: Prediction, Prevention, and Management. *Anesthesiology* 2023; 139:880–898 doi: https://doi.org/10.1097/ALN.0000000000004734
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Preoperative Considerations

1. **Assess risk factors**
2. **Determine baseline kidney function**
3. **Assess for anemia**
4. **Assess for albuminuria**
5. **Statin initiation**: Not proven to reduce risk of AKI[1-3]
    1. High-dose atorvastatin did not reduce AKI overall after cardiac surgery [4]
    2. Preop treatment with a statin was not associated with postop AKI, RRT, or mortality [4]

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1. Nadim, M., Bihorac, A, Koyner, J., Kellum J. Et al.: Cardiac and Vascular Surgery-Associated Acute Kidney Injury: The 20th International Consensus Conference of the ADQI (Acute Disease Quality Initiative) Group. J Am Heart Assoc 2018; 7
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Preoperative Considerations continued

6. Maintain Normoglycemia
7. Hold ACE inhibitors and ARBs [1-3]
   - TRIBE-AKI study found increase in AKI in patients receiving ACEIs and ARBs (no ACEIs or ARBs: 31% incidence compared to 34% in held ACEIs/ARBs vs. 42% incidence with continued ACEIs/ARBs) [4]
   - Large meta-analysis (29 studies) found preop use of ACE/ARB until day of surgery increased odds of developing AKI [5]

References:

1. Nadim, M., Forni, L., Kellum, J.. Et al: Cardiac and Vascular Surgery-Associated Acute Kidney Injury: The 20th International Consensus Conference of the ADQI (Acute Disease Quality Initiative) Group. J Am Heart Assoc 2018;
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3. Rao, S., Shenoy, P,. Kiran, A. Et al: Applicability of the Cleveland clinic scoring system for the risk prediction of acute kidney injury after cardiac surgery in a South Asian cohort. Indian Heart J 2018; 70:533–7
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5. Yacoub R, Patel N, Arora, P. Et al.: Acute kidney injury and death associated with renin angiotensin system blockade in cardiothoracic surgery: a meta-analysis of observational studies. Am J Kidney Dis 2013; 62:1077–86

Intraoperative Considerations

1. Maintain normoglycemia
2. Avoid hydroxyethyl starch
3. Use balanced crystalloid solutions & vasopressors to maintain hemodynamics
4. Avoid hyperthermic perfusion during CPB
5. Avoid significant hemodilution during CPB
6. Limit blood transfusions

References

1. Fiaccadori E, Sabatino A, Morabito S, Bozzoli L, Donadio C, Maggiore U, Regolisti G: Hyper/hypoglycemia and acute kidney injury in critically ill patients. Clin Nutr 2016; 35:317–21
2. Moorthy V, Sim MA, Liu W, Chew STH, Ti LK: Risk factors and impact of postoperative hyperglycemia in nondiabetic patients after cardiac surgery: A prospective study. Medicine 2019; 98:e15911
3. Gumus F, Polat A., Alagol, A. et al: Use of a lower cut-off value for HbA1c to predict postoperative renal complication risk in patients undergoing coronary artery bypass grafting. J Cardiothorac Vasc Anesth 2013; 27:1167–73
4. Bansal B, Carvalho P, Mehta Y, Yadav J, Sharma P, Mithal A, Trehan N: Prognostic significance of glycemic variability after cardiac surgery. J Diabetes Complications 2016; 30:613–7

Intraoperative Considerations:

1. **Maintain normoglycemia**
   - AKI may further complicate glycemic control as it is associated with insulin resistance and reduced renal clearance of insulin [1]
   - Aortic cross-clamp time and blood transfusion as independent risk factors of postoperative hyperglycemia after cardiac surgery in non-diabetics [2]
   - In a study of 510 patients undergoing cardiovascular surgery and found the incidence of AKI to be higher in patients with high HbA1c levels preoperatively; Every 1% increase over 6% in HgA1c levels increased the risk of renal complications by 24% [3]
   - Glycemic variability, a standard deviation of all POC-BG readings, is associated with increased postoperative LOS-ICU, rise in creatinine, and AKI [4]

