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

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Background. **The pediatric-modified Risk, Injury, Failure and Loss, and End-Stage (pRIFLE) criteria and a different but conceptually similar system termed Acute Kidney Injury Network (AKIN) were created to standardize the definition of acute kidney injury (AKI) in children. Kidney Disease: Improving Global Outcomes (KDIGO) currently recommends a combination of AKIN and pRIFLE in AKI. This study aimed to compare the three classifications for predicting AKI in pediatric patients undergoing cardiac operations.**

Methods. **We analyzed the prospectively collected data of 1,489 consecutive pediatric patients undergoing cardiac operations between January 2004 and December 2008. AKI presence and severity was assessed for each classification using the change in serum creatinine and estimated creatinine clearance levels calculated by the Schwartz equation.**

Results. **AKI was present in 285 (20%), 481 (34%), and 409 (29%) patients according to the AKIN, pRIFLE, and KDIGO systems, respectively. The KDIGO classification categorized 121 patients (8%) who were placed in the AKIN 0 category, whereas the pRIFLE system categorized 74 (5%) in KDIGO 0 and 200 (14%) in AKIN 0 stages as having an AKI. The overall mortality rate was 3.9%. The KDIGO stage III (odds ratio [OR], 18.8; 95% confidence interval [CI], 9.6 to 36.6, $p < 0.001$), the AKIN stage III (OR, 38.3; 95% CI, 20.6 to 70.9, $p < 0.001$), and pRIFLE failure group (OR, 13.6, 95% CI, 7 to 26.3; $p < 0.001$) were associated with increased mortality.**

Conclusions. **The pRIFLE system was the most sensitive test in detecting AKI, and this was especially so in the infant age group and also in the early identification of AKI in low-risk patients. The AKIN system was more specific and detected mostly high-risk patients across all age groups. The KDIGO classification system fell between pRIFLE and AKIN in performance. All three had increasing severity of AKI associated with mortality.**

(Ann Thorac Surg 2014;97:202–10)

Acute kidney injury (AKI) occurs in one-third of patients undergoing cardiac operations [1]. In addition, AKI is associated with an increased complication rate, including morbidity and mortality [2]. The complication rate is also affected by the degree and severity of AKI, and the need for renal replacement therapy (RRT) is approximately 1.1% to 1.4% after cardiac operations [3].

An association of morbidity and mortality with AKI has been shown in pediatric populations [4–6]. The Risk, Injury, Failure and Loss, and End-Stage (RIFLE) assessment and, more recently, the Acute Kidney Injury Network (AKIN) system, have been validated in pediatric populations [5]. The use of differing criteria to define AKI in children is a fundamental problem because of the difficulties in making comparisons across studies [7, 8].

The current Kidney Disease: Improving Global Outcomes (KDIGO) recommendations for AKI in children are based on the report of pediatric-modified RIFLE (pRIFLE) in 150 patients aged older than 1 year at a single center [5] and on extrapolation from adult data. Analyses of the adult data from AKIN and RIFLE have led to the KDIGO proposal of a combined system because AKIN detects some patients not detected by RIFLE but only those of low risk. However, pRIFLE, which uses calculated creatinine clearance (CrCl), overcomes some of these issues in pediatrics, and that KDIGO recommends combining AKIN and pRIFLE without further analysis in a pediatric cohort is therefore surprising. Using the validated pRIFLE criteria in a large cohort of pediatric patients, we have found that AKI was associated with increased morbidity and resource utilization [9].

Accepted for publication Sept 4, 2013.

