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PERFORMANCE OF FLUID BALANCE AS A MARKER OF ACUTE KIDNEY INJURY IN CHILDREN AFTER OPEN HEART SURGERY

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Acute kidney injury (AKI) is a serious complication in the perioperative period and is consistently associated with increased morbidity and case fatality rate. This has been best studied in the cardiac surgery setting where it has been shown that up to 11.5–86.0% of patients exposed to cardiopulmonary bypass (CPB) will develop AKI, with 2.0–18.9% requiring renal replacement therapy (RRT). A prospective uncontrolled cohort study was conducted between 2011 and 2015, in which 93 children with various congenital heart lesions undergoing CPB were enrolled. Serum creatinine (SCr) level was determined by Jaffé's method (Cobas 6000 analyser, Roche). Postoperative fluid balance was estimated as the difference between fluid intake and output. Data for further processing were retrieved from anaesthesia and intensive care data management system flowsheets (IntelliView, Philips). AKI developed in 42 patients (45.6%) by meeting at least KDIGO (Kidney Disease: Improving Global Outcomes) stage I criteria (with SCr rise by more than 50% from the baseline). Thirty eight patients complied with the 1st stage of AKI, three with 2nd stage and two with 3rd stage, according the KDIGO classification and staging system. One patient having severity stage II and two patients having severity stage III of AKI required initiation of RRT using peritoneal dialysis. Two patients from the RRT group survived, one died. The median intraoperative urine output was 2.32 ml/kg/h, (range from 0.42–5.87 ml/kg/h). Median CPB time was 163 min., median aortic cross-clamping time was 97.9 min., cooling during CPB to 29.5 °C. The diagnosis of AKI using SCr was delayed by 48 hours after CPB. Median fluid balance (FB) on the first postoperative day in non-AKI patients was 13.58 ml/kg (IQR 0–37.02) vs 49.38 ml/kg (IQR 13.20–69.32) in AKI patients, $p < 0.001$. *AKI is a frequent complication after open heart surgery in children with congenital heart lesions. From 93 patients included in the study, 42 (45.2%) met at least KDIGO Stage I criteria for AKI. FB is a sensitive marker of kidney dysfunction. Median FB in the 1st postoperative day significantly differed between AKI patients: 49.38 ml/kg (13.20–69.32) versus 13.58 ml/kg in patients with intact kidney function (AUC = 0.84;* $p = 0.001$). *Thus it can be used as a marker of AKI.*

Key words: *acute kidney injury, fluid balance, paediatric open-heart surgery.*

INTRODUCTION

Acute kidney injury (AKI) is a serious complication in the perioperative period and is consistently associated with increased morbidity and case fatality rate. This has been best studied in the cardiac surgery setting where it has been shown that up to 11.5–86% of patients exposed to cardiopulmonary bypass (CPB) will develop AKI, with 2–18.9% requiring renal replacement therapy (RRT). Depending on the criteria used to define AKI and the postoperative period studied, mortality ranges from 1% to 30%, although this is consistently higher, approaching 80%, if RRT is required. AKI may contribute to chronic kidney disease and negative long-term health outcomes. There is no clear understanding of the pathogenesis of CPB associated AKI and no effective treatment or prevention has yet been established for this

syndrome. Fluid overload (FO), which often accompanies significant AKI, was first recognised in a retrospective study of paediatric bone marrow transplant patients (Lane *et al.*, 1994). Studies of adult critically ill patients have shown that positive FB above 10% is associated with higher long-term mortality and higher occurrence of AKI, thus indicating this threshold as a potential indicator of adverse outcome (Van Biesen *et al*. 2005). The study of Hassinger *et al.* showed that patients with early positive FB, more than 5% by the end of POD 1, were more likely to develop AKI (43.3% vs 33.8%, $p = 0.023$). The authors also observed that positive FB was associated with a prolonged lengths of hospital stay (3.5 more days in the hospital), two more days on inotropes, and increased prevalence of prolonged mechanical ventilation (Hassinger *et al*., 2014).