References

1. Fiaccadori E, Sabatino A, Morabito S, Bozzoli L, Donadio C, Maggiore U, Regolisti G: Hyper/hypoglycemia and acute kidney injury in critically ill patients. Clin Nutr 2016; 35:317–21
2. Moorthy V, Sim MA, Liu W, Chew STH, Ti LK: Risk factors and impact of postoperative hyperglycemia in nondiabetic patients after cardiac surgery: A prospective study. Medicine 2019; 98:e15911
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4. Bansal B, Carvalho P, Mehta Y, Yadav J, Sharma P, Mithal A, Trehan N: Prognostic significance of glycemic variability after cardiac surgery. J Diabetes Complications 2016; 30:613–7

Intraoperative Considerations:

1. **Maintain normoglycemia (continued)**
   - In a randomized controlled trial, moderate glucose control defined as 127-179 mg/dl was found to be preferable to tight control ≤ 126 in patients undergoing CABG [1]
   - Incidence of AKI was higher in patients with time-weighted average intraop glucose of >150mg/dl (8%) as compared to patients with blood glucose 110-150 mg/dl (3%) [2]
   - KDIGO - recommends maintaining blood glucose between 110 - 149 mg/dL in critically ill patients [3,4]
   - Tight glucose control (<150mg/dl) is seen as *controversial* as risks of hypoglycemia are significant: NICE-SUGAR meta-analysis [4]
   - Society of Thoracic Surgeons (STS) Practice Guidelines recommend **maintaining serum glucose levels ≤ 180 mg/dL for at least 24 hours after cardiac surgery** [5]

References:

1. Bhamidipati, C., LaPar, D., Ailawadi, G. et al.: Superiority of moderate control of hyperglycemia to tight control in patients undergoing coronary artery bypassgrafting. J Thorac Cardiovasc Surg 2011; 141:543–51
2. Song, J., Shim, J., Yoo, K., Kwak, Y. et al.: Impact of intraoperative hyperglycaemia on renal dysfunction after off-pump coronary artery bypass. Interact Cardiovasc Thorac Surg 2013; 17:473–8
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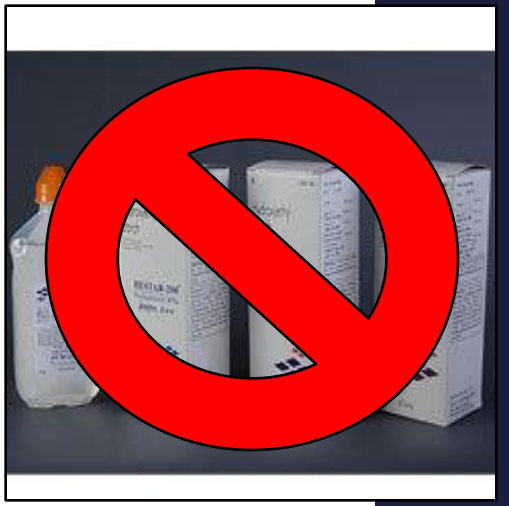
6. Lazar, H., McDonnell, M., Shemin, R. et al., Society of Thoracic Surgeons Blood Glucose Guideline Task Force: The Society of Thoracic Surgeons practice guide line series: Blood glucose management during adult cardiac surgery. Ann Thorac Surg 2009; 87:663–9

Intraoperative Considerations:

2. **Hydroxyethyl Starch (HES) studies show mixed results**
   - Hydroxyethyl starch-containing solutions may increase AKI occurrence
     - Scandinavian Starch for Severe Sepsis/Septic Shock (6S) Trial [1]
   - Crystalloid versus Hydroxyethyl Starch Trial (CHEST) published in 2012 initially found an increased need for renal replacement therapy in patients receiving HES vs. crystalloids; later analysis (2016) did not find this to be true- **no difference in patient outcomes** [2]
   - Need for further research, should be used cautiously



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Intraoperative Considerations:

