Original article

Acute kidney injury in children after cardiac surgery: Risk factors and outcomes. A retrospective cohort study

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ABSTRACT

Introduction. Acute kidney injury (AKI) has been described as a common complication of cardiac surgery in pediatric patients, whose impact on morbidity and mortality has been documented. Its incidence has been estimated to be approximately 40 % in this patient group. The objective of this study was to estimate the incidence of AKI in patients who underwent cardiovascular surgery and to define associated risk factors and the impact of AKI on the parameters of the post-operative course.

Population and methods. This was a retrospective, observational study of pediatric patients who underwent cardiovascular surgery between January 2015 and December 2017 at Hospital Británico de Buenos Aires. The incidence of AKI was defined as per the Kidney Disease: Improving Global Outcomes criteria, based on pre- and post-operative blood creatinine levels and urine output.

Results. A total of 125 patients were included. Of them, 35 % developed AKI. The analysis of risk factors showed a statistically significant difference for the administration of vancomycin and thiazide diuretics, red blood cell transfusion requirement, extracorporeal circulation pump time, clamp time, maximal intraoperative lactate level, minimum temperature, and delayed chest closure. In relation to the parameters of the post-operative course, we observed a longer hospital stay, higher inotropic requirement, more days of mechanical ventilation, bleeding, and neurological complications.

Conclusion. In this study, the incidence of AKI was 35 %. Modifiable and non-modifiable associated risk factors were defined and a greater rate of complications was observed in patients who developed AKI.

Key words: *acute kidney injury, cardiovascular surgery, pediatrics.*

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INTRODUCTION

Acute kidney injury (AKI) has been described as a common complication of cardiac surgery in pediatric patients, whose impact on morbidity and mortality has been documented. Its incidence has been described to be approximately 40 % in this patient group.[1]

AKI has been associated with more days of mechanical ventilation, a higher inotropic requirement, a longer length of stay, and mortality, even in patients with small variations in creatinine levels.[2-4]

Delayed growth, hypertension, and chronic kidney failure have been described in the long term.[5,6]

The risk factors include high pre-operative blood creatinine levels, age younger than 1 year, prolonged extracorporeal circulation time, higher inotrope requirements, and low post-operative cardiac output.[1,3,7]

Likewise, an association has been described with the greater surgery complexity,[8] which is reflected on the risk adjustment for congenital heart surgery (RACHS-1) category.[9,10]

There are different definitions of AKI, which have gradually evolved seeking for a more accurate assessment. For example, the Risk, Injury, Failure, Loss, and End-stage (RIFLE) criteria, their pediatric adaptation (pRIFLE), and the Acute Kidney Injury Network (AKIN) classification. More recently, in 2012, the Kidney Disease: Improving Global Outcomes (KDIGO) group developed new criteria in an attempt to reconcile the differences among the previous definitions,[2,11,12] and they have been validated in both children and adults.[13-15]

The pathophysiology of AKI in these patients involves multiple mechanisms: a low cardiac output, the release of pro inflammatory cytokines, the ischemia-reperfusion phenomenon, blood mechanical trauma, oxidative stress, and nephrotoxins.[5,15]

Identifying the risk factors would allow to develop strategies aimed at reducing morbidity and mortality. Therefore, the objective of this study was to estimate the incidence of AKI in patients who underwent cardiovascular surgery and to determine the associated risk factors and the impact of AKI on the parameters of the post-operative course.

POPULATION AND METHODS

Design

This was a retrospective, observational cohort study of pediatric patients who underwent cardiovascular surgery between January 2015 and December 2017 at Hospital Británico de Buenos Aires, a referral tertiary care facility. Medical records were reviewed to collect the data of the study variables to be analyzed.

Eligibility criteria

Inclusion criteria

- Age younger than 16 years.
- Surgery performed by the hospital's Cardiac Surgery Team between January 2015 and December 2017.

Exclusion criteria

- Patients with incomplete or missing medical records.

Recorded study variables

- Incidence of AKI: As per the KDIGO criteria (see *Annex*).
- Risk factors: Age, sex, weight, gestational age, birth weight, family history, comorbidities, type of heart disease, prior surgery, nephrotoxic drugs, inotropic use, RACHS-1 category, hypotension, transfusions, intravenous fluids, hyperglycemia, infections, arrhythmia, post-operative catheterization, extracorporeal circulation pump time, clamp time, delayed chest closure, maximal lactate level, minimum temperature, graft or prosthetic material use.
- AKI assessment: Creatinine levels, urea levels, and urine output (pre-operative, post-operative, at the time of AKI diagnosis, and worst level achieved).
- Parameters of post-operative course: Length of stay in days, days of mechanical ventilation (MV), inotropes, renal function replacement therapy, cardiorespiratory arrest, extracorporeal membrane oxygenation (ECMO) requirement, multiple organ failure, and death. In addition, a combined event was defined, which included the occurrence of death and neurological, liver, infectious or bleeding post-operative complications.

