ACUTE KIDNEY INJURY IN CARDIAC SURGERY PATIENTS

The Clinical Journey from Cardiac Surgery to Renal Replacement Therapy
What is cardiac surgery associated-acute kidney injury?

**AKI** is a **COMMON** complication of **cardiac surgery**¹–⁷

**Incidence of CSA-AKI**

20–40% of cardiac surgery patients develop CSA-AKI¹–⁷

1–9% of cardiac surgery patients require RRT¹–⁷

**A LARGE PROPORTION** of patients undergoing **CARDIAC SURGERY** develop **AKI**¹–⁷

**CSA-AKI** is associated with a high **CLINICAL BURDEN** and a high **ECONOMIC BURDEN**¹–¹¹

**Average costs (2002 USD) of a post-cardiac surgery patient with and without CSA-AKI**

<table>
<thead>
<tr>
<th>Resource</th>
<th>AKI (n = 258)*</th>
<th>No AKI (n = 258)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICU</td>
<td>$25,949</td>
<td>$13,836</td>
</tr>
<tr>
<td>ICU supply</td>
<td>$721</td>
<td>$129</td>
</tr>
<tr>
<td>Laboratory</td>
<td>$3350</td>
<td>$1083</td>
</tr>
<tr>
<td>Pharmacy</td>
<td>$2550</td>
<td>$796</td>
</tr>
<tr>
<td>Ventilatory</td>
<td>$396</td>
<td>$234</td>
</tr>
</tbody>
</table>

$*P < 0.001 for AKI vs No AKI

Retrospective single-centre cohort study of cardiac surgery admissions from June 1998 to May 2002

**CSA-AKI** is associated with both a high **CLINICAL BURDEN** and a high **ECONOMIC BURDEN**¹–¹¹

**In patients who undergo cardiac surgery, the development of AKI is associated with an INCREASED RISK OF MORBIDITY AND MORTALITY**²–⁴,⁷–¹⁰

**CSA-AKI** is a **SERIOUS** condition²–⁴,⁷–¹⁰

Among patients who have undergone cardiac surgery, the **ECONOMIC BURDEN** is significantly greater for those with **AKI** compared with those without **AKI**⁸,¹¹

**Incidence typically reported in published studies**
**Why do cardiac patients get AKI?**

In addition to **PATIENT RISK FACTORS**, there are many **PROCEDURE-RELATED RISK FACTORS** for developing CSA-AKI\(^\text{12–15}\).

**Patient risk factors**
- Advanced age
- Female sex
- High BMI
- Hypertension
- CKD
- DM requiring insulin
- COPD
- Peripheral vascular disease
- Cerebrovascular disease
- Congestive heart failure
- Sepsis
- Ascites

**Procedure-related factors**
- Long duration of surgery
- Packed red blood cell transfusion
- Intra-aortic balloon pump
- Intraoperative hypotension
- Vasopressor exposure
- Nephrotoxic agents
- Longer length of cardiopulmonary bypass
- Longer cross-clamp time
- Haemodilution

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**CSA-AKI** has **UNIQUE** risk factors that **DIFFERENTIATE** it from other causes of AKI\(^\text{12–15}\).

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**Pathophysiological mechanisms associated with CSA-AKI development\(^\text{14}\)**

**Haemodynamic perturbations**
- Effect of CPB circuit
  - Low cardiac output
  - Blood pressure
  - Venous pressure
  - Preload/volume
  - Anaemia/haemolysis

**Mechanical factors**
- Emboli
  - Arterial obstruction
  - Venous congestion
  - Perfusion pressure
  - Abdominal hypertension

**Other mechanisms**
- Neurohormonal
  - Vasocnstriction
  - Venous congestion
  - Tubular toxicity

**Inflammation/immunity**
- Inflammation
  - Oxidant stress
  - Complement activation
  - Toxins/drugs
  - Contrast media

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HAEMODYNAMIC PERTURBATIONS during surgery can lead to **CSA-AKI**\(^\text{12,14}\).
What about patient haemodynamics?