3. **Use Vasopressors & crystalloids to maintain hemodynamic stability:**
   - Either norepinephrine or vasopressin can be used for hemodynamic support in the patient post-cardiac surgery [1]
   - European Society of Intensive Care Medicine recommendations: [11]
     - Norepinephrine recommended as first-choice vasopressor to protect kidney function (Grade 1B evidence)
       - Suggest vasopressin in patients with vasoplegic shock after cardiac surgery (Grade 2C evidence)
       - Controlled fluid resuscitation in volume depletion, while avoiding volume overload using balanced crystalloids (Grade 1C/2C)
   - American Heart Association - Cardiac and Vascular Surgery- Associated Acute Kidney Injury Consensus Guidelines recommend:[10]
     - Use of balanced crystalloid solutions guided by measures of fluid responsiveness (Grade 1B)
     - In adult cardiac surgery with CPB, fenoldopam may be reasonable to reduce the risk of CSA-AKI, as long as hypotension is avoided[4]

References:

1. Thiele, R., Isbell, J., Rosner, M. et al.: AKI associated with cardiac surgery. Clin J Am Soc Nephrol 2015; 10:500-14
2. Nadim, M., Forni, L., Kellum JA et al.: Cardiac and Vascular Surgery-Associated Acute Kidney Injury: The 20th International Consensus Conference of the ADQI (Acute Disease Quality Initiative) Group. J Am Heart Assoc 2018; 7
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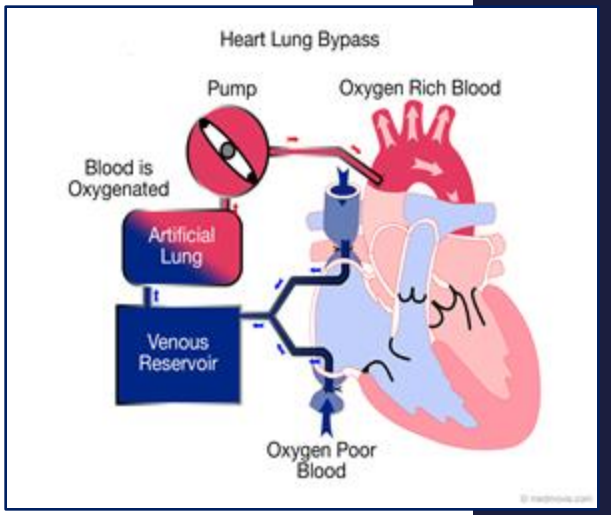
Intraoperative Considerations

4. **Avoid periods of hyperthermic perfusion**
   - CABG patients re-warmed on CPB to 37°C had a higher incidence of renal dysfunction (17%) as compared to patients re-warmed to 34°C (9%); n=223 [1]

5. **Avoid significant hemodilution**
   - Hemodilution during CPB is an independent risk factor for AKI in adult cardiac surgery [2]
   - In a retrospective analysis of 16,790 cardiac surgery patients, relative risk of AKI increased by 7% for every percentage point decrease in nadir HCT during CPB [3]

6. **Limit blood transfusions**
   - Transfusion of ≥ 2 units of packed red blood cells has been associated with higher incidence of AKI[4]
   - In 2 different RCTs, patients were randomized to liberal (Hg<9.5) or restrictive (Hb<7.5) groups intraoperatively and postoperatively and there was no difference in postop AKI. [5-6]



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6. Murphy, G., Pike, K., Rogers, C., Reeves, B. et al TITRe2 Investigators: Liberal or restrictive transfusion after cardiac surgery. N Engl J Med 2015; 372:997–1008

Goal-Directed Perfusion Trial (GIFT)[1]

- Multicenter RCT conducted at nine institutions in Europe, Australia, New Zealand, and the United States

- 350 cardiac surgery patients with cardiopulmonary bypass ≥ 90 minutes
  - Intervention group: Maintain DO_2 value ≥ 280mL · min^{-1} · m^{-2} during CPB; Adjust arterial pump flow based on Hct value to maintain DO_2; Transfuse 1U PRBC if SvO_2 <68% and/or the oxygen extraction rate was >40%
  - Control group: Arterial pump flow based on body surface area and temp, target value of 2.4L · min^{-1} · m^{-2} at normothermia. Transfusion trigger based on Hct value alone.