MATERIALS AND METHODS

Children undergoing elective CPB for surgical correction or palliation of congenital heart lesions between January 2011 and June 2015 were prospectively enrolled. Exclusion criteria included preexisting renal dysfunction. Renal dysfunction was defined as a SCr level that was greater than the 90th percentile for the child's age and gender. Patients with a history of potential nephrotoxin use during the preoperative day were excluded because of potential confounding effects. Ethical approval was obtained from the Ethics Committee of the Children's Clinical University Hospital.

Creatinine concentrations were measured in the hospital's clinical chemical laboratory using Jaffes method on a Cobas 8000 analyser. The primary outcome variable was the development of AKI. AKI was defined according to the KDIGO classification and staging system based on urine output and SCr level: Stage I was SCr 1.5–1.9 times baseline ≥ 26.5 μmol/L increase or UO < 0.5 ml/kg/h for 6–12 hours, stage II was SCr 2–2.9 times baseline and UO < 0.5 ml/kg/h for ≥ 12 hours, stage III was SCr 3 times baseline or ≥ 354 μmol/L and/or UO < 0.3 ml/kg/h for ≥ 24 hours OR anuria for ≥ 12 hours (Kellum *et al*., 2012).

Intraoperative fluid intake was assessed by total of intravenous fluid volume, cardioplegia volume, and pump volume (total volume added during cardiopulmonary bypass plus reservoir volume at the start of cardiopulmonary bypass minus reservoir volume at the termination of cardiopulmonary bypass). Intraoperative fluid output was the total of urine produced on cardiopulmonary bypass, chest tube drainage before the patient left the operating room, and estimated blood loss. Intraoperative net fluid balance was the difference between fluid intake and output. Data for further processing were retrieved from anaesthesia and intensive care data management *IntelliView Clinical Information Portfolio* (Philips) system flowsheets (Fig. 1). Similarly, fluid balance was calculated after the completion of surgical repair. Patient data were collected from day of admission to Intensive care (denoted as POD-1).

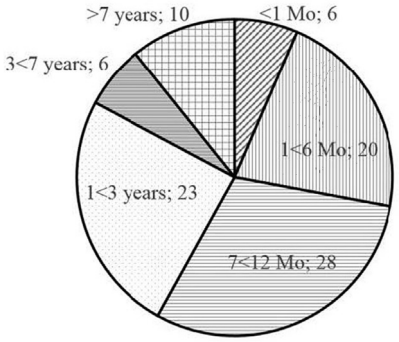

Fig. 1. Age distribution of patients.

Sample collection and processing. Creatinine concentrations were measured in the hospital's clinical chemical laboratory by Jaffes method on a Cobas 8000 analyser. All samples were obtained at the following time points: (1) preoperative; (2) 24 hours and (3) 48 hours after the surgical repair. The primary outcome variable was the development of AKI. AKI was defined according to the KDIGO classification and staging system based on urine output and SCr level: Stage I was SCr 1.5–1.9 times baseline ≥ 26.5 μmol/L increase or UO < 0.5 ml/kg/h for 6–12 hours, stage II was SCr 2–2.9 times baseline and UO < 0.5 ml/kg/h for ≥ 12 hours, stage III was SCr 3 times baseline or ≥ 354 μmol/l and/or UO 0.3 ml/kg/h for ≥ 24 hours OR anuria for ≥ 12 hours (Kellum *et al*., 2012). Recorded variables included age, gender, CPB time, lowest temperature during CPB and urine output, doses of diuretics, inotropes and vasopressors, and postoperative fluid balance. Outcome variables included percent change in serum creatinine, days in AKI, dialysis requirement, duration of MV, lengths of stay in ICU and hospital LOS.

Anaesthesia management. Induction to anaesthesia was provided using inhalation of Sevoflurane by face mask or intravenously by Propofol or Midazolam in combination with Ketamine. Anaesthesia was maintained at (0.8–1.0 minimal alveolar concentration) of sevoflurane and fentanyl (3–5 μg kg/h) using a Primus anaesthesia machine (Drãger Medical, Lübeck, Germany). Muscle relaxation was achieved with pipecuronium (0.6 mg/kg). During CPB, isoflurane was applied via the CPB circuit. All patients were ventilated in a volume-controlled mode; with a tidal volume of 6 ml/kg and respiratory rate adjusted to achieve normocapnia. The heart-lung machine SORIN S 5 (LivaNova, United Kingdom) with a membrane oxygenator Affinity Pixie ® Oxygenatior (Medrtronics, USA) was used for neonates, infants and small children requiring cardiopulmonary bypass at flow rates up to 2.0 L/min. For older patients Terumo, Medtronic C oxygenator with CPB circuit was used. Surgical procedures were performed with CPB in moderate hypothermia. Cardioplegic arrest was achieved by cold blood cardioplegia and repeated every 20 minutes. Nonpulsatile perfusion was performed during CPB. Pump flow, oxygen flow, and MAP were adjusted to maintain $ScvO_2$ levels within the preoperative range and at least higher than 50% absolute. In patients monitored with a pulmonary artery catheter (PAC), haemodynamic therapy was titrated to achieve car-