Ethical aspects

This study was approved by the hospital's Institutional Review Board in accordance with the Declaration of Helsinki. Due to the study's retrospective nature, we requested the waiver of informed consent.

Statistical analysis

Continuous variables were described as mean and standard deviation (SD) for those with a normal distribution or as median and interquartile range (IQR) for those with an abnormal distribution. Categorical data were expressed as frequency and percentage. The assumption of normality was assessed using the Shapiro-Wilk test. Continuous data were assessed using the t test in the case of normal distribution or the Mann-Whitney U test in case of abnormal distribution. Categorical data were compared with the χ^2 test or Fisher's exact test, as applicable.

The association between potential risk factors and the occurrence of AKI was assessed using a multivariate logistic regression model, which included all variables with a p value < 0.1 in the univariate analysis (besides age, sex, and weight). The final model was selected by making all possible combinations of predictor variables included in the initial model and leaving those that showed a statistically significant association and the best predictive power (as per the Akaike information criterion). If predictor variables were continuous, receiver operating characteristic (ROC) curves were developed and the best cut-off point was identified using the Youden index. Regression analyses were then repeated using the dichotomized variables. For each predictor variable, the odds ratio (OR) and its corresponding 95 % confidence interval (CI) were calculated.

To assess the association between AKI and post-operative outcomes, multivariate regression models were used (a logistic regression for the combined event and a Poisson regression for the length of stay in days), and the development of AKI was used as a predictor variable, with adjustments for other confounding factors. The variables for these models were selected in the same way as described above for the occurrence of AKI, except that AKI was forced into the model in both cases. The multivariate association between length of stay in days and AKI in the Poisson regression analysis was described as an incidence rate ratio (IRR) and its corresponding 95 % CI.

All analyses were two-tailed, and a p value < 0.05 was considered statistically significant. The sample size was determined by convenience because, due to logistical reasons, it was possible to include patients between the dates mentioned above. Analyses were done using the GraphPad Prism 8.0.1® and the R 3.5.1 software programs.

RESULTS

Characteristics of the population under study

During the study period, 145 patients underwent surgery; of them, 20 met the exclusion criteria, so a total of 125 patients were eligible and included in the study group. The incidence of post-operative AKI was 35 % (n = 44). In this group, defined as "AKI patients," 70.5 % (n = 31), 22.7 % (n = 10), and 6.8 % (n = 3) met the criteria for categories 1, 2, and 3 of AKI, respectively. *Table 1* shows the characteristics of the population under study.

No statistically significant differences were observed in relation to the type of heart disease, except in the case of anomalous origin of left coronary artery from pulmonary artery (ALCAPA), which was more frequent in AKI patients (*Table 2*).

Risk factors for acute kidney injury

Table 3 shows the distribution of risk factors for AKI. Variables associated with the development of AKI in the univariate analysis were the administration of vancomycin ($p = 0.012$) and the use of thiazides ($p = 0.015$). However, no association was observed between AKI and infections, thrombosis, arrhythmia, greater surgical complexity as per the RACHS-1 or post-operative catheterization as risk factors.

AKI patients showed a non-significant tendency towards a higher frequency of hyperglycemia. When the hypoperfusion and tissue hypoxia variables were analyzed as potential event triggers, AKI patients were observed to have a significantly higher requirement for red blood cell transfusions ($p < 0.001$). However, no significant differences were observed for pre-operative inotropic requirement as per the vasoactive inotropic score (VIS),[16,17] the hypotension score (cardiovascular section of the Pediatric Sequential Organ Failure Assessment [pSOFA])[1,18] or the fluid intake in the first 48 h, as an indirect measure of low cardiac output.

