Acute kidney injury and fluid overload in pediatric cardiac surgery

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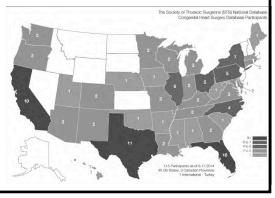
The Importance of Patient-Specific Preoperative Factors: An Analysis of The Society of Thoracic Surgeons Congenital Heart Surgery Database

Jeffrey Phillip Jacobs, MD, Sean M. O'Brien, PhD, Sara K. Pasquali, MD, MHS, Sunghee Kim, PhD, J. William Gaynor, MD, Christo Ivanov Tchervenkov, MD, Tara Karamlou, MD, Karl F. Welke, MD, Francois Lacour-Gayet, MD, Constantine Mavroudis, MD, John E. Mayer Jr, MD, Richard A. Jonas, MD, Fred H. Edwards, MD, Frederick L. Grover, MD, David M. Shahian, MD, and **Marshall Lewis Jacobs, MD**

Results—In all, 25,476 operations were included (overall discharge mortality 3.7%, n = 943). The prevalence of common preoperative factors and their associations with discharge mortality were determined. Associations of the following preoperative factors with discharge mortality were all highly significant ($p < 0.0001$) for neonates, infants, and children: mechanical circulatory support, renal dysfunction, shock, and mechanical ventilation.



Postoperative complications (**62.851 patients**)

Complication	Occurrence: n (%)	Mortality n (%)
Acute kidney injury	705 (1.1%)	396 (56.2%)
Neurological deficit at discharge	500 (0.8%)	152 (30.4%)
AV-block and permanent pacemaker	593 (0.9%)	28 (4.7%)
Mechanical circulatory support	1110 (1.8%)	617 (55.6%)
Phrenic nerve injury/palsy	578 (0.9%)	35 (6.1%)
Not planned reoperation	2942 (4.7%)	636 (21.6%)

[6] **Jacobs, M.L. et al.** *An empirically based tool for analyzing morbidity associated with operations for congenital heart disease.* J Thorac Cardiovasc Surg, 2013. **145**(4): p. 1046-1057

CURRENT OPINION

Cardiac intensive care for the neonate and child after cardiac surgery

Holly C. DeSena, David P. Nelson, and David S. Cooper

KEY POINTS

- Optimal nutrition, in particular enteral nutrition, is a challenge in infants with critical cardiac disease.
- The benefit of treatment for hyperglycemia following cardiac surgery is less clear and needs further study.
- AKI has a significant impact on postoperative morbidity and mortality. Earlier diagnosis utilizing novel urinary biomarkers may allow timely intervention.
- Fluid overload is common after cardiac surgery, especially in neonates, and is associated with an increased morbidity and mortality.
- Early extubation following cardiac surgery can be done safely and is associated with an improved resource utilization and decreased ICU LOS.

Curr Opin Cardiol 2015, 30:81–88

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Neonates

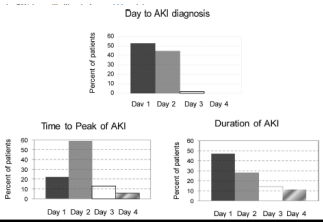
Mortality 10%
Circulatory support 33.6%
Shock 33.6%
Renal dysfunction 26.1%
Prolonged mechanical ventilation 15.1%
Coagulation disorder 45.5%

Potential Preoperative Risk Factors	Neonates (n = 5,630) Mortality Rate[a] (p Value)
Overall mortality rate	9.88%
Preoperative/preprocedural mechanical circulatory support[b]	20/37 = 54.1% (<0.0001)
Shock, persistent at time of surgery	42/123 = 33.6% (<0.0001)
Renal dysfunction	31/119 = 26.1% (<0.0001)
Mechanical ventilation to treat cardiorespiratory failure	271/1792 = 15.1% (<0.0001)
Gastrostomy present	3/18 = 16.7% (0.4132)
Shock, resolved at time of surgery	63/421 = 15.0% (0.0006)
Coagulation disorder, hypocoagulable state secondary to medication	5/11 = 45.5% (0.0026)
Hypothyroidism	6/23 = 26.1% (0.0211)
Preoperative neurologic deficit	10/47 = 21.3% (0.022)
Preoperative complete atrioventricular block	10/50 = 20.0% (0.0276)
Stroke, CVA, or intracranial hemorrhage grade >2 during lifetime	7/41 = 17.1% (0.1179)
Seizure during lifetime	7/51 = 13.7% (0.3426)