diac index > 2.2 L/min/m2 and mixed venous oxygen saturation (Sv O_2) greater than 65%.

Fluid therapy was performed with balanced crystalloid (Lactated Ringers solution, Sterofundin VG, BBraun; Melsungen, Germany). The pump prime consisted of various amounts of Ringer lactate and whole blood, depending on estimated blood volume, haematocrit, and total priming volume used. Hypothermic myocardial protection was provided by core cooling at flow rates of 150 to 200 ml/kg/min. (2.0 to 3.0 kg) or 100 to 150 ml/kg/min. (3.0 to 5.0 kg) to rectal and esophageal temperatures of ≤ 30°C, followed by aortic cross clamping. Once optimal hypothermic temperatures were reached, continuous low-flow cardiopulmonary bypass was instituted during completion of intracardiac stage. Core rewarming was instituted during completion of the intracardial stage. Mean perfusion pressures were maintained between 30 mm Hg and 70 mm Hg during rewarming. All patients were weaned from cardiopulmonary bypass after the rectal temperature reached 35 °C. Lactated Ringers, fresh whole blood, blood products, and increased inotropic support were given as necessary to maintain normal filling pressures and a systolic perfusion pressure of at least 60 mm Hg.

Postoperative management. Analgesia and sedation were provided by a continuous fentanyl or morphine infusion, typically 2–4 μg $kg^{-1} \cdot h^{-1}$ and Midazolam or Dexmedetomidine. Routine continuous postoperative monitoring included the surface ECG, transcutaneous pulse oximetry, pulmonary arterial and right and left atrial pressures (through transthoracic catheters), and systemic arterial pressure. Inotropic, chronotropic, and afterload reducing agents were used as clinically indicated. Vasoactive medications were typically started in the operating room at the discretion of the attending cardiac surgeon and anaesthesiologist based on individual patient characteristics, including, residual lesions, transesophageal echocardiographic findings, and physiological status. On arrival to the ICU, medications are adjusted by the bedside nurse under the direction of the ICU team. Patients with hypotension typically receive norepinephrine and epinephrine initially, volume infusions (plasma or 5% albumin) were given to maintain adequate filling pressures with systolic perfusion pressures of at least 50 mm Hg. Diuretics (usually furosemide 1 to 2 mg/kg per dose, two to four times daily) were prescribed at the attending physician's discretion if a targeted fluid balance or urine output of > 0.5 ml/kg/hour could not be achieved. Some patients received continuous infusion of Furosemide and Aminophilline.

During the study continuous fentanyl or morphine infusions were discontinued on the first postoperative morning in the haemodynamically stable patient or continued for longer periods as dictated by the clinical status of the patient. Mechanic ventilation was provided with a Viasys Avea ventilator (Cardinal Health, USA) at the mode suitable for specific cardiac lesion. The rate of weaning of mechanical ventilation was determined by the patient's fluid balance and gas exchange as indicated by arterial blood sampling, pattern of breathing, and daily radiographic findings.

The initial mode of ventilation was pressure-regulated volume control in all patients. Once the patient was breathing spontaneously and ready for weaning, the ventilator mode was switched to pressure-controlled, synchronised, intermittent, mandatory ventilation.