A statistically significant difference was noted in terms of the intraoperative risk factors, such as extracorporeal circulation pump time ($p = 0.008$), clamp time ($p = 0.016$), delayed chest closure

Table 1. *Characteristics of the study population*

Variable	All (n = 125)	Without AKI (n = 81)	With AKI (n = 44)	p value
Male sex, n (%)	73 (58.4)	50 (61.7)	23 (52.3)	0.404
Age (months old), median (IQR)	5.0 (2.0-23.0)	5.0 (2.0-19.0)	4.5 (0.8-28.3)	0.714
Preterm birth, n (%)	15 (12.0)	7 (8.6)	8 (18.2)	0.201
Low birth weight, n (%)	11 (8.8)	6 (7.4)	5 (11.4)	0.338
Comorbidity, n (%)				
Nephropathy	7 (5.6)	5 (6.2)	2 (4.5)	1.00
Lung disease	1 (0.8)	0 (0)	1 (2.3)	0.352
Genetic disorder	20 (16)	11 (13.6)	9 (20.5)	0.456
Family history, n (%)				
Heart disease	3 (2.4)	1 (1.2)	2 (4.5)	0.283
Nephropathy	1 (0.8)	1 (1.2)	0 (0.0)	1.00
Prior surgery, n (%)	42 (33.9)	24 (29.6)	17 (39.5)	0.409

AKI: acute kidney injury; IQR: interquartile range.

($p = 0.016$), maximal lactate level ($p = 0.002$), and minimum temperature ($p = 0.041$) (*Figure 1*).

The multivariate logistic regression analyses identified red blood cell transfusion and maximal lactate level as independent variables. For the first one, a cut-off value of 35 mL/kg or higher was identified (OR: 3.26; 95 % CI: 1.31-8.21; $p = 0.011$), whereas for the second, the cut-off point was set at 26.5 mg/dL or higher (OR: 3.11; 95 % CI: 1.28-7.61; $p = 0.012$).

Parameters of post-operative course

Table 3 shows the analysis of these parameters. A statistically significant increase in the length of stay in days and in the days of MV was observed in AKI patients ($p = 0.005$ and $p < 0.001$, respectively) (*Figure 2. A-B*). Likewise, a longer duration of inotropic use ($p < 0.001$) and a higher inotropic use as per the VIS ($p = 0.010$) were observed (*Figure 2. C-D*).

The development of AKI was associated with a higher risk for bleeding ($p = 0.005$) and neurological complications ($p = 0.004$). In total, 11.4 % (n = 5) of AKI patients died, compared to 3.7 % (n = 3) of those who did not develop AKI ($p = 0.131$). All patients with multiple organ failure (n = 3) had AKI, which accounted for 6.8 % of them. The only patient who was on ECMO had developed stage 3 kidney injury with peritoneal dialysis requirement. Out of all AKI patients, 9.1 % required peritoneal dialysis. The combined event occurred in 12 patients (14.8 %) without AKI and in 18 (40.9 %) with AKI ($p = 0.002$).

The association between the length of stay in days and the development of AKI was no longer statistically significant after the adjustment for confounding factors (IRR: 1.05; 95 % CI: 0.91-1,20; $p = 0.505$). Something similar was observed with the combined event: the association between it and AKI was no longer significant after the adjustment for confounding variables (OR: 1.88; 95 % CI: 0.46-7.62; $p = 0.370$).

Parameters for the measurement of acute kidney injury

The patients who developed AKI had, in the immediate post-operative period, a higher blood creatinine level (0.42 ± 0.2 versus 0.36 ± 0.1 mg/dL; $p = 0.020$) and a lower urine output (1.6 ± 1.3 mL/kg/h versus 2.5 ± 1.4 mL/kg/h; $p < 0.001$) (*Figure 3. A-B*). In relation to the time of AKI onset, 57 % of patients developed it in the first day after the surgery; 29 %, on the second day; and the rest, in the subsequent days; the latest case occurred 27 days after the surgery. In relation to the duration in hours, most cases resolved within 24 h (65 %) (*Figure 3. C-D*).

The association between the AKI stage and the RACHS-1 categories was not observed to be statistically significant, but there was a relevant proportional increase in the AKI stage based on the RACHS-1 category.

TABLE 2. *Incidence of acute kidney injury by type of underlying heart disease*

Heart disease	**Without AKI (n = 81)**	**With AKI (n = 44)**	***p* value**
Tetralogy of Fallot, n (%)	13 (16.0)	5 (11.4)	0.656
Single ventricle, n (%)	12 (14.8)	3 (6.8)	0.305
Ventricular septal defect, n (%)	9 (11.1)	6 (13.6)	0.899
Coarctation of the aorta, n (%)	10 (12.3)	2 (4.5)	0.212
Atrioventricular canal, n (%)	8 (9.9)	2 (4.5)	0.492
Pulmonary atresia/stenosis, n (%)	6 (7.4)	3 (6.8)	1.00
Shone's complex, n (%)	5 (6.2)	4 (9.1)	0.719
Transposition of the great arteries, n (%)	5 (6.2)	3 (6.8)	1.00
Atrial septal defect, n (%)	5 (6.2)	1 (2.3)	0.424
Hypoplasia of the left chambers, n (%)	1 (1.2)	4 (9.1)	0.051
ALCAPA, n (%)	0 (0.0)	3 (6.8)	0.042
Anomalous venous return, n (%)	2 (2.5)	1 (2.3)	1.00
Interruption of the aortic arch, n (%)	1 (1.2)	2 (4.5)	0.283
Patent ductusarteriosus, n (%)	1 (1.2)	1 (2.3)	1.00
Truncusarteriosus, n (%)	0 (0.0)	2 (4.5)	0.122
Aortic stenosis, n (%)	0 (0.0)	1 (2.3)	0.352
Double-outlet right ventricle, n (%)	1 (1.2)	0 (0.0)	1.00
Aortopulmonary window, n (%)	1 (1.2)	0 (0.0)	1.00
Other, n (%)	1 (1.2)	1 (2.3)	1.00