Incidence, risk factors, and outcomes of acute kidney injury after pediatric cardiac surgery: A prospective multicenter study☆

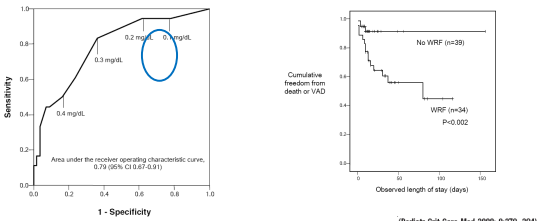
Simon Li, MD; Catherine D. Krawczeski, MD; Michael Zappitelli, MD, MSc; Prasad Devarajan, MD; Heather Thiessen-Philbrook, MMath, AStat; Steven G. Coca, DO, MS; Richard W. Kim, MD; Chirag R. Parikh, MD, PhD; for the TRIBE-AKI Consortium

- Cyanosis
- Length of CPB
- Age
- Elevated preoperative serum creatinine
- Low cardiac output syndrome



Worsening renal function in children hospitalized with decompensated heart failure: Evidence for a pediatric cardiorenal syndrome?☆

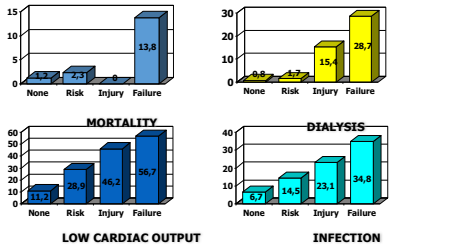
Jack F. Price, MD; Antonio R. Mott, MD; Heather A. Dickerson, MD; John Lynn Jefferies, MD; David P. Nelson, MD, PhD; Anthony C. Chang, MD; E. O'Brian Smith, PhD; Jeffrey A. Towbin, MD, FACC; William J. Dreyer, MD, FACC; Susan W. Denfield, MD, FACC; Stuart L. Goldstein, MD



(Pediatr Crit Care Med 2008; 9:279–284)

Acute Kidney Injury Is Associated With Higher Morbidity and Resource Utilization in Pediatric Patients Undergoing Heart Surgery

Roland Tóth, MD, Tamás Breuer, MD, Zsuzsanna Cserép, MD, Dániel Lex, Levente Fazekas, MD, PhD, Erzsébet Sápi, MD, András Szatmári, MD, PhD, János Gál, MD, PhD, and Andrea Székely, MD, PhD



LOW CARDIAC OUTPUT

INFECTION

(Ann Thorac Surg 2012;93:1984 –91)

AKI and complications

Table 3. Comparison of Outcomes in the Nonmatched and Matched Groups

	Before Propensity Score Matching					After Propensity Score Matching				
	AKI (n = 481)		Non-AKI (n = 1,029)			AKI (n = 325)		Non-AKI (n = 325)		
Variable	N/median	%/IQR	N/median	%/IQR	*p* Value	N/median	%/IQR	N/median	%/IQR	*p* Value
Mortality	43	8.9%	12	1.2%	<0.001	17	5.2%	8	2.5%	0.09
Low cardiac output	222	46.2%	115	11.2%	<0.001	116	35.7%	80	24.6%	0.002
Pulmonary failure	124	25.8%	122	11.9%	<0.001	77	23.7%	66	20.3%	0.63
Dialysis	88	18.3%	8	0.8%	<0.001	23	7.1%	6	1.8%	<0.001
Infection	101	21.0%	64	6.2%	<0.001	69	21.2%	47	14.5%	0.03
ICU stay (days)	6.1	(3.4–9.2)	3.5	(1.7–4.5)	<0.001	5.1	(2.9–7.9)	4.1	(2.2–7.1)	0.001
MV (hours)	87	(32–166)	13	(7–35)	<0.001	49	(26–112)	33	(15–76)	<0.001