Patients who undergo cardiac surgery may experience perioperative HAEMODYNAMIC PERTURBATIONS; FLUIDS and vasopressors are typically used to restore haemodynamic stability. During or after CARDIAC SURGERY, patients may experience a significant SHIFT IN FLUIDS from the intravascular to the extravascular space.

This fluid shift, in combination with the potentially LARGE VOLUMES of FLUID that may be needed to restore haemodynamic stability, can result in a positive fluid balance.

Total perioperative (0–24 hr) fluid balance by AKI severity:

Management of perioperative haemodynamic instability may lead to a POSITIVE FLUID BALANCE after cardiac surgery, especially in patients with AKI.

The development of FLUID OVERLOAD is associated with an increased risk of mortality and an increased risk of AKI or the need for RRT.

In patients who undergo cardiac surgery, HAEMODYNAMIC INSTABILITY and FLUID OVERLOAD are INDEPENDENTLY ASSOCIATED with an increased risk of MORTALITY and the need for RRT.

Low MAP and high vasopressor use:

- Increased mortality
- Higher need for RRT

High positive fluid balance:

- Independently associated with:
  - Increased mortality
  - Higher need for RRT

*From the induction of anesthesia until 24 hr after commencement of cardiopulmonary bypass. 2007 single-centre, prospective cohort study of 282 adult cardiac surgery patients.
Some patients require fluid removal by RRT, but undesirable fluctuations in fluid balance may occur with certain modalities\(^25-27\). RRT helps support kidney recovery in patients with CSA-AKI, in part by restoring fluid balance and haemodynamic stability\(^14,25-27\).

RRT modalities that are able to remove excess fluid in a slow, continuous manner may help avoid exacerbation of haemodynamic instability\(^14,25-27\).

Theoretical fluid removal by continuous and intermittent RRT\(^14,25-27\):

- **Continuous therapy** is noted for its slow and steady fluid removal.
- **Intermittent therapies** may cause considerable fluctuations in fluid balance\(^25-27\).

Current clinical practice guidelines recommend use of continuous RRT in AKI patients who are haemodynamically unstable\(^14,25,26\).

The 20th ADQI International Consensus Conference for CSA-AKI recommends the use of continuous therapies in patients with haemodynamic instability and in situations where shifts in fluid balance are poorly tolerated\(^14\).
CSA-AKI is a common and serious complication of cardiac surgery.\textsuperscript{1-11} Owing to the unique pathophysiology of CSA-AKI, there are specific risk factors that differentiate it from AKI due to other causes.\textsuperscript{12-15} Management of perioperative haemodynamic instability may lead to a positive fluid balance after cardiac surgery.\textsuperscript{7,14,17,22} In cardiac surgery patients, haemodynamic instability and fluid overload are associated with an increased need for RRT and an increased risk of mortality.\textsuperscript{17,23,24} In patients with CSA-AKI, fluid removal by RRT can be challenging due to the risk of worsening haemodynamic status.\textsuperscript{14,25,26} Current clinical practice guidelines recommend or suggest the use of continuous RRT in CSA-AKI patients who are haemodynamically unstable and in whom fluid shifts are poorly tolerated.\textsuperscript{14,25,26}

**References/abbreviations/acronyms**

ADQI, Acute Dialysis Quality Initiative; AKI, acute kidney injury; BMI, body mass index; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CPB, cardiopulmonary bypass; CRRT, continuous renal replacement therapy; CSA-AKI, cardiac surgery associated-acute kidney injury; DM, diabetes mellitus; ESRD, end-stage renal disease; ICU, intensive care unit; RIFLE, classification of kidney disease as Risk, Injury, Failure, Loss, End-stage (RIFLE-0, no risk; RIFLE-R, at risk; RIFLE-I, with kidney injury; RIFLE-F, with kidney failure); RRT, renal replacement therapy