ALCAPA: anomalous origin of left coronary artery from pulmonary artery.

DISCUSSION

AKI is one of the most common complications in pediatric patients who undergo surgery for congenital heart disease. The incidence of AKI in our patients, as per the KDIGO criteria, was 35 %, which is slightly below what has been described in the bibliography.[1,3-5,19] Such difference is attributed to the fact that most of

Table 3. *Pre-, intra-, and post-operative variables analyzed as potential risk factors and parameters of post-operative course*

Variable	Without AKI (n = 81)	With AKI (n = 44)	*p* value
RISK FACTORS			
Duration of pre-operative MV (days), mean ± SD	0.4 ± 2.01 [0-14]	1.2 ± 3.9 [0-23]	0.160
Pre-operative inotropes, mean ± SD			
Duration (days)	0.4 ± 2 [0-14]	0.7 ± 2.3 [0-12]	0.319
Higher VIS	0.5 ± 2.2 [0-16]	1 ± 2.9 [0-13]	0.185
Drugs, n (%)			
NSAIDs	76 (93.8)	39 (88.6)	0.516
Vancomycin	7 (8.6)	12 (27.3)	0.012
Penicillins	6 (7.4)	7 (15.9)	0.218
Cephalosporins	2 (2.5)	2 (4.5)	0.613
TMS	0 (0.0)	1 (2.3)	0.352
Aminoglycosides	1 (1.2)	3 (6.8)	0.125
Diuretics (in general)	77 (95.1)	44 (100)	0.296
Loop diuretics	77 (95.1)	44 (100)	0.296
Thiazide diuretics	14 (17.3)	17 (38.6)	0.015
Potassium-sparing diuretics	48 (59.3)	26 (59.1)	1.00
ACE inhibitors	23 (28.4)	14 (31.8)	0.845
Prostaglandins	11 (13.6)	8 (18.2)	0.672
RACHS-1, mean ± SD	2.5 ± 1.2 [1-6]	2.8 ± 1.2 [1-6]	0.199
Hypotension on day 1 after surgery, mean ± SD	2.5 ± 1 [0-4]	2.8 ± 0.8 [0-4]	0.264
Total fluid intake in the first 48 h (mL/kg/day), mean ± SD	80.2 ± 28 [19-195]	84.1 ± 32.4 [25-203]	0.556
Red blood cell transfusion requirement (mL/total kg)	22.4 ± 16 [0-84]	50.5 ± 49.4 [14-266]	< 0.001
Hyperglycemia during fasting, n (%)			
> 140 (mg/dl)	68 (84.0)	40 (90.9)	0.417
> 200 (mg/dl)	53 (65.4)	34 (77.3)	0.242
Infections, n (%)	7 (8.6)	7 (15.9)	0.244
Arrhythmia, n (%)	6 (7.4)	7 (15.9)	0.218
Post-operative catheterization, n (%)	1 (1.2)	1 (2.3)	1.00
Extracorporeal circulation pump requirement, n (%)	70 (86.4)	42 (95.5)	0.137
Pump time (min), mean ± SD	58.1 ± 39.9 [0- 160]	82.9 ± 47.9 [0-218]	0.008
Clamp time (min), mean ± SD	34.7 ± 30.5 [0-119]	51.1 ± 36.2 [0-157]	0.016
Delayed chest closure, n (%)	3 (3.7)	8 (18.2)	0.016
Maximal intraoperative lactate level (mg/dL), mean ± SD	21.5 ± 8.9 [7-55]	34.2 ± 24.3 [9-124]	0.002
Minimum intraoperative temperature (°C), mean ± SD*	31.5 ± 3.1 [21.6-37.2]	30.3 ± 3.7 [20-36.3]	0.041
Graft use, n (%)	34 (41.9)	19 (43.2)	1.00
Prosthetic material use, n (%)	33 (40.7)	24 (54.5)	0.217