(Ann Thorac Surg 2012;93:1984–91)

Methods

Creatinine clearance calculation by the Schwartz-equation

$$eCCl\ (ml/min/1.73\ m^2) = \frac{k \times \text{height (cm)}}{\text{plasma creatinine (mg/dl)}}$$

k = 0,55
< 1 year: 0,45
Male > 13year : 0,7

SCr=0.73 mg/dl eCCl: 38 ml/min/1.73 m2 if neonate and 62 cm and eCCL: 24 if preterm and 53 cm

Schwartz et al. *Pediatr Clin North Am.* 1987; 34: 571-90.

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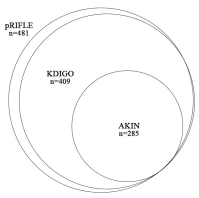
RIFLE and AKIN criteria

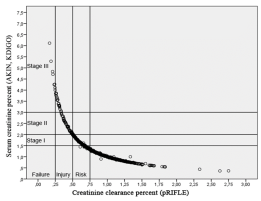
pRIFLE			AKIN	
Class	Urine output	eCrCl by Schwartz	Stage	SCr
Risk	<0.5 ml/kg/h × 8 h	↑CrCl by 25%	I	↑SCr >0.3 mg/dl or ↑SCr >150–200% from baseline
Injury	<0.5 ml/kg/h × 16 h	↑CrCl by 50%	II	↑SCr to >200–300% from baseline
Fail	<0.3 ml/kg/h × 24 h or anuric × 12 h	↑CrCl by 75% or <35 ml/min/1.73m^2	III	↑SCr of >300% from baseline or SCr >4 mg/dl with an acute rise of at least 0.5 mg/dl
Loss	Failure >4 weeks			
ESRD	Failure >3 months			

AKIN, Acute Kidney Injury Network; CrCl, creatinine clearance; eCrCl, estimated creatinine clearance; ESRD, end-stage renal disease; GFR, glomerular filtration rate; pRIFLE, pediatric RIFLE; RIFLE, risk, injury, failure, loss and end-stage; SCr, serum creatinine.

A Comparison of the Systems for the Identification of Postoperative Acute Kidney Injury in Pediatric Cardiac Patients

Daniel J. Lex, MD, Roland Tóth, MD, Zsuzsanna Cserép, MD, Stephen I. Alexander, MBBS, MPH, Tamás Breuer, MD, Erzsébet Sápi, MD, András Szatmári, MD, PhD, Edgár Székely, MD, János Gál, MD, PhD, and Andrea Székely, MD, PhD





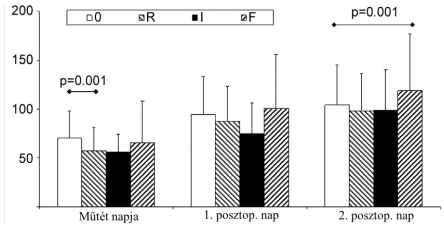
(Ann Thorac Surg 2014;97:202–10)

Adjusted Risk Models for Dialysis

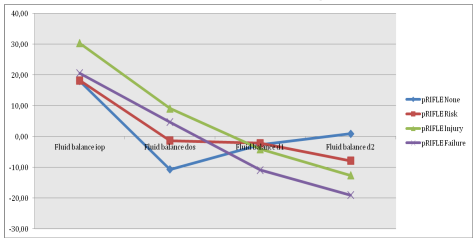
		All patient	Neonate	Infant	Children
pRIFLE	AUC	0,87	0,85	0,89	0,86
	(95% C.I.)	(0,83-0,91)	(0,78-0,92)	(0,85-0,94)	(0,79-0,92)
	p-value	0,001	0,001	0,001	0,001
	Sensitivity	91%	92%	96%	87%
	Specificity	72%	67%	70%	76%
AKIN without RRT	AUC	0,75	0,7	0,78	0,76
	(95% C.I.)	(0,69-0,81)	(0,58-0,83)	(0,67-0,88)	0,66-0,86)
	p-value	0,001	0,001	0,001	0,001
	Sensitivity	60%	52%	65%	63%
	Specificity	87%	88%	86%	87%
KDIGO without RRT	AUC	0,5	0,51	0,52	0,46
	(95% C.I.)	(0,44-0,55)	(0,40-0,62)	(0,42-0,62)	(0,38-0,55)
	p-value	0,99	0,8	0,6	0,4
	Sensitivity	-	-	-	-
	Specificity	-	-	-	-