- Lower incidence of AKIN Stage 1 AKI in GDP group; same incidence for stage 2 & 3

References

1. Ranucci, M, Johnson I, Pistuddi, V. et al.: Goal-directed perfusion to reduce acute kidney injury: A randomized trial. J Thorac Cardiovasc Surg 2018; 156:1918–27.e2

Goal Directed Resuscitation in Cardiac Surgery [1]

126 cardiac surgery patients undergoing CABG or valve surgery were randomized to two groups:

- Control group: 64 patients receiving usual care
- Goal directed therapy group: 62 patients receiving protocol-based care (see graphic)

Outcomes:

- 30-day mortality and major complications reduced in the GDT group (27% compared to 45% in the control) p=0.037
- However, no significant difference in AKI requiring dialysis or hemofiltration

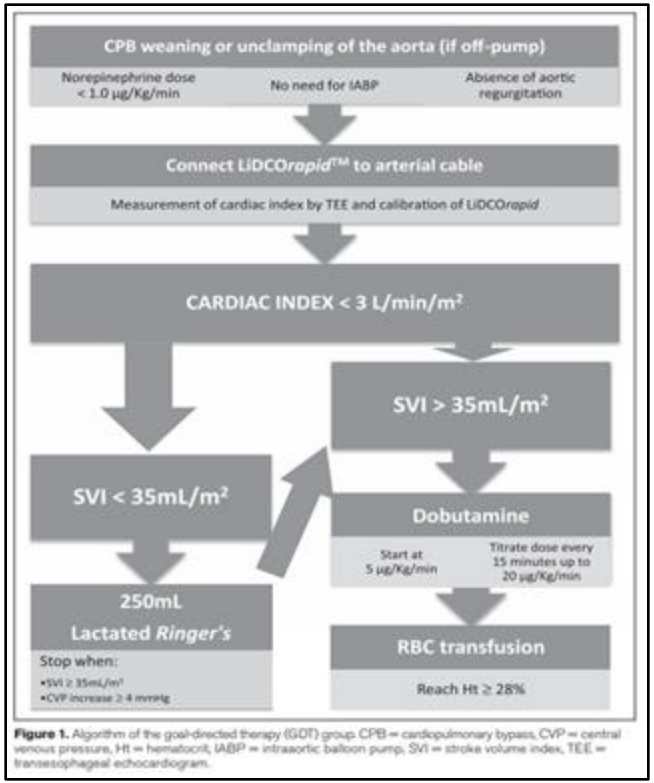

Figure 1. Algorithm of the goal-directed therapy (GDT) group. CPB = cardiopulmonary bypass, CVP = central venous pressure, Ht = hematocrit, IABP = intraaortic balloon pump, SVI = stroke volume index, TEE = transesophageal echocardiogram.

Reference

1. Osawa, E., Rhodes, A., Hajjar, L. et al: Effect of Perioperative Goal-Directed Hemodynamic Resuscitation Therapy on Outcomes Following Cardiac Surgery: A Randomized Clinical Trial and Systematic Review. Crit Care Med 2016; 44:724–33

PrevAKI Study [1]

- Cardiac surgery, n = 276
- Successfully reduced AKI in cardiac population through 3 primary interventions:
  1. Optimized hemodynamics:
     - Dobutamine or epinephrine for cardiac index <3.0
     - Norepinephrine for MAP <65
  2. Avoided hyperglycemia
  3. Held ACEi/ARB for 48 hours after surgery

SEVEN-DAY PROFILE PUBLICATION

Prevention of cardiac surgery-associated AKI by implementing the KDIGO guidelines in high risk patients identified by biomarkers: the PrevAKI randomized controlled trial

Melanie Meersch[1], Christoph Schmidt[1], Andreas Hoffmeier[2], Hugo Van Aken[1], Carola Wempe[1], Joachim Gerss[3] and Alexander Zarbock[1*]

TABLE 3. - Standard of Care and Kidney Disease Improving Global Outcomes Bundle Intervention.

Control	Intervention KDIGO Bundle
Standard care	Discontinuation of all nephrotoxic agents if possible
ACEi and ARBs continued according to ACC recommendations	Discontinuation of ACE inhibitors and ARBs for the first 2 days after surgery
MAP will be kept >65 mm Hg	Close monitoring of serum creatinine and urinary output
CVP between 8 and 10 mm Hg	Avoidance of hyperglycemia by close monitoring
	Consideration of alternatives to radio contrast agents
	Hemodynamic monitoring and optimization according to a hemodynamic algorithm

Adapted from Meersch M, Schmidt C, Hoffmeier A, et al. Prevention of cardiac surgery-associated AKI by implementing the KDIGO guidelines in high risk patients identified by biomarkers: the PrevAKI randomized controlled trial. *Intensive Care Med.* 2017;43:1551-1561; and Acute Kidney Injury Work Group. Kidney Disease: Improving Global Outcomes (KDIGO). KDIGO clinical practice guideline for acute kidney injury. *Kidney Int.* 2012;2(suppl 1):1-138.