see next page

PARAMETERS OF POST-OPERATIVE COURSE			
Length of hospital stay after surgery (days), mean ± SD	8.1 ± 6 [1-40]	15.4 ± 16.7 [3-94]	0.005
Days of MV after surgery, mean ± SD	1.2 ± 1.4 [0-6]	5.5 ± 10.6 [0-53]	< 0.001
Inotropes, mean ± SD			
Duration (days)	2.9 ± 2.0 [0-9]	5.3 ± 3.4 [1-17]	< 0.001
Higher VIS	11.3 ± 6.9 [0-40]	16.2 ± 10.2 [4-63.5]	0.010
Death, n (%)	3 (3.7)	5 (11.4)	0.131
Renal function replacement therapy			
Requirement, n (%)	-	4 (9.1)	-
Duration (days), mean ± SD	-	6 ± 4.4 [1-11]	-
ECMO, n (%)	0 (0.0)	1 (2.3)	0.352
Infection, n (%)**			
Yes	9 (11.1)	8 (18.2)	0.407
Bacteremia	3 (3.7)	2 (4.5)	1.00
Catheter-related	0 (0.0)	2 (4.5)	0.12
Urinary tract	3 (3.7)	4 (9.1)	0.24
Pneumonia	2 (2.5)	1 (2.3)	1.00
Abdominal	1 (1.2)	1 (2.3)	1.00
Bleeding, n (%)	4 (4.9)	10 (22.7)	0.005
Revision surgery requirement, n (%)	4 (4.9)	4 (9.1)	0.450
Cardiorespiratory arrest, n (%)	4 (4.9)	6 (13.6)	0.163
Neurological complications, n (%)	2 (2.5)	8 (18.2)	0.004
Liver complications, n (%)	0 (0.0)	3 (6.8)	0.042
Pulmonary hypertension, n (%)[23]	8 (9.9)	3 (6.8)	0.745
Pleural effusion, n (%)	3 (3.7)	5 (11.4)	0.128
Pericardial effusion, n (%)	2 (2.5)	4 (9.1)	0.183
Chylothorax, n (%)[24]	5 (6.2)	3 (6.8)	1.00
Pneumothorax, n (%)	1 (1.2)	2 (4.5)	0.283
Multiple organ failure, n (%)	0 (0.0)	3 (6.8)	0.042
Combined event, n (%)	12 (14.8)	18 (40.9)	0.002

* 110 patients with data.
** 2 AKI patients had combined sources of infection.
MV: mechanical ventilation; SD: standard deviation; VIS: vasoactive inotropic score; NSAIDs: non-steroidal anti-inflammatory drugs; ACE: angiotensin-converting enzyme; ECMO: extracorporeal membrane oxygenation; TMS: trimethoprim-sulfamethoxazole; RACHS-1: risk adjustment for congenital heart surgery.