(Ann Thorac Surg 2014;97:202–10)

Urine output in pRIFLE categories



Fluid balance and RIFLE categories



Lex DJ et al Fluid overload and adverse outcomes PCCM 2016

Cumulative fluid overload greater than 5% at the second postoperative day

Predictors	Adjusted OR (95% CI)	p
Body weight (kg)	0.884 (0.783-0.998)	0.046
Maximum SCr (umol/l)	1.013 (1.003-1.023)	0.013
Low cardiac output syndrome	3.056 (1.285-7.267)	0.011
Blood loss DOS (ml/kg)	1.016 (1.005-1.027)	0.003
Maximum VIS score	1.019 (1.005-1.032)	0.008

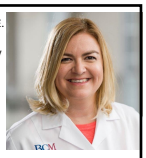
Multivariable logistic regression model for in-hospital mortality

Predictors	Adjusted OR (95% CI)	p
Age (log)	0.416 (0.202-0.856)	0.017
Acute operation	4.791 (1.312-17.49)	0.018
CPB time (min)	1.007 (1.001-1.013)	0.02
Renal replacement therapy	3.018 (1.088-8.369)	0.034
Low output syndrome	10.26 (2.152-48.91)	0.003
Maximum VIS score	1.015 (0.998-1.033)	0.08
cFO DOS (%)	1.166 (1.018-1.336)	0.027

TABLE 1. Calculation of Fluid Overload Kidney Injury Score

Parameter		Points
pRIFLE creatinine criteria		
None	GFR decrease by < 25%	0
Risk	GFR decrease by 25%	1
Injury	GFR decrease by 50%	2
Failure	GFR decrease by 75% or estimated creatinine clearance < 35 mL/min/1.73 m² or patients receiving renal replacement therapy	3
pRIFLE urine output criteria		
None	> 0.5 mL/kg/hr for 8 hr	0
Risk	< 0.5 mL/kg/hr for 8 hr	1
Injury	< 0.5 mL/kg/hr for 16 hr	2
Failure	< 0.3 mL/kg/hr for 24 hr or anuric for 12 hr	3
Fluid overload criteria, %		
< 15		0
15 to < 20		1
20 to < 25		2
25 to < 30		3
30 to < 35		4
≥ 35		5
Nephrotoxic medications criteria		
< 3 nephrotoxic medications		0
Three nephrotoxic medications		1
Each additional nephrotoxic medication		+1

Akcan-Arikan A, Gebhard DJ, Arnold MA, Loftis LL, Kennedy CE. Fluid Overload and Kidney Injury Score: A Multidimensional Real-Time Assessment of Renal Disease Burden in the Critically Ill Patient. *Pediatric Critical Care Medicine* 18(6), 524-30, PubMed PMID: 28406863, 2017.



Nephrotoxic Medication List
Acetazolamide
Amikacin
Amphotericin
Chlorothiazide
Cisplatin
Cyclosporine
Ethacrynic acid
Furosemide
Gentamicin
Ibuprofen
IV Contrast
Ketorolac
Metolazone
Tacrolimus
Tobramycin
Vancomycin

Conclusions

- Small decrease in CCl was independently associated with increased risk for complications
- Calculation of CCl would be useful tool in perioperative settings
- Application of pRIFLE criteria might identify the risk for morbidity
- Permanent AKI is a risk for further complications.
- Fluid overload was associated with increased mortality
- The link between fluid overload and AKI could be the temporary imbalance between kidney output and demand.

Thank you for your attention!