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Published by Elsevier Inc

0003-4975/$36.00
http://dx.doi.org/10.1016/j.athoracsur.2013.09.014

Abbreviations and Acronyms

AKI = acute kidney injury
AKIN = Acute Kidney Injury Network
CI = confidence interval
CPB = cardiopulmonary bypass
CrCl = creatinine clearance
DHCA = deep hypothermic cardiac arrest
eCrCl = estimated creatinine clearance
ICU = intensive care unit
IQR = interquartile range
KDIGO = Kidney Disease: Improving Global Outcomes
LOS = low-output syndrome
OR = odds ratio
pRIFLE = Pediatric-modified Risk Injury Failure Loss and End-stage renal disease
RACHS = Risk Adjustment for Congenital Heart Surgery
RBC = red blood cells
RRT = renal replacement therapy
SCr = serum creatinine
SD = standard deviation
w/o = without

This report addresses the issue with a comparison of the utility of the KDIGO, pRIFLE, and AKIN classification systems, three clinical measures of kidney injury, in a pediatric cardiac surgical population. We hypothesized that the validated and previously standardized pRIFLE system would still provide the best results in the early detection of AKI.

Patients and Methods

Institutional Review Board approval (IRB 189/2008) was given for the selected data collated from a prospectively collected database of consecutive pediatric patients undergoing cardiac operations who were admitted to our cardiac intensive care unit (ICU) between January 1, 2004, and December 31, 2008, including waiving the requirement for informed consent from the parents. During the study period, 1,665 cardiac operations were performed. Only the first operation that each patient underwent was considered for the present analysis.

The perioperative data were obtained by a method previously described [10]. The cardiac surgical procedures were graded as class 1 to 6 according to the complexity of the operation using the Risk Adjustment for Congenital Heart Surgery method [11]. The modified Wernovsky score [12] was used to calculate the cumulative inotropic index.

Definitions

Low output syndrome (LOS) was defined as hepatomegaly, oliguria, tachycardia, systolic blood pressure below 80 mm Hg, and a base excess lower than −4 mmol/L or a lactate level higher than 2 mmol/L in two consecutive arterial blood samples. Pulmonary failure was defined as noninfectious, nonvascular oxygenation problems, including atelectasia, pneumothorax, chylothorax, and phrenic paresis. Serious infection was defined as sepsis, deep sternal wound infection, or a positive blood culture. Death was defined as an in-hospital death after arrival at the ICU. An intensivist and a cardiologist separately determined all of the patient outcomes included in the database during the patient's discharge from the hospital.

Outcome Assessment

AKI was classified according to the pRIFLE categories [5]. The Schwartz formula was used to determine the estimated CrCl (eCrCl) [13].

For pRIFLE, the risk stage was defined as an eCrCl decrease of 25%, injury was defined as an eCrCl decrease of 50%, and failure was defined as an eCrCl decrease of 75% or an eCrCl of less than 35 mL/min/1.73 m^2.

For AKIN, stage I was defined as an increase of the serum Cr (SCr) level by 0.3 mg/dL or more or an increase to 150% to 200% of the preoperative (24 hours before the operation) value in 48 hours; stage II was defined as an increase to 200% to 300% of the preoperative value in 48 hours; and stage III was defined as an increase to more than 300% of the reference value, a value greater than 4.0 mg/dL, or the need for RRT.

As proposed, KDIGO stage III was additionally defined by a decrease in eCrCl to less than 35 mL/min/1.73 m^2.

Urine output criteria were not used for AKI diagnosis. RRT was defined as the implementation of peritoneal or hemodialysis.

Statistical Analysis

Categoric variables are summarized as frequencies and percentages. Continuous variables are expressed as the means and standard deviations for parametric variables or medians and interquartile ranges for nonparametric variables. The p values for categoric variables are based on a two-sided χ^2 or the Fisher exact test (as appropriate), comparing AKI patients vs non-AKI patients. The p values for continuous variables are based on a t test or the Wilcoxon rank sum test. The unadjusted associations of the three thresholds of KDIGO, pRIFLE, and AKIN categories with death were calculated using univariate analysis. We further assessed the RIFLE and AKIN definitions in different age groups on their ability to predict in-hospital mortality and dialysis by means of calculation of the area under the receiver operating characteristic (AUC-ROC) curve. SPSS 16.0 statistical software (SPSS Inc, Chicago, IL) was used for analysis. A p value of less than 0.05 was considered statistically significant.

The future use of risk classifications for pediatric cardiac patients is a major area to improve risk recognition and stratification that can enhance clinical care. Thus, the selection of the appropriate tool for measuring risk of acute kidney injury in these patients is of major importance.