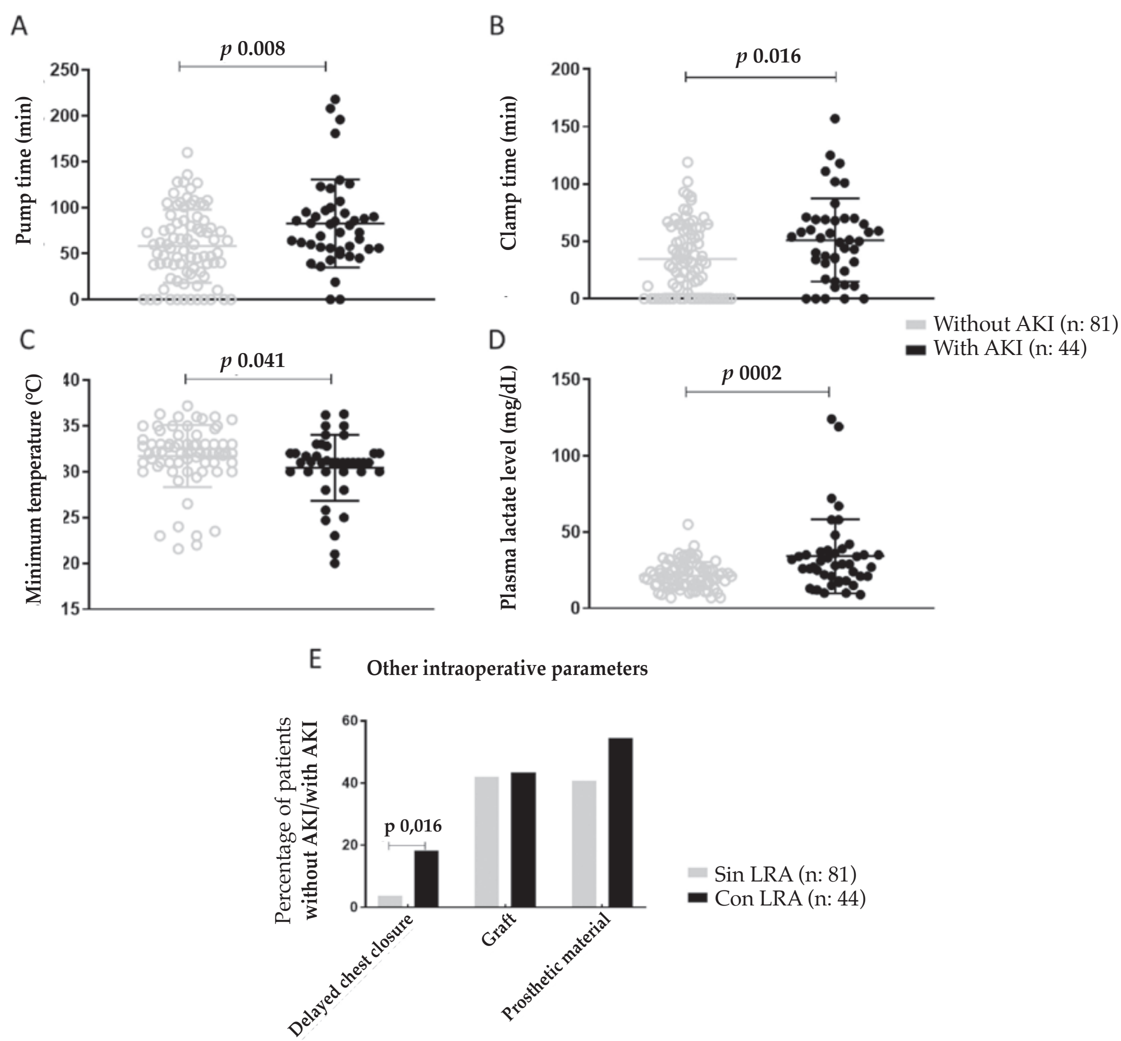
the published case reports defined AKI as per the pRIFLE criteria (before the validation of the KDIGO criteria in pediatrics), which had a greater sensitivity and a lower specificity,[19,20] especially in the first stages of risk. Most cases developed in the first day after the surgery; the criteria for stage 1 AKI were met; and AKI was resolved in the first 24 h, similar to what has been described to date.[1-3]

In addition, a greater incidence of AKI was not observed in patients younger than 1 month, unlike what has been published in the bibliography.[3-5] Such discrepancy may be due to the fact that the KDIGO criteria measure a variation in blood creatinine levels (instead of creatinine clearance), and it has been described that this population has high blood creatinine levels during the first days of life provided by the mother, so the absolute baseline value may be higher.[19] This would make it harder to detect a percent increase to meet the diagnostic criterion. However, the KDIGO criteria currently recommended to define AKI have an intermediate sensitivity compared to the previous two instruments[12,19,20] and are easily implemented because of the variables used (height is not invariably required to estimate the glomerular filtration rate, which is usually underestimated in medical records).

Among the studied risk factors, no differences were observed in terms of the incidence of AKI as per the RACHS-1 category, but there were differences between this and the AKI stage in the patients who developed it. It would appear then that, although surgery for congenital heart disease is a risk factor itself for the development of AKI and such complication may have a multifactorial origin, the greater surgical complexity would favor the development of higher AKI stages. Among the studied nephrotoxic drugs, an association was observed between AKI and the use of vancomycin and thiazide diuretics. For this reason, it may be concluded that, as well as in the general pediatric population, in these patients, strategies for the rational use of antibiotic, diuretics and other drugs should be recommended; because, even though these are complex patients with prolonged hospitalizations and risk for infection, it is important to consider the greater impact that drug nephrotoxicity has on them. Consistent with prior publications, a greater incidence of AKI in patients who had higher hyperglycemia levels has been demonstrated;[21,22] however, such association was not statistically significant and, based on the studies reviewed to date, no recommendations have been found in relation to a strict hyperglycemia control.[7,22]

Considering that a pathophysiological hypothesis suggests that a low cardiac output

Figure 1. *Intraoperative risk factors*



A) Pump time; B) Clamp time; C) Minimum temperature; D) Maximal lactate level; E) Other intraoperative parameters.
AKI: acute kidney injury.