The criteria for extubation was protocolised, as follows: stable haemodynamic profile, normal cardiac rhythm, adequate oxygenation on fraction of inspired oxygen < 0.4, maintenance of a pH > 7.35, and $PacCO_2$ < 45 mm Hg on continuous positive airway pressure < 6 cm H_2O with pressure support < 8 cm H_2O for at least 1 h, the level of consciousness consistent with adequate airway protective reflexes, absence of accessory respiratory muscle recruitment, and approval by the attending intensivists. Corticosteroids were routinely administrated 4 to 6 h before extubation. All patients were monitored with invasive arterial and central blood pressure monitoring. In patients undergoing complex cardiac surgery, a left atrial or pulmonary artery catheter was inserted during surgical repair. Transesophageal echocardiography was performed in all valve surgery cases. Cerebral oxygen saturation (ScO_2) was determined in all patients with an INVOS 5100 monitor (Somanetics, Troy, USA). All patients received routine standard care during the study period, which included the use of dextrose-containing crystalloid solutions (Sterofundin HEG, Sterofundin BG, Sterofundin VG (BBraun, Melsungen, 50–80 ml/kg/day) during the first 24–48 hours postoperatively, followed by the initiation of enteral tube feeding.

Statistical methods. Unless indicated otherwise, continuous data are expressed as median values with interquartile range (IQR) and discrete data as numbers with percentages (%). Patients were grouped according to whether they lacked AKI or had AKI within 48 hours following CPB. Clinical characteristics and biomarker levels were compared between AKI and non-AKI patients using the Student's t test for normally distributed continuous variables. The Mann-Whitney U test was performed for non-normally distributed continuous variables and Pearson's χ^2 or Fisher's exact test (as appropriate) was performed on all categorical variables. Statistical significance was defined as a probability value less than 0.05. Univariate logistic analysis was performed to examine the relationship between multiple clinical variables as well as the presence of AKI and clinical outcomes (ICU length of stay, hospital length of stay, duration of mechanical ventilation, and in-hospital mortality). Variables with a probability value less than 0.1 were then cast into a multivariate logistic regression analysis. Odds ratio, CI, and probability values were calculated. All univariate and multivariate logistic regression analyses were conducted for the entire cohort. Receiver operating characteristics (ROC) curves were generated for the occurrence of AKI within 48 hours following cardiopulmonary bypass using FB at POD-1. The areas under the curve (AUC), with 95% confidence intervals (95% CI), were calculated. Also, the optimal cut-off value was calculated with corresponding

sensitivity and specificity. Using those cut-off values, sensitivity and specificity of FB for predicting AKI were calculated for patients who developed AKI. Two-sided $p = 0.05$ was considered the limit of significance in all analyses. Data were analysed using IBM SPSS statistics version 21 (Statistical Package for the Social Sciences, Chicago, IL).

RESULTS

Median age of patients was ten months, and body weight was 7.6 kg (Table 1). The majority from 93 included patients 54 (58.00%) were less than 12 months old, 6 patients (6.45%) were less than 1 months old, 20 (21.51%) patients were between 1 and 6 months of age; and 28 (30.11%) patients had age of 7 to 12 months were. Age group of 1 to 3 years represents 23 (24.73%) children. 6.45% were patients between 3 to 7 years, and 10.75% were older than 7 years, (Fig. 2, Table 2). Types of congenital heart lesions are summarised in Table 3.

Postoperative AKI occurred in 42 (45.16%) of 93 children. Thirty-seven of them reached severity stage I according the KDIGO classification and stating system, three reached stage II and two reached stage III, based on SCr and (or) urine output criteria (Fig. 3). Fig. 4 shows changes in % from the baseline SCr concentration to maximum during 48 hours. It shows number of patients for each AKI severity stage.

Postoperative fluid balance (FB POD-1) was 13.58 ml/kg (median) in the non-AKI group versus 27.20 ml/kg in the AKI group, $p = 0.025$ (Fig. 5, Table 4). In addition, FB was calculated separately according the severity stage of AKI.

Table 1

DEMOGRAPHIC DATA

Variable	Median	IQR (Q1–Q3)	Range
Age, months	10.0	6.0–17	0.2–180.0
Body weight (kg)	7.6	5.6–10	2.6–60.0
M/F ratio:			
35/58			

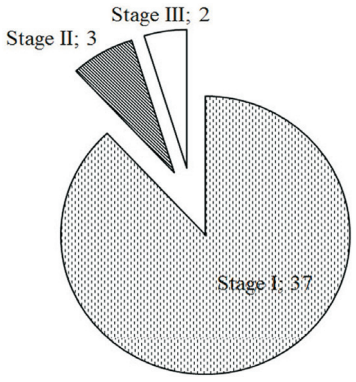

Fig. 2. Severity of acute kidney injury.