Abbreviations: ACC, American College of Cardiology; ACEi, angiotensin-converting enzyme inhibitor; ARB, angiotensin-receptor blocker; CVP, central venous pressure; KDIGO, Kidney Disease: Improving Global Outcomes; MAP, mean arterial pressure.

References

1. Meersch M, Schmidt C, Hoffmeier A, Van Aken H, Wempe C, Gerss J, Zarbock A: Prevention of cardiac surgery-associated AKI by implementing the KDIGO guidelines in high risk patients identified by biomarkers: the PrevAKI randomized controlled trial. Intensive Care Med 2017; 43:1551–61

Urinary Biomarker Study

- N= 412
- Retrospective study using the STS Adult Cardiac Database. Patients on dialysis preoperatively and those with a serum creatinine level >2.0 mg/dL were excluded. Measurement of UBs was implemented into routine clinical practice at that site in July 2017.
- Study demonstrated relative risk reduction of 89% for stage 2/3 CSA-AKI.

Using urinary biomarkers to reduce acute kidney injury following cardiac surgery

Read at the 99th Annual Meeting of The American Association for Thoracic Surgery, Toronto, Ontario, Canada, May 4-7, 2019.

Daniel T. Engelman MD [a], Cheryl Crisafi MS, RN [a], Michael Germain MD [b], Barbara Greco MD [b], Brian H. Nathanson PhD [c], Richard M. Engelman MD [a], Thomas A. Schwann MD, MBA [a]

TABLE 2. Patient outcomes

Outcome	Before urinary biomarkers (N = 435)	After urinary biomarkers/acute kidney response team (N = 412)	*P* value
Stage 2 or 3 AKI, n (%)	10 (2.30)	1 (0.24)	**.01**
All AKI results, n (%)			**.04**
Stage 0	373 (85.8)	370 (89.8)	
Stage 1	52 (12.0)	41 (10.0)	
Stage 2	3 (0.7)	0 (0)	
Stage 3	7 (1.6)	1 (0.2)	
Total LOS, d, mean (SD)	10.7 (6.0)	11.2 (7.8)	.29
Postoperative LOS, d, mean (SD)	7.8 (4.4)	8.4 (6.5)	.11
Total cost, USD, mean (SD)	45,415 (21,549)	47,303 (27,261)	.26
30-d mortality, %, mean (SD)	5 (1.1)	3 (0.7)	.73
30-d readmission, n (%)	42 (9.8)	42 (10.3)	.81

Boldface indicates *P* values <.05. *AKI*, Acute kidney injury; *LOS*, length of stay; *SD*, standard deviation.

Reference

1. Engelman, D., Crisafi, C., Germain, M., Greco, B., Nathanson, B., Engelman, R., Schwann, T. Using urinary biomarkers to reduce acute kidney injury following cardiac surgery, *The Journal of Thoracic and Cardiovascular Surgery*, Volume 160, Issue 5, 2020, Pages 1235-1246.e2, ISSN 0022-5223, https://doi.org/10.1016/j.jtcvs.2019.10.034

MPOG MULTICENTER PERIOPERATIVE OUTCOMES GROUP

Minimally Invasive Extracorporeal Circulation (MiECC)

- MiECC has been proposed as an alternative approach to performing cardiac surgery using standard cardiopulmonary bypass. [1]
- A recent meta-analysis reported MiECC reduced the odds of CSA-AKI by >50% comparted with conventional CPB. [1]
- Recommendation from the STS and the SCA/ American Society for Extracorporeal Technology Clinical Practice Guidelines for the Prevention of Adult Cardiac Surgery-Associated Acute Kidney Injury:
  - *In adult cardiac surgery with CPB, it might be reasonable to use minimally invasive extracorporeal circulation (MiECC) techniques to reduce the risk of CSA-AKI. (Class of Recommendation: IIB, Level of Evidence: B-R)*