and tissue hypoxia may trigger AKI,[1,19] variables for the indirect measurement of these two factors have been analyzed. An association was observed between a greater red blood cell transfusion requirement and the incidence of AKI, but not between AKI and a higher inotropic requirement in the pre-operative period, hypotension score or a higher total fluid intake. On the basis of this, the impact of tissue hypoxia (as indirectly measured by transfusion requirement) would be greater than that of a low cardiac output. In addition, and considering the intra-operative variables, it has been observed that the incidence of AKI was higher with a longer pump time, clamp time and higher plasma lactate levels and with a lower temperature during surgery. These findings were similar to those reported in the bibliography.[1,3,14,19]

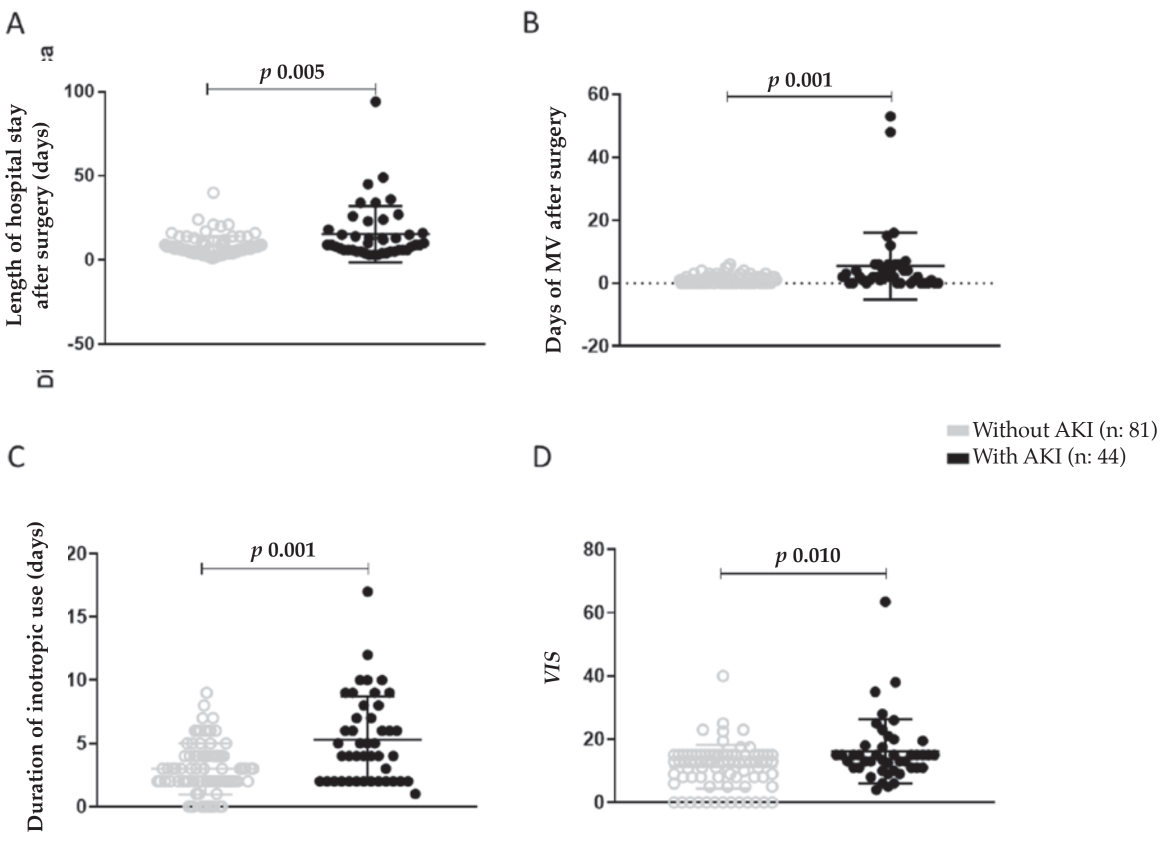
Finally, the analysis of the impact of AKI on morbidity and mortality showed that AKI patients had a greater rate of multiple organ failure and death. Likewise, in this group, a longer length of stay after the surgery, more days of MV, a higher inotropic requirement, and a greater incidence of bleeding, liver and neurological complications were detected.

CONCLUSIONS

The incidence of AKI in pediatric patients who underwent cardiovascular surgery was 35 % in this study.