Table 2

AGE STRUCTURE

Age group	Number of patients	(%)
Less than 1 month	6	6.45
1 < 6 months	20	21.51
7 < 12 months	28	30.11
1 < 3 years	23	24.73
3 < 7 years	6	6.45
7 years and older	10	10.75
Total:	93	100.00

Table 3

TYPES OF SURGICAL INTERVENTION

Surgical intervention	Number of patients	%
AVSD (atrioventricular septal defect) repair	20	21.51
DORV (double outlet right ventricle)	3	3.23
Pulmonary stenosis repair	5	5.38
Tricuspid regurgitation repair	2	2.15
Unifocalization procedure	2	2.15
Aortic stenosis repair	3	3.23
VSD (ventricular septal defect) repair	37	39.78
Mitral valve plastics	2	2.15
TAPVD (total anomalous pulmonary vein drainage)	4	4.30
TGA (transposition of great arteries)	6	6.45
TOF (tetralogy of Fallot)	9	9.68
Total:	93	100.00

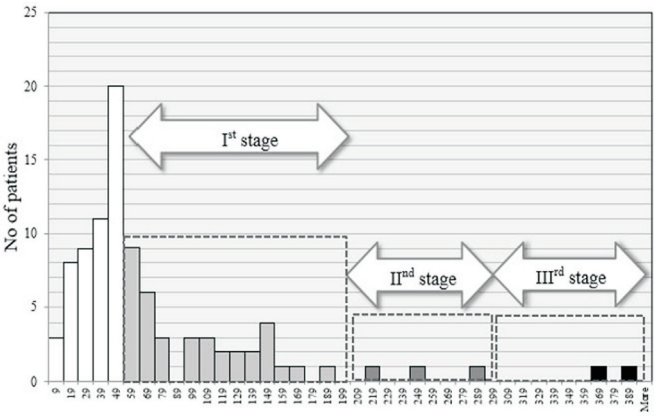

Fig. 3. ΔSCr (serum creatinine) histogram.

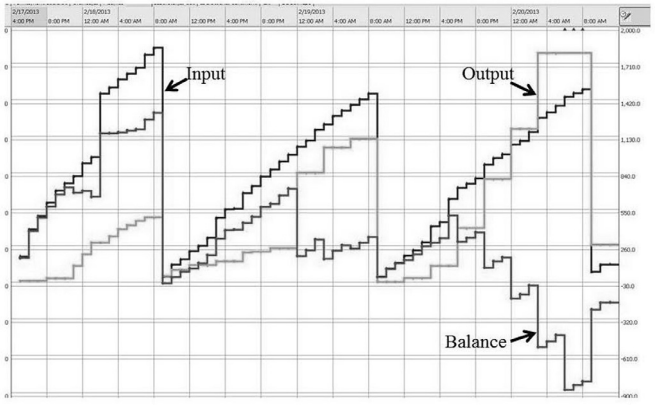

Fig. 4. Postoperative fluid balance (screenshot from the ICIP (Philips) patient data management system).

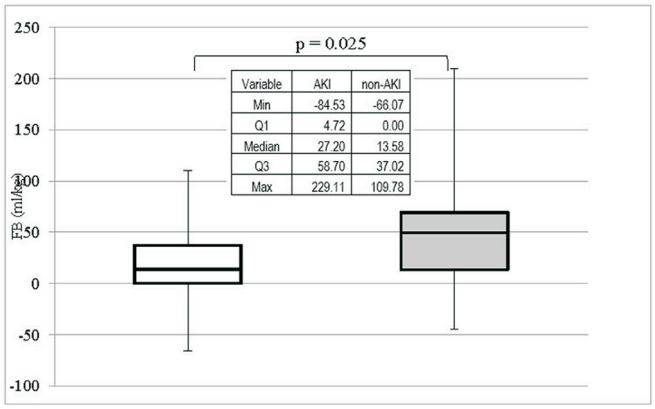

Fig. 5. Fluid balance (FB) at POD-1 (patient data collected from day of admission to intensive care) in acute kidney injury (AKI) and non-AKI patients**.** Box and whisker plot showing FB (ml/kg) in AKI (filled box) and non-AKI (empty box) patients.