Reference

1. Brown, J; Baker, R.; Hammon, J. et al. *The Society of Thoracic Surgeons/Society of Cardiovascular Anesthesiologists/American Society for Extracorporeal Technology* Clinical Practice Guidelines for the Prevention of Adult Cardiac Surgery–Associated Acute Kidney Injury. Anesthesia & Analgesia 136(1):p 176-184, January 2023. | DOI: 10.1213/ANE.0000000000006286

MPOG MULTICENTER PERIOPERATIVE OUTCOMES GROUP

Postoperative Considerations

1. **Avoid low-dose dopamine to treat/prevent AKI**
   - In a meta-analysis of 58 studies examining dopamine use, 24 studies included outcomes: low-dose dopamine was not associated with the prevention of acute renal failure [1]
   - A second meta-analysis of 61 studies established similar findings: low-dose dopamine increased urine output but did not prevent renal dysfunction [2]

2. **Monitor sCr and urine output for early detection of AKI[3]**

3. **Maintain blood glucose**
   - Society of Thoracic Surgeons (STS) Practice Guidelines recommend maintaining serum glucose levels ≤ 180 mg/dL for at least 24 hours after cardiac surgery [4]

4. **Avoid radiocontrast agents**
   - Contrast dose > 240 mg/kg resulted in greater incidence of CSA-AKI for patients who underwent cardiac catheterization ≤7 days before cardiac surgery than those > 7 days before cardiac surgery (39% vs. 29%, p = 0.025) [5]

Reference

1. Kellum, J., Decker, J. et al: Use of dopamine in acute renal failure: a meta-analysis. Crit Care Med 2001; 29:1526–31
2. Friedrich, J, Adhikari, N., Herridge, M., Beyene, J.: Meta-analysis: low-dose dopamine increases urine output but does not prevent renal dysfunction or death. Ann Intern Med 2005; 142:510–24
3. Nadim, M., Forni, L., Kellum, J. et al: Cardiac and Vascular Surgery-Associated Acute Kidney Injury: The 20th International Consensus Conference of the ADQI (Acute Disease Quality Initiative) Group. J Am Heart Assoc 2018; 7
4. Lazar, H., McDonnell, M., Shemin R. et al. Society of Thoracic Surgeons Blood Glucose Guideline Task Force: The Society of Thoracic Surgeons practice guideline series: Blood glucose management during adult cardiac surgery. Ann Thorac Surg 2009; 87:663–9
5. Jiang W, Yu J, Teng, J. et al. : Impact of cardiac catheterization timing and contrast media dose on acute kidney injury after cardiac surgery. BMC Cardiovasc Disord 2018; 18:191

Dopamine infusion nor mannitol are recommended to prevent AKI in Cardiac Surgery

Per STS/Cardiovascular Anesthesiologist Practice Guidelines:

- In adult cardiac surgery patients with CBP, dopamine infusion during bypass and in the postoperative period is not recommended to reduce the risk of CSA-AKI. (Class of recommendation III: No benefit, Level of Evidence: A). [1]

- In adult cardiac surgery patients with CBP, mannitol is not recommended to reduce the risk of CSA-AKI. (Class of recommendation III: No Benefit, Level of Evidence, B-R). [1]

Reference

1. Brown, J; Baker, R.; Hammon, J. et al. *The Society of Thoracic Surgeons/Society of Cardiovascular Anesthesiologists/American Society for Extracorporeal Technology* Clinical Practice Guidelines for the Prevention of Adult Cardiac Surgery–Associated Acute Kidney Injury. Anesthesia & Analgesia 136(1):p 176-184, January 2023. | DOI: 10.1213/ANE.0000000000006286

Summary of Considerations for preventing AKI after Card Surgery

1. Assess Risk Factors for AKI
2. Establish Baseline Renal Function
3. Maintain Blood Glucose
4. Avoid Hydroxyethyl Starch
5. Maintain Hemodynamics: Balanced crystalloids & vasopressors
6. Avoid hyperthermic perfusion & significant hemodilution during CPB
7. Limit Blood Transfusions
8. Avoid Low-dose Dopamine to treat/prevent AKI
9. Continue to monitor creatinine and urine output postoperatively
10. Avoid Radiocontrast Agents: Postpone surgery if possible after contrast