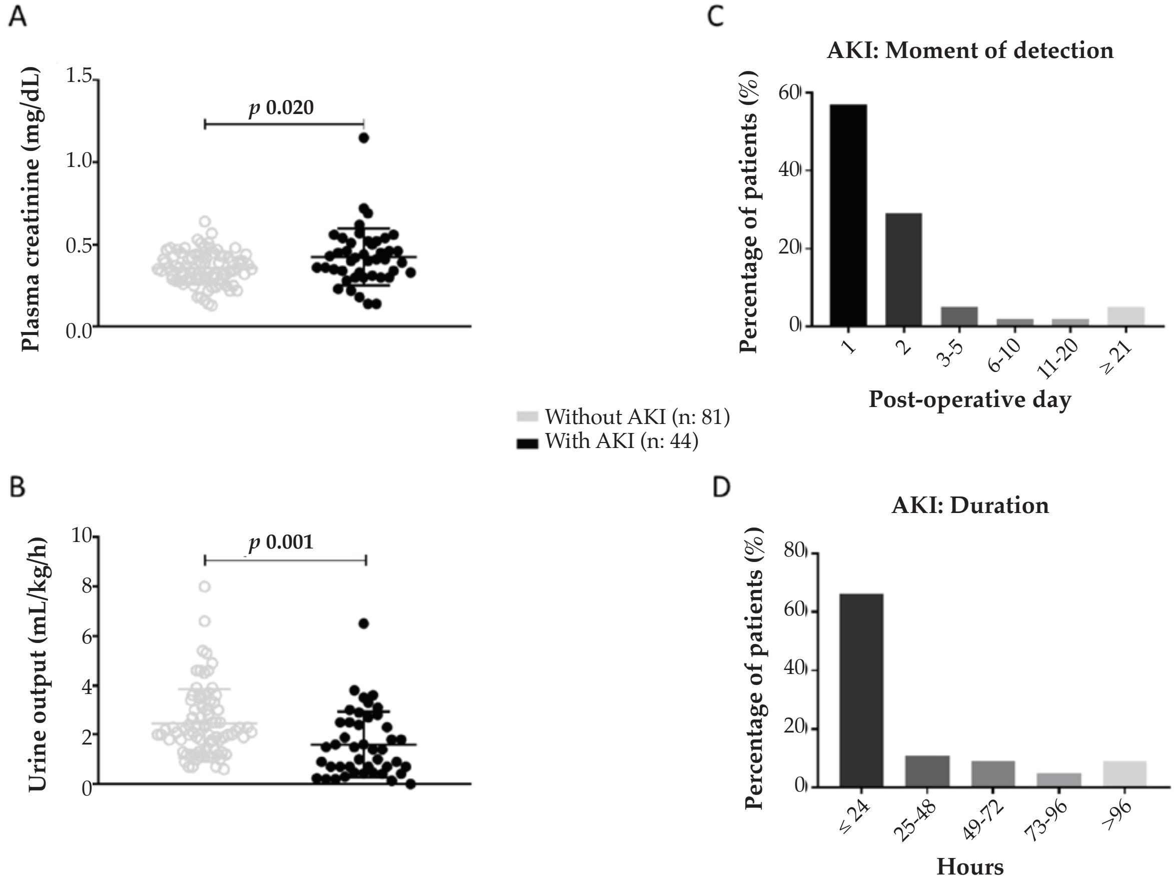
The analysis of the assessed risk factors showed a statistically significant difference for the administration of vancomycin and thiazide diuretics, red blood cell transfusion requirement, extracorporeal circulation time, clamp time, maximal intraoperative lactate level, minimum temperature, and delayed chest closure. In relation to the parameters of the post-

Figure 2. *Quantitative parameters of post-operative course*



A) Length of stay in days; B) Days of MV; C) Duration of inotropic use; D) VIS.
MV: mechanical ventilation; VIS: vasoactive inotropic score.

FIGURE 3. *Assessment of kidney function*



A) Creatinine in the immediate post-operative period; B) Urine output in the immediate post-operative period; C) Moment of AKI detection; D) Duration of AKI.
AKI: acute kidney injury.

operative course, we detected a statistically significant longer hospital stay, higher inotropic requirement, more days of mechanical ventilation, bleeding, and neurological complications. ■

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ANNEX

Definition and staging of acute kidney injury as per the Kidney Disease: Improving Global Outcomes criteria

Stage	Blood creatinine level	Urine output
1	Value: 1.5-1.9 times baseline or ≥ 0.3 mg/dL increase	< 0.5 mL/kg/h for 6-12 h
2	Value: 2-2.9 times baseline	< 0.5 mL/kg/h for ≥ 12 h
3	Value: 3 times baseline or ≥ 4.0 mg/dL or initiation of renal replacement therapy or decrease in glomerular filtration rate to < 35 mL/min/1.73 m^2	< 0.3 mL/kg/h for ≥ 24 h or anuria for ≥ 12 h