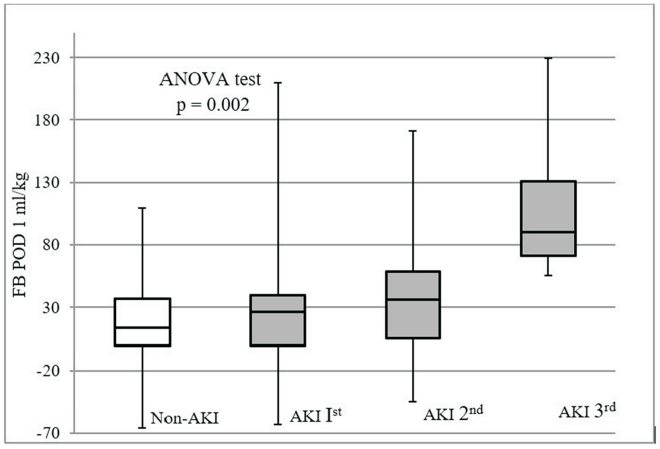

Fig. 6. Postoperative fluid balance (FB) and severity of acute kidney injury (AKI). Box and whisker plot showing FB POD-1 in non-AKI patients (empty box) and patients having Ist, 2nd and 3rd stage of AKI (filled boxes).

Table 4

CLINICAL OUTCOME CHARACTERISTICS BY AKI STATUS

Variable/category	Non-AKI	AKI	*p* value
FB POD-1 ml/kg, median (IQR)	13.58 (0.00–37.02)	27.20 (4.72–58.70)	0.025*
FB POD-1 ≥ 50 ml/kg, n (%)	18/51 (35.29%)	25/42 (59.52%)	0.046#

#Fisher's exact test, *Mann–Whitney U test

Fluid balance in patients reaching 1st stage of AKI severity increased from 13.58 ml/kg (median) to 26.27 ml/kg, 2nd stage to 36.29 ml/kg and 3rd stage to 90.09 ml/kg, ANOVA test $p = 0.002$ (Fig. 6). To evaluate postoperative fluid balance as a marker for AKI, ROC analysis was performed (Fig. 7). AUC was 0.842 (CI 95% 0.838–0.926), sensitivity of 80%, specificity of 71% and cut-off value of 25 ml/kg.

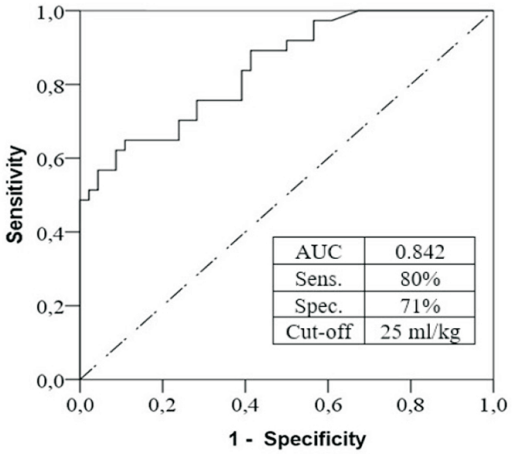

Fig. 7. Receiver operating characteristics curve of fluid balance POD-1 in acute kidney injury (AKI) and non-AKI patients.

DISCUSSION

Studies of paediatric patients requiring RRT showed correlation of the degree of positive FB with poor outcome and mortality, hinting at a dynamic positive FB value for predicting adverse outcomes, with the 10% cut-off value proving to be clinically significant (Horiguchi *et al*., 2014). Infants 72 hours after cardiac surgery with a positive fluid balance had 10 times higher odds of prolonged mechanical ventilation than infants without a positive fluid balance (Shi *et al*., 2008). Patients with ≥ 20% fluid overload had an 8.5-fold greater adjusted odds ratio of death than those with less than 20% fluid overload (Sutherland *et al*., 2010). A recent study by Hassinger *et al*. (2014) also demonstrated that increasing positive FB, as measured by daily fluid balance, is associated with worse outcome following congenital heart surgery in infants. In the study of Lex *et al*. (2016), where postoperative FB was analysed in 1520 paediatric patients after open heart surgery, there was a positive FB between 5% and 10% in 120 patients (7.8%), and in 33 patients (2.1%) FB was above 10%. Multivariable analysis showed that higher fluid overload on the day of the surgery was independently associated with mortality (adjusted odds ratio, 1.14; 95% CI, 1.008–1.303; $p = 0.041$) and low cardiac output syndrome (adjusted odds ratio, 1.21; 95% CI, 1.12–1.30; $p = 0.001$). Higher maximum SCys C levels (adjusted odds ratio, 1.01; 95% CI, 1.003–1.021; $p = 0.009$), maximum vasoactive-inotropic scores (adjusted odds ratio, 1.01; 95% CI, 1.005–1.029; $p = 0.042$), and higher blood loss on the day of the surgery (adjusted odds ratio, 1.01; 95% CI, 1.004–1.025; $p = 0.015$) were associated with a

Table 5

POSTOPERATIVE FLUID BALANCE (ML/KG) AT POD-1 AND SEVERITY OF AKI

Variable/Severity	Non-AKI	AKI Ist stage	AKI IInd stage	AKI IIIrd stage
Median	13.58	26.27	36.29	90.19
Interquartile range (Q1-Q3)	0–37.02	0–39.63	5.60–58.56	70.97–130.61

higher risk of fluid overload that was greater than 5% (Lex *et al*., 2016).

The etiology of positive FB in this patient population is multifactorial. Cardiopulmonary bypass results in both haemodilution and increased capillary permeability, both of which promote extravasation of fluid into the extracellular fluid compartment (Zhang *et al*., 2004). Fluid resuscitation and blood product administration in the immediate postoperative period further contributes to third spacing. As body wall oedema increases, intra-abdominal pressure rises and renal perfusion pressure is decreased (Wauters *et al*., 2009). When combined with postoperative myocardial dysfunction, there is also a stimulus to retain fluid via the renin-angiotensin-aldosterone system (Sorof *et al*., 1999). Given the acute nature of CPB mediated kidney injury and the observation that most infants have normal renal function prior to surgery, these patients may be ideal candidates for aggressive postoperative goal-directed protocols aimed at minimisation of positive FB. Peritoneal dialysis has been shown to be a safe and effective method of fluid removal in post-cardiotomy infants (Pedersen *et al*. 2008), and early initiation of this therapy can improve haemodynamics and ICU outcomes (Sorof *et al*., 1999).

By examining fluid balance early after cardiac surgery, the current study adds to the growing body of evidence that positive fluid balance is independently associated with kidney dysfunction. FB POD-1 ≥ 50 ml/kg, in the non-AKI group was 35.29% versus 59.52% in AKI group, $p = 0.046$ (Table 4). Median postoperative fluid balance in the non-AKI group was 13.58 ml/kg versus 27.20 ml/kg in the AKI group, $p = 0.025$ (Table 4, Fig. 5), OR of FB ≥ 50 ml/kg in AKI vs. non-AKI was 2.58 (CI 95% 0.94–7.07), $p = 0.026$. After performing ROC analysis, AUC of FB POD-1 was 0.842 with sensitivity of 80%, specificity of 71% (CI 95% 0.838–0.926) and cut-off value was 25 ml/kg, $p = 0.001$ (Fig. 7). Similar results were published in the study of Hassinger *et al*. (2014). They found postoperative positive fluid balance > 50 ml/kg in 31% of patients, which is less than in this study. The reported AUC was 0.963; 95% CI, 0.916–1.000; $p = 0.002$ (Hassinger *et al*., 2014).

CONCLUSIONS

Fluid balance is a suitable marker for the prediction of postoperative AKI. 35.29% patients had FB POD-1 ≥ 50 ml/kg in the non-AKI group had versus 59.52% in the AKI group, $p = 0.046$. Median postoperative fluid balance in the non-AKI group was 13.58 ml/kg versus 27.20 ml/kg in the AKI group, $p = 0.025$, OR of FB ≥ 50 ml/kg in AKI versus non-AKI was 2.58 (CI 95% 0.94–7.07), $p = 0.06$. After performing ROC analysis, AUC of FB POD-1 was 0.842 with sensitivity of 80%, specificity of 71% (CI 95% 0.838–0.926) and the cut-off value was 25 ml/kg, $p = 0.001$. The role of fluid balance in the postoperative management is underestimated and daily FB monitoring now becomes essential.

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ŠĶIDRUMA BALANSA KĀ NIERU BOJĀJUMA MARĶIERA VEIKTSPĒJA BĒRNIEM PĒC SIRDSKAITES KOREKCIJAS MĀKSLĪGĀ ASINSRITĒ

Akūts nieru bojājums (ANB) ir nopietna pēcoperācijas perioda komplikācija, kas konsekventi saistīta ar pieaugošu morbiditāti un mortalitāti. Tas ir visvairāk pētīts kardioķirurģijā, kur pierādīts, ka līdz 11,5–86,0% pacientu, kam veic operācijas MA (māslīgā asinsritē), attīstās ANB, 2,0–18,9% no tiem nepieciešama nieru aizstājējterapija (NAT). Atkarībā no kritērijiem, ko izmanto, lai definētu ANB, mirstība svārstās no 1% līdz 30%, lai gan tas ir konsekventi augstāks, tuvojoties 80%, ja ir nepieciešams NAT. ANB var veicināt hronisku nieru slimību un negatīvus ilgtermiņa veselības rezultātus. Nav skaidri saprotama ar MA saistītā ANB patogenitāte, un šim sindromam vēl nav izstrādāta efektīva ārstēšana vai profilakse. 2011.–2015. gadā tika veikts prospektīvs nekontrolēts kohortas pētījums, kurā tika iekļauti 93 bērni ar dažādām iedzimtām sirdskaitēm, kas tika koriģētas MA. Seruma kreatinīna (SCr) līmeni noteica ar *Jaffé* metodi (Cobas 6000 analizators, Roche), šķidruma balanss (ŠB) tika aprēķināts kā starpība starp kopējo ievadīto un izdalīto šķidruma apjomu. Skaitliskie lielumu tika iegūti, izmantojot *IntellyView* intensīvās terapijas klīnisko informācijas sistēmu (*Philips*). ANB attīstījās 42 pacientiem (45,6%), sasniedzot vismaz KDIGO I smaguma pakāpes kritērijus (ar SCr pieaugumu vairāk nekā 50% no izejas koncentrācijas). 38 pacienti saskaņā ar KDIGO klasifikācijas sistēmu sasniedza II, bet divi pacienti sasniedza ANB III smaguma pakāpi. Vienam pacientam ar II smaguma pakāpi un diviem pacientiem, kuriem bija III smaguma pakāpe, bija nepieciešama NAT uzsākšana, izmantojot peritoneālo dialīzi. Divi pacienti no NAT grupas izdzīvoja, viens nomira. Mediānā intraoperatīvas urīna izvade bija 2,32 ml/kg/h (diapazons no 0,42–5,87 ml/kg/h). Vidējais MA laiks bija 163 min, vidējais aortas oklūzijas laiks bija 97,9 min, hipotermija līdz 29,5 °C. ANB diagnoze, izmantojot SCr, aizkavējās 48 stundas pēc MA. Vidējais pozitīvais šķidruma balanss (ŠB) pirmajā pēcoperācijas dienā pacientiem ar intaktu nieru funkciju, bija 13,58 ml/kg (IQR 0,00–37,02) salīdzinājumā ar 49,38 ml/kg (IQR 13,20–69,32) pacientiem ar ANB, p fs22 0,001. AKI ir bieža komplikācija pēc sirdskaites korekcijas MA bērniem. No 93 pētījumā iekļautajiem pacientiem 42 (45,2%) atbilda vismaz KDIGO I pakāpes ANB kritērijiem. ŠB ir jutīgs nieru disfunkcijas marķieris. ŠB 1. pēcoperācijas dienā ir statistiski nozīmīga atšķirība starp pacientiem ar ANB 49,38 ml/kg (IQR 13,20–69,32) salīdzinājumā ar 13,58 ml/kg pacientiem ar intaktu nieru funkciju (AUC = 0,84; p = 0,001), un to var izmantot kā ANB marķieri.