More research needed

Interventions requiring more research

Beta-blockers may lead to decreased risk of renal dysfunction after cardiac surgery

- Preop beta-blocker use was not associated with postop AKI [1]
- In a large North American observational analysis (629,877 patients), preoperative beta-blocker therapy was associated with a slightly lower risk of renal failure in patients undergoing CABG (3% vs. 4%) [2]

Reference

1. O'Neal J., Billings, F., Shaw A. et al: Effect of Preoperative Beta-Blocker Use on Outcomes Following Cardiac Surgery. Am J Cardiol 2017; 120:1293–7
2. Ferguson, T. Jr, Coombs, L., Peterson, E. Society of Thoracic Surgeons National Adult Cardiac Surgery Database: Preoperative beta-blocker use and mortality and morbidity following CABG surgery in North America. JAMA 2002; 287:2221–7

Interventions requiring more research

Volatile anesthetics may protect against AKI [1,2]

A meta-analysis of 10 trials with 1600 patients found that volatile anesthetics significantly reduced AKI incidence compared with control data (relative risk: 0.65; 95% CI, 0.43-0.97; P=0.04) [1]

Remote Ischemic Preconditioning [3-5]

Application of controlled ischemia to remote tissues or organs to create a protective adaptive response in distant organs

Mixed results in studies -> differing protocols, patient populations, and study design

- Further investigation needed before adopting into practice

References:

1. Cai , J., Xu, R., Ding, X. et al: Volatile anesthetics in preventing acute kidney injury after cardiac surgery: a systematic review and meta-analysis. J Thorac Cardiovasc Surg 2014; 148:3127–36
2. Yoo, Y., Shim, J., Kwak Y. et al: Anesthetics influence the incidence of acute kidney injury following valvular heart surgery. Kidney Int 2014; 86:414–22
3. Zarbock, A., Kellum, J., Meersch, M.. et al: Long-term Effects of Remote Ischemic Preconditioning on Kidney Function in High-risk Cardiac Surgery Patients: Follow-up Results from the Renal RIP Trial. Anesthesiology 2017; 126:787–98
4. Pierce, B., Bole, I,, Patel, V., Brown, D. et al: Clinical Outcomes of Remote Ischemic Preconditioning Prior to Cardiac Surgery: A Meta-Analysis of Randomized Controlled Trials. J Am Heart Assoc 2017; 6
5. Murphy, N, Vijayan, A, Conlon, N. et al: Remote ischemic preconditioning does not affect the incidence of acute kidney injury after elective abdominal aortic aneurysm repair. J Cardiothorac Vasc Anesth 2014; 28:1285–92

Interventions requiring more research

Alpha-2 agonists

- A study in pediatric patients undergoing congenital cardiac surgery showed that dexmedetomidine was associated with lower instances of acute kidney injury [1]
- A meta-analysis stated that dexmedetomidine may be promising as an agent to prevent postoperative renal dysfunction after cardiac surgery [2]

Intraoperative FiO2

- The ROCS trial is examining the impact of hyperoxia on end organ injury during cardiac surgery [3]
- A sub-analysis of an ongoing RCT did not find a significant increase in AKI with intraoperative hyperoxia during **non-cardiac** surgery [4]

Reference

1. Kwiatkowski, D., Axelrod, D., Tesoro, T., Krawczeski, C.. Dexmedetomidine Is Associated With Lower Incidence of Acute Kidney Injury After Congenital Heart Surgery. Pediatr Crit Care Med. 2016;17(2):128-134.
2. Shi, R., Tie, H. Dexmedetomidine as a promising prevention strategy for cardiac surgery-associated acute kidney injury: a meta-analysis. Crit Care 21, 198 (2017).
3. Lopez , M., Pretorius M, Shotwell, M., et al. The Risk of Oxygen during Cardiac Surgery (ROCS) trial: study protocol for a randomized clinical trial. Trials. 2017;18(1):295.
4. Ruetzler K, Cohen B, Leung S, et al. Supplemental Intraoperative Oxygen Does Not Promote Acute Kidney Injury or Cardiovascular Complications After Noncardiac Surgery: Subanalysis of an Alternating Intervention Trial. Anesth Analg. 2020;130(4):